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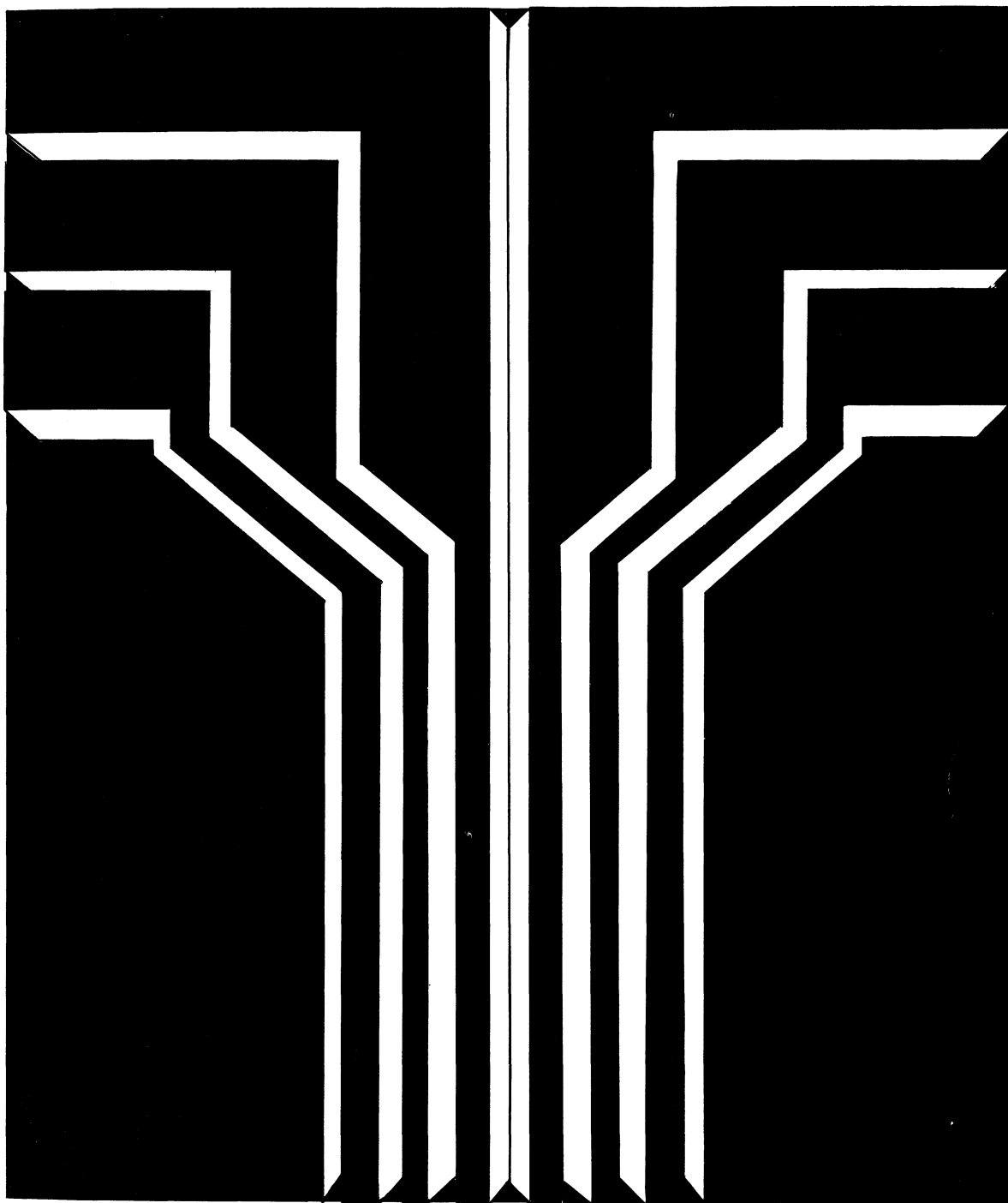
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In 1969, during its eightieth session, the State Legislature of Nebraska passed Legislative Bill 776, which appropriated funds to aid the Nebraska Academy of Sciences in the publication of scientific works submitted by Nebraska scientists. Volumes I and II of the *Transactions* were published under this arrangement, but Volume III was privately financed. Volume IV is being published under the auspices of the Nebraska Department of Education with funds authorized by the State Legislature, supported by the Governor.

* * * *

This cover was designed by Jill Sack, Nebraska Department of Education, and represents the merging of the disciplines of the biological and social sciences with those of the earth and physical sciences.

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Printed by
THE NEBRASKA DEPARTMENT OF EDUCATION
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of the
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Volume IV
August, 1977

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The editor gratefully acknowledges the assistance of the many individuals who reviewed manuscripts submitted for this volume 4.

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ANTHROPOLOGY

CALCIUM CARBONATE INCLUSIONS IN POTTERY: SOME CAUTIONS FOR THE ARCHAEOLOGIST

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Studies of original firing temperature of pottery based on thermal properties of calcium carbonate and cultural inferences about potters' capabilities derived from such studies must be examined in the context of other intervening variables. These variables include original firing atmosphere, length of firing, size and concentration of the carbonate inclusions.

† † †

The presence of calcium carbonate inclusions in pottery chiefly in the form of limestone, calcite, and shell, has for some time: 1) afforded a convenient gauge for estimating the original firing temperature of a ceramic piece (Tite, 1969:14; Kidder and Shepard, 1936:425-427); and 2) provided a basis for statements about limitations on firing temperature of primitive pottery which contains carbonate inclusions (Shepard, 1956:30, 1952:265, 1940:271; Colton, 1953:26). While such studies are meritorious in their own right and while they may have a scientific basis, they seldom consider some important variables and can, therefore, be dangerously oversimplifying. In view of the increasing attention being given to studies of ancient ceramic technology and in view of the widespread use of carbonate tempers and calcereous clays in primitive pottery, it is my intent to present some of the commonly glossed-over variables and to detail some of the fallacies associated with carbonate-inclusion analysis.

The estimation of original firing temperature from calcium carbonate is related to the distinctive properties which this mineral displays upon heating. Calcium carbonate (CaCO_3) decomposes rapidly to Calcium Oxide (CaO) with the emission of carbon dioxide in the 750°-850°C temperature range (Tite, 1972:229). The calcined calcium oxide is very porous and will absorb moisture from the air to form calcium hydroxide (Ca(OH)_2), which can combine with atmospheric carbon dioxide to reform calcium carbonate. Unaltered calcium carbonate differs in appearance from recarbonated calcium carbonate, the latter taking on a cryptocrystalline structure as opposed to a coarsely crystalline structure for the former. The presence of calcium carbonate which has not altered to CaO or Ca(OH)_2 is generally taken to indicate that the temperature of calcination was not reached and that the ceramic piece was probably originally fired below 800°C, while large calcined fragments indicate a firing temperature above 800°-850°C.

The formation of calcium hydroxide (Ca(OH)_2) from calcium oxide (CaO) is accompanied by a large expansion, and sufficient pressure can be developed to disrupt the fired product (Lawrence, 1972:35-36). This "lime-popping" is most evident on the vessel surface and can be structurally damaging to the vessel to the point that it crumbles. Because lime-popping occurs around 800°C in an *oxidizing* atmosphere, it is understandable that investigators might acknowledge the use of calcium carbonate inclusions in ancient pottery as setting stringent limitations on firing temperature (for example, Hammond, 1971:16; Colton, 1953:26; Shepard, 1940:276). In other words, the ceramic vessel would have to have been fired below the temperature at which calcium oxide and calcium hydroxide form.

Several factors which prevent precise statements of original firing temperature and potters' limitations (in regard to carbonate inclusions) are: initial firing atmosphere; duration of firing; size and concentration of the carbonate particles. These variables to a large extent influence at what temperature the conversion of calcium carbonate will occur, if the conversion will indeed occur, and if it does occur, the extent of structural weakness to the vessel.

It is well-known among brick manufacturers that "lime-popping" tendencies are significantly influenced by kiln atmosphere in that an environment of abundant oxygen produces more "lime-popping" than an environment deficient in oxygen (Houseman and Koenig, 1971:79-80). Hence, in a smoky fire with an excess of carbon monoxide or carbon from fuel combustion, the rate of calcination with strongly reducing gases would be retarded or calcination might not occur at all.

Laboratory experiments at the University of Utah Archaeometry Laboratory bear this out. Two groups of wafers made from the same raw clay (Kaolinite with some palygorskite and sepiolite), containing the same amounts of limestone temper, were fired separately under conditions of oxidation (group A) and reduction (group B). The wafers were fired in an electric-resistance furnace at 50°C increments, beginning at 700°C and continuing up to 1050°C (above

which the clay vitrifies). Reducing conditions were created by pulverizing block graphite and totally immersing the wafer in the powder, preventing oxygen from reaching the wafer. Group A oxidized wafers began disintegrating at 800°C and continued doing so when fired to 850°C and 900°C. Beyond 900°C these wafers did not evidence any calcination or "lime-popping." Evidently, these higher temperatures were sufficiently high to cause the calcium oxide to fuse with the clay, forming calcium aluminosilicates. These silicates, which form above 850°C, render the calcium oxide completely unreactive and insoluble (Lawrence, 1972:35-36; Matson, 1943:85-86), while, at the same time, they increase the strength of the ceramic body (Grim, 1962:268). All the reduced group B wafers failed to show any calcination and "lime-popping." Between 800°-900° these wafers failed to crumble because an excess of carbon dioxide prevented the reaction of calcium carbonate to calcium oxide. Beyond 900°C aluminosilicates were formed. In the above experiment, had the calcite inclusions been of greater size or concentration, the reduced wafers would have calcined, but at temperatures 50°-100°C above those wafers fired under oxidizing conditions (studies in the Archaeometry Laboratory also bear this out).

Clearly, any estimations of original firing temperature based on whether calcium carbonate had converted to calcium oxide and calcium hydroxide would have to consider the primitive firing atmosphere of the ceramics being studied. A calcite-tempered sherd originally fired to 900°C in a smoky, reducing atmosphere might still contain unaltered calcium carbonate, while the same piece receiving sufficient oxygen might have calcined at 800°C. At best, statements of original firing temperature using the calcium carbonate/calcium oxide/calcium hydroxide indicator must be limited to broad temperature ranges and can perhaps be most effectively used to supplement firing temperature studies employing other means (see Leicht, 1975:126).

Also, in light of the high-temperature phases which calcium oxides can display in the form of aluminosilicates, it is meaningless to talk about pottery-bearing calcium carbonate inclusions as being restricted to firing temperatures below those which cause calcination. Under sufficient oxygen deprivation, a shell, limestone, or calcite-tempered vessel can be fired to vitrification without incurring any structural damage or evidence of "lime-popping." Undoubtedly, many primitive firings were neutral and reducing, so the firing of carbonate-inclusion pottery above a critical temperature would have been less of a problem to the potter than is usually supposed. It is conceivable that limited oxidation would have been sought by the ancient ceramist, not necessarily for reasons of fuel economy, but for reasons relating to the bearing power (strength) of a vessel and/or its final color when fired under the right atmospheric conditions.

The length of firing time influences the rate of reactions which occur in the carbonates. At any particular temperature

high enough to cause calcination, a relatively longer duration of firing will result in more crystal dissociation than will a relatively shorter rate of firing. In fact, it is not uncommon to observe sherd cross-sections in which the central core has unaltered calcium carbonate, while the area near the surface contains calcium carbonate which has dissociated. The difference is due to a time/temperature/atmosphere differential in the interior and near the surface. Because original firing time is an imponderable in ceramic technology, one cannot be certain whether milky-white calcined calcite crystals were fired to, for example, 750°C for one hour or 850°C for five minutes. The investigator can at best only approximate a possible temperature range in which the pieces could have been fired.

The size of the carbonate grains in the clay body exerts a strong influence on the extent of structural disturbance a vessel displays when heated to the temperature where calcium carbonate breaks down to calcium oxide. Finely divided calcite, limestone, or shell fractions (for example, less than 0.05mm) when calcined will react with water vapor to form calcium hydroxide and, subsequently, a cryptocrystalline form of calcium carbonate. No "lime-popping" will accompany the hydration of these smaller particles; whereas, larger grains will exhibit popping to the extent that the vessel surface might disintegrate from expansion pressure of the larger grains. Because of the fineness of various types of carbonate crystals which occur naturally as accessory constituents in many clays, it is possible to fire these clays above temperatures of carbonate dissociation without harmful effects to the vessel (even under conditions of strict oxidation). Very often, however, the carbonate tempers added by potters are larger than the natural carbonate inclusions and may physically harm the fired product if they are calcined and hydrated. The structural damage caused by calcination will also be a function of the density of the carbonate particles, especially if the particles are relatively large. Experiments in our laboratory show that a shell or limestone concentration in the order of 10% of total clay volume will (if the grains are over 1.0mm in length) do less structural damage than if the same particles are in the order of 30% or more density.

Because of the various factors which govern the temperature of calcium carbonate dissociation and the extent of the dissociation, it is not possible to arrive at precise statements of original firing temperature solely on the basis of carbonate thermal properties. If the factors of atmosphere, grain size, and inclusion concentration can be controlled, an approximation of gross firing temperature range can be achieved for a given ceramic piece. However, such approximations must necessarily be only suggestive in view of the difficulty of obtaining an accurate determination of the duration of firing. After a consideration of appropriate variables, an investigator might be justified in making a statement that his originally oxidized sherds that show no evidence of calcination were originally fired below 800°C, or that his strong-

ly reduced ceramics that show evidence of calcium aluminosilicates were originally fired above 850°C. At no time, however, would he be justified in advancing as fact that all the sherds in his lot with unaltered calcium carbonate were fired below 800°C; nor would he be justified in supposing that sherds exhibiting dissociated calcium carbonate were a potter's mistake and were structurally unsound, especially if the calcium carbonate particles were initially small and sparsely scattered.

In areas where easy access made some form of calcium carbonate a desired tempering material, it is very probable that primitive ceramists, at even the most rudimentary level of pottery making, would quickly learn about the pyrochemical properties of the material. While the potter would doubtless be unaware of the actual reactions taking place in his heated wares, he would know from experience that by firing in a smoky, reducing, or oxygen-starved atmosphere, he could reduce vessel breakage or weakness caused by "lime-popping" and he could pay less attention to actual firing-temperature limits. He would also know that if he ground his shell, calcite, or limestone finely enough, the damaging effects of "lime-popping" could be minimized or avoided completely.

Archaeologically, we may never know how many vessels were destroyed by thermal changes in calcium carbonate because these vessels would have disintegrated within a few weeks of their manufacture (Shepard, 1956:30). However, we can observe, in an archaeological context, carbonate-tempered sherds in which the carbonate has dissociated or even popped, but which remain structurally sound—a phenomenon which seems enigmatic if one supposes that carbonate inclusions impose strict limits on firing temperature (see Shepard, 1940:271). It is not puzzling if the investigator realizes the various circumstances under which the detrimental effects of "lime-popping" can be attenuated. If these conditions are recognized by the investigator, then misleading conclusions relating to the potter's technology can be avoided. Indeed, altered calcium carbonate and "lime-popping," rather than being attributed to lack of control and skill on the part of the potter, might more realistically be attributed to a potter's ingenuity and expertise which permitted his carbonate-tempered pottery to be fired to any temperature without structural damage.

ACKNOWLEDGMENTS

The writer is indebted to Dr. Philip Hammond for use of the research facilities of the Archaeometry Laboratory, University of Utah.

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THE GROUP FOSTER HOME COUNSELOR: AN ANTHROPOLOGICAL ANALYSIS

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The group, foster home provides an appropriate setting for an anthropological analysis of the evolution of political power—its acquisition, maintenance, and transfer. This paper discusses the relationship of roles between the group-home counselor (as the leader) and the adolescent, foster boys (as the leader's power base). As this power base is established, the leadership role changes from "strong" to "weak" and is transferred to subsequent counselors who must undergo this same political process.

† † †

INTRODUCTION

The following study is based on an eighteen-month, personal experience as a live-in counselor in a Midwestern group, foster home for adolescent boys. Because of the structured nature of the home, it was apparent that the political-anthropological model posited by F.G. Bailey in his book *Strategems and Spoils* (Bailey, 1969) would be appropriate to use for a political analysis.

The counselor position in the group, foster home provided an excellent example to test the Bailey model. The attainment, maintenance, and subsequent transfer of political power are discussed as a four phase, evolutionary process: Settling-In, Confliction, Stabilization, and Transition. Factors which enhance or detract from the counselor's status are also discussed.

This process basically involves an initial "strong leader" role with strict application of normative rules. As a power base is established and the counselor's authority is recognized, he can safely rely on pragmatic rule to govern the group home in a "weak leader" role.

The discussion begins with an explanation of Bailey's terminology, followed by a descriptive account of the group-home setting and the counselor's position. The foster-care system and its administrative structure are also briefly described. The main body of the paper is a political analysis of the counselor's position as outlined in the four phases above.

Before proceeding further, the Bailey terminology used throughout this study should be defined. Those terms frequently used are: *strong and weak leaders*, *moral and transactional teams*, *confrontations and encounters*, and *normative and pragmatic rules*.

There is a basic role differentiation between a "strong" and "weak" leader. The power to implement tasks assigned by these leaders is relatively the same but is utilized in different fashions. That is to say, by the terms "strong" and "weak" there should be no confusion over the competency to lead of these two types of leaders.

The "strong leader" *commands* out of necessity. He maintains a transactional arrangement with his team. That is, he commands and obtains compliance through the distribution of money and privileges. The relationship is purely transactional as is the leader's base of support or "team."

Conversely, the "weak leader" operates under a different arrangement. He obtains compliance by *request* only, as his relationship to his power base or team is moral-based on some common ideology held by himself and others. The team adheres to this ideology, which provides the unifying element. Thus, the relationship in this case is moral.

The struggle to maintain political power takes the form of confrontations and encounters. A confrontation is a message sent from a leader to his follower telling the latter of his own strengths and resources. This may escalate into an encounter when a particular behavior or event occurs. These two forms of competition are the bases of power control in a political situation.

Finally, both normative and pragmatic rules may serve as a guide to conduct in political competition. Normative rules are *culturally* defined behaviors, commonly shared and internalized by the group. They are ideological. Conversely, pragmatic rules are *situationally* defined as those most appropriate and practical for any particular situation. These may involve a re-interpretation of the normative rule not explicitly stated in that rule or a temporarily created rule for a particular time and place.

THE SETTING

The position of a group-home counselor demands that an individual be on duty (as a surrogate parent) twenty-four hours per day, twenty-two days per month. Basic requirements are: disciplining and counseling of one to eight adolescent foster boys (ages thirteen to eighteen years), caring of the

house, grocery shopping, transportation and bookkeeping.

The basic philosophy of a group home is to provide peer-group association, coupled with the guidance of the group-home counselor and the boys' social worker. This arrangement ideally prepares the boys for placement in an individual-family foster home (for the younger boy) or for independent living (for the older boy).

Because of the unusual nature of many of the boys, a structured arrangement was established. In the study-case, group home, a Behavioral Modification system was instituted whereby certain established normative behaviors were rewarded with "points" which were readily transferable into money and privileges. Failure to comply with the normative rule meant loss of points and the associated rewards. The system was designed to encompass all the boys' daily activities—hygiene, school attendance, housework duties, curfew, etc. The social worker referred to this treatment program as a "token economy." This is the setting in which the counselor operated.

THE COUNSELOR'S POSITION

The position of counselor in a group foster home is, in some respects, identical to that of a real parent. The distinction of roles lies in the fact that there is a treatment structure in the group home not found in the "real world." Also, counselors are, of course, not real parents.

A diagram best serves to illustrate the position of a group-home counselor in the hierarchical structure of the Division of Family Services for the Midwestern state in which the study-case, group home is located (Fig. 1).

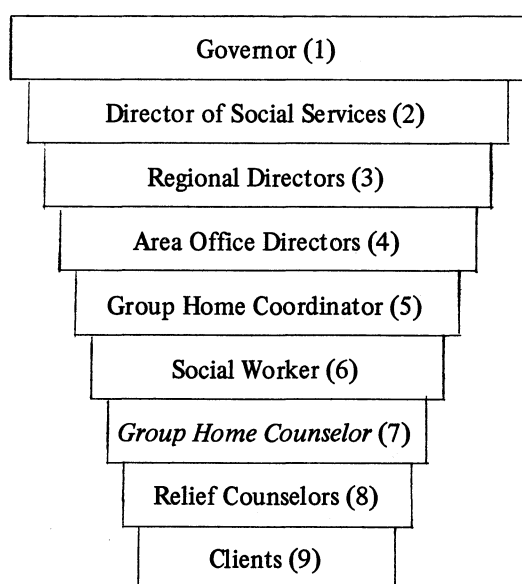


Figure 1. Administrative structure of the Division of Family Services.

The relative position here indicates that the group home counselor is near the bottom. The foster boys (or "clients") are lowest in the structure. In examining this diagram, the most important consideration to keep in mind is that interaction that is intensively related to the daily functioning of the group home occurs between numbers 5 through 9. The administrative structure above (numbers 1 through 4) is the policy-making body. Those below them (numbers 5 through 8) carry out this policy and obtain their positions from this body. They constitute the counselor's (leader's) initial *moral* team and remain a moral team. Position 9 is the leader's initial *transactional* team.

The counselor's position as a leader is *both* an achieved and an ascribed status. It is ascribed in that the administrative structure has legitimately licensed the individual to operate the home. However, the counselor must also *achieve* the status of leader. The respect and authority necessary to implement the leadership role must be earned. Leadership is based on ability *and* achievement. This involves: 1) assertion of the normative structure (or house rules); 2) support from the leader's staff (or moral team); and 3) gradual compliance and acceptance of the leadership status by the client-transactional team.

FOUR PHASES OF POWER ACQUISITION AND TRANSITION

The functioning of the group-home leader involves a four-phase process. During the entire period of the counselor's stay, political credit and power are acquired, and authority is recognized by all. It should be pointed out that these four phases are in no way exclusive of one another. The process is *not* totally clearcut or in select stages, but rather an ongoing political procedure.

These four phases may be described as: first, *Settling-In*; second, *Conflict*; third, *Stabilization*; and fourth, *Transition*. The first two phases involve a basic period of personality conflict. The particular type of boy dealt with is significant in affecting the composition of the client group at any time. During these phases, it is essential to maintain consistent adherence to the normative rules, thereby acquiring political power for the leader.

The remaining two phases mainly consist of the maintenance and transfer of political power. The leadership position has already been achieved by this time, and most daily matters involve bolstering one's power through a more loosely structured system of consent by request rather than by demand.

SETTLING-IN AND CONFLICT PHASES

When a new leader is settling into his new role as group-home counselor, he must act as a "strong leader." In the Settling-In phase, the new counselor must attempt to tran-

scend the moral commitment that the clients have toward their former leader. The new leader must make it known that *he* is now the leader and will be commanding the respect of each of the boys.

In the study-case, group home, the former leader did not accept the normative structure; he reinforced by pragmatic rule entirely. He did not seek the moral team support of his staff, but rather formed a faction with the clients in direct conflict and competition with the staff. Therefore, the clients adopted the political philosophy of the former leader, making the re-establishment of the original normative structure difficult.

It was necessary to establish a new set of normative rules (within the boundary of the original structure) based on the values of the new leader. This added additional strength to the new leader's power base in that the new rules structure was specifically tailored to his political philosophy.

During this time period, the relationship between the leader and client is necessarily transactional. Certain behaviors are rewarded with favors in the form of money and other resources. The clients form the leader's transactional team, while his staff is his moral team. The entire moral team is ideologically united in their political philosophy regarding the treatment program. They are rewarded by the successes obtained in utilizing this program (as measured by the clients' progress). This phase is an initial "feeling out" period. The leader has been ascribed his position, but as time passes, there are increased challenges and tests of his authority.

These instances are part of the Conflict phase. During this period, stress situations (in the form of confrontations and encounters) are frequent occurrences. The transactional team is attempting to test the power of their leader, based on his adherence to the rules *they* have broken and on his ability to meet the challenge of each new encounter. This becomes a matter of withstanding these stresses consistently.

In the case-study group home, it was necessary to utilize a change in one aspect of the normative structure to overcome the challenges of the transactional team on the leader's authority. The clients still recognized the normative structure as the ultimate authority. In a moral team meeting, it was decided that the leader's authority should, at certain times, overrule the rules' system. This implied that behavioral deviances not covered specifically on the rules sheet would be dealt with individually. The decision strengthened the leadership status in that an important judicial task was added to the leader's role. Nonetheless, leadership was ultimately acquired through consistent adherence to a "strong" leadership role with the transactional, client team.

STABILIZATION PHASE

Up to this point, the leader's moral team in the group

home is his staff, from whom he draws support and with whom he reaffirms the normative structure. Client support is based solely on a transactional arrangement, whereby resources in the form of money and privileges are exchanged for conformity to the rules.

Once power, authority, and respect have finally been recognized by the transactional team and realized by the leader, the Stabilization phase begins. In the past, the leader had maintained a "strong" role, commanding respect based on compliance to the normative rules in exchange for certain rewards. During the Stabilization phase, it is possible for the leader to assume a "weak" role. The stress brought about by the constant confrontation and encounter situations is greatly reduced. It is only during isolated incidents (such as client acting-out) that the leader again reasserts a "strong" position.

With this stable situation and his recognized political power, the leader can begin to revert to requesting compliance through pragmatic rule interpretation. Both the leader and client have accepted one another's roles. This shared recognition makes way for the formation of a second moral team, the former transactional client team. This team is evolved and maintained separate from the staff moral team and is ideologically based on friendship rather than the treatment goal. There is mutual respect. There is also the remaining transactional element in the rewards system. However, favors beyond the scope of the house rules as political intangibles are exchanged. The client may be no more satisfied or in agreement *philosophically* about the normative structure (as the leader's first moral team is) but, again, compliance is contingent on the moral tie to the leader. This tie continues to maintain the system until the leader departs and transfers his power to his successor.

TRANSITION PHASE

The final phase of the evolutionary political process begins as the leader makes preparations for his departure. The condition in which he leaves the political structure of the group home will greatly affect the new leadership. If the leader has consistently adhered to the normative structure, it will be advantageous to his successor.

The outgoing leader also finds it necessary to break the moral ties with both teams, although never entirely. He must stress the importance of carrying on the tradition of the structure to both teams. Ideally, this will help to assure a continuity in the transfer of power and provide some added incentive for the new leader.

SUMMARY

The preceding discussion has centered on the political analysis of power acquisition, maintenance, and transfer as illustrated by the position of a counselor in a group foster

home. This process was traced in four different, but not mutually exclusive, phases: Settling-In, Conflict, Stabilization, and Transition. The political model of the social anthropologist F.G. Bailey was used as a guide for this analysis.

The counselor begins as an ascribed leader and must acquire power through adherence to the normative rule structure. In Bailey's terms, he must be a "strong" leader. In the beginning, his moral team is his professional staff, while his client group forms his transactional team.

As a power base is established with the client team following extensive confrontation and encounter with them, the leader builds up political credit based on successful performance as a "strong" leader. Thereafter, he can comfortably assume the "weak" leader role based on pragmatic interpretation of the normative rules' structure. The transactional client team eventually becomes the leader's second moral team (distinct from the staff moral team) with rewards based on the ideology of friendship and mutual respect.

As the leader relinquishes his position to his successor, this political process begins anew. However, the condition in which the leadership role is left will greatly influence the effectiveness of the new leader.

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MAN-MADE ARTIFACTS FROM THE RED WILLOW GRAVEL PITS

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Hell Gap and Frederick Points pumped from gravel pits in Red Willow County to extend the geographic range of these point types. They indicate that western Nebraska was occupied during the late Pre-Boreal and Atlantic I climatic periods.

† † †

INTRODUCTION

The Red Willow gravel pits are located on the flood plain of the Republican River Valley in southwestern Nebraska (Fig. 1). Sand and gravel are pumped from as much as 35 feet below the surface. Frequently, Late Pleistocene or Holocene fossil bones are pumped from the pits (Corner, this volume) along with an occasional man-made artifact. While the provenience of these specimen is unknown, their presence in these gravel pits extends the known geographic distribution of these point types.

EVIDENCE OF MAN

Five, flaked, stone tools from the Red Willow gravel pits are available for study through the courtesy of the pit operators, Frank Gillen, Clarence Gillen, and Lee Davidson. The clear, sharp definition of the flaking patterns indicates that these artifacts had not been carried far from their point of deposition. The artifacts include two lanceolate projectile points and the tip of a third (Table I) along with two knives or blanks. The tip of a fourth projectile point was found embedded in the proximal end of a bison humerus, well within the range of *Bison antiquus* from the Scottsbluff Bison Quarry (Schultz and Eiseley, 1935, 1936). All four of the points and one of the knives were pumped from Rw 101, while the second knife is from Rw 102. The point embedded in the bison bone is in the collections of the University of Nebraska State Museum (U.N.S.M. 48533), while the other artifacts are in private collections. Lee Davidson, the pit operator of Rw 102, reports that other artifacts have come from his pit, but they were not available for study.

Projectile points

The first point is characterized by parallel flaking, a concave base, pronounced basal thinning, and heavy basal grinding (Fig. 2). On one side of the point, oblique flakes

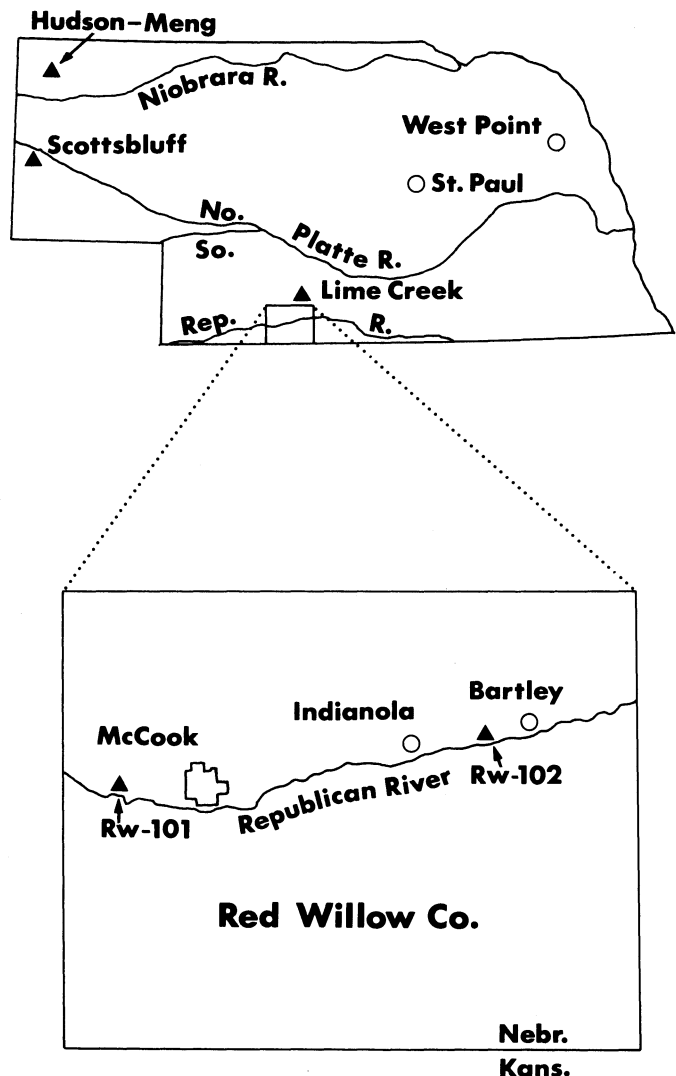


Figure 1. The State of Nebraska showing the location of selected archaeological and paleontological sites.

Table I:

Metric Characteristics of Projectile Points
From the Red Willow Gravel Pits

Attribute	A75.6.1	A75.15.1	A75.15.2
maximum length	(47.5) mm	75.0 mm	85.0 mm
maximum width	25.0	28.0	27.0
maximum thickness	7.0	7.0	8.0
basal width	—	21.0	27.0
concavity depth	—	—	3.5
hafting thickness	—	5.0	6.0
hafting width	—	21.5	26.0
hafting index	—	.233	.230

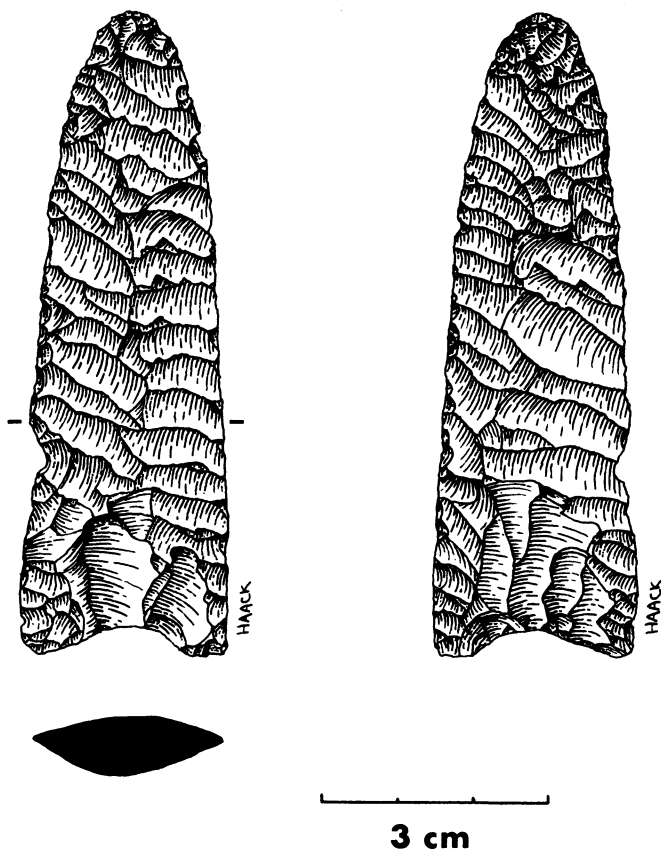
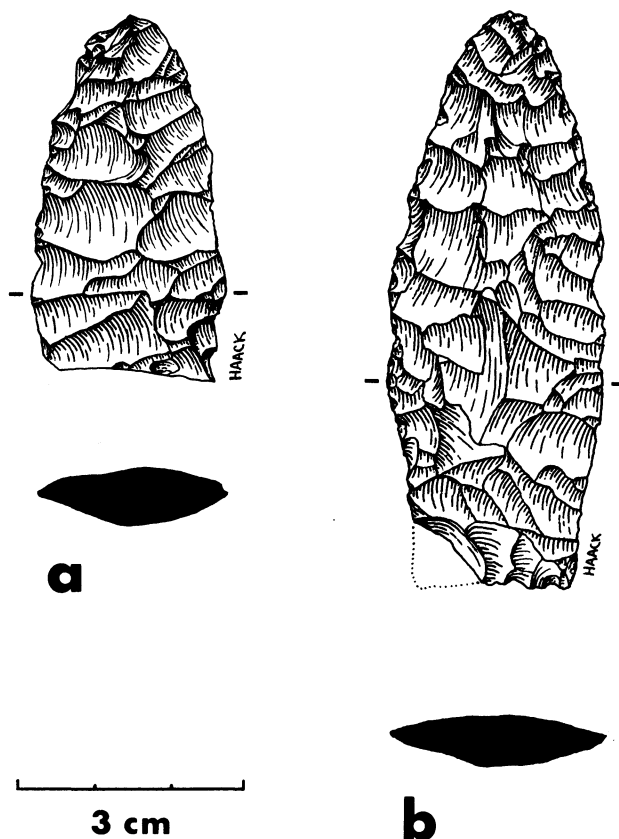


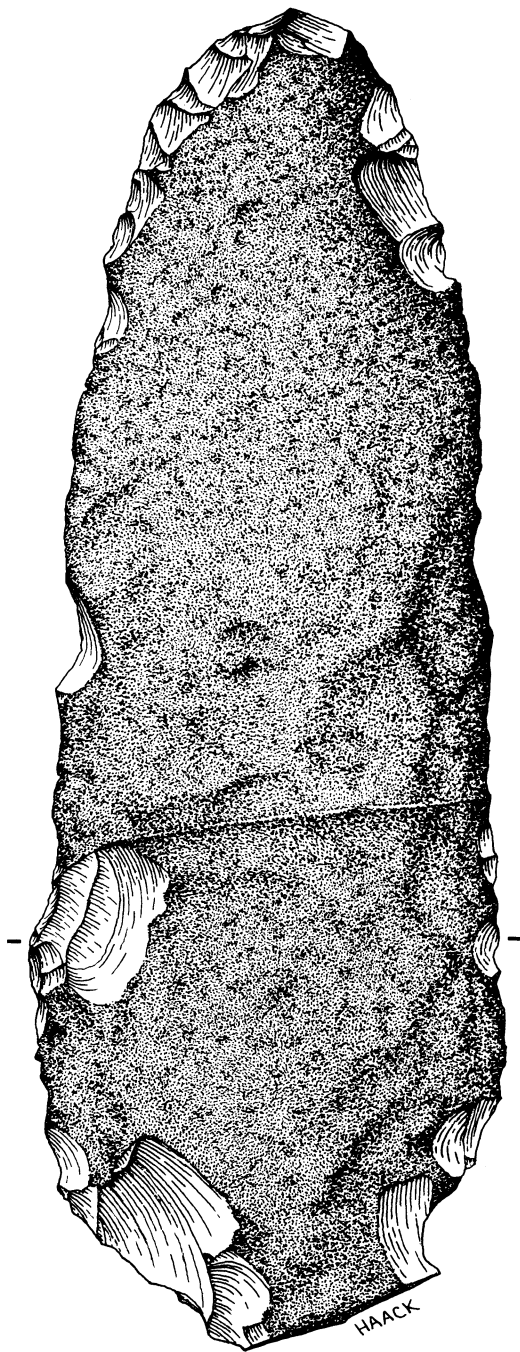
Figure 2. Frederick Point (A75.15.2) from Rw 101.

slant from upper left to lower right and usually carry across the mid-section of the point without a noticeable medial ridge. On the other side, the flakes are closer to horizontal and tend to meet in the center where they form a slight medial ridge. This point is classified as a Frederick Point (Irwin-Williams *et al.*, 1973: 50) which is distinguished from the Jimmy Allen Point (Mulloy, 1959) mainly by the depth of the basal concavity.

The other two points fall into the Hell Gap type (Fig. 3). They are characterized by lanceolate shape, controlled percussion flaking, and, on the complete example, by a straight base with basal thinning. The complete point is nearly identical to points from the Casper site on the North Platte River in central Wyoming (Frison, 1974; Figs. 1.39 - 1.43).

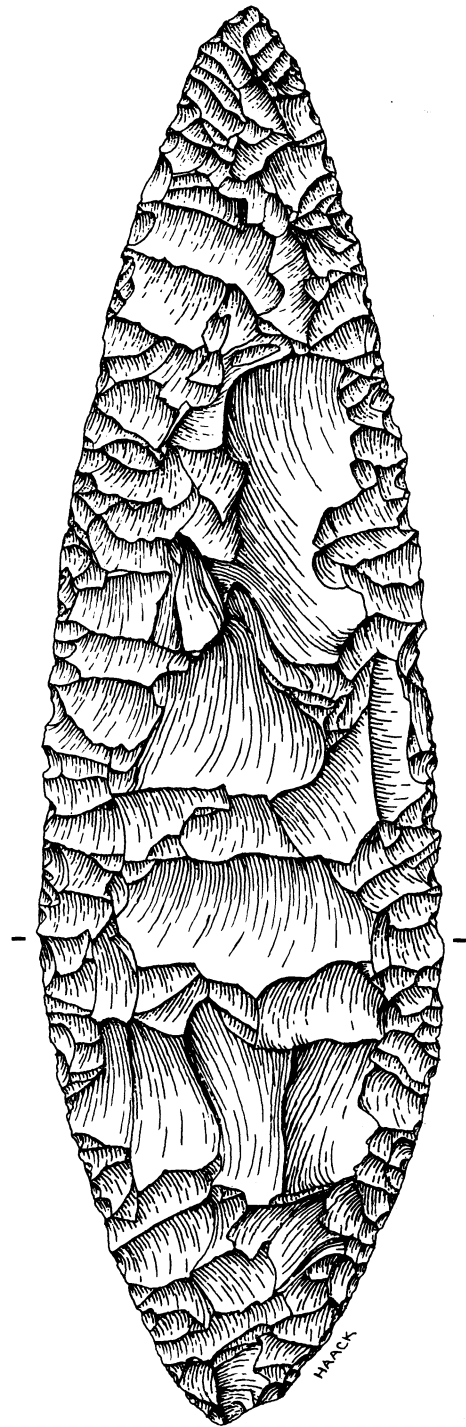
Figure 3. Hell Gap Points from Rw 101:
a, A75.6.1;
b, A75.15.1.

The fourth point is so deeply embedded in the bison bone that the flaking pattern could not be determined. The wound was not fatal since the bone had begun to grow over the point fragment. The artifact was not removed from the bone since its value as an exhibit specimen far exceeds the value of discerning the flaking pattern on a point tip. Its association with *Bison antiquus* is compatible with the known age of Hell Gap and Frederick Points.



a

3 cm



b

Figure 4. Knives from the Red Willow gravel pits:
a, A75.6.2 (Rw 101);
b, A75.7.1 (Rw 102).

Knives

One of the knives is a thin, elongated knife made of yellow jasper. Large shallow percussion flakes are found near the center of the implement, while the edges are trimmed to shape by careful percussion flaking. This knife form first appears in the Agate Basin and Hell Gap levels of the Hell Gap sequence in eastern Wyoming (Irwin-Williams *et al.*, 1973: 47-8, Fig. 5.5).

The other knife is similar in size and shape, but the flaking pattern is quite different (Fig. 4b), perhaps because it was never completed. This piece is particularly interesting because it was made from a thin band of yellow jasper which had not been entirely separated from the matrix. Use of such thin bands of raw material would have facilitated the production of such large, thin knives.

DISCUSSION

The stratigraphic and temporal position of Hell Gap and Frederick Points has been established by excavations at Hell Gap and other sites in eastern Wyoming. Hell Gap points date from about 8100-7500 B.C., while Frederick and the Closely related Jimmy Allen points date from around 6400-6000 B.C. (Frison, 1974; Irwin-Williams *et al.*, 1973: 48, 51). These time periods correlate with the late Pre-Boreal and early Atlantic I climatic periods suggested by Bryson and his co-workers (1970). However, we know little about the conditions which existed during these periods in western Nebraska.

Since these point types were found in gravel pits, it is apparent that their makers were utilizing either the river valley itself or the bluffs adjacent to the valley. Now and in the recent past, the floodplain of the Republican River valley has been characterized by a floodplain and prairie environment as far west as eastern Dundy County (Kaul, 1975), about 60 miles west of the Red Willow gravel pits. Mastodont bones from the gravel pits indicate that gallery forest had also stretched far into western Nebraska at some time during the Pleistocene, but there are no woodland fauna from the pits which would have been contemporary with man's occupation of the area (Corner; this volume; and personal communication). In contrast, such woodland fauna has been found in gravel pits near St. Paul and West Point, Nebraska (Corner; personal communication). This may mean that the upper Republican River valley was forest free during part of man's occupation of the area.

One of the greatest needs in Nebraska archaeology is to determine the environmental conditions which prevailed during man's occupancy of the state.

ACKNOWLEDGMENTS

I am indebted to Frank and Clarence Gillen and to Lee Davidson for allowing me to borrow the artifacts on which this paper is based. Without this kind of cooperation between

amateur and professional archaeologists, our knowledge of prehistory would be much the poorer. I am also indebted to R.G. Corner and M.R. Voorhies of the University of Nebraska State Museum for their stimulating discussion and willingness to act as a sounding board for some of the ideas expressed in this paper. However, no blame for factual errors or interpretation should be ascribed to them unless specifically cited.

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BIOLOGICAL AND MEDICAL SCIENCES

PLANT GALLS OF THE VICINITY OF SEWARD, NEBRASKA

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This report is based on twenty years of collecting and culturing insects from galls in the vicinity of Seward, Nebraska. It includes a listing of gall insects, inquilines, and parasites discovered in this study. Some forty-seven gall makers, forty-nine parasites, and fourteen inquilines are listed.

† † †

INTRODUCTION

One of the most interesting areas of study for the novice in biology is that of the plant-insect relationships evident in plant galls. In order to offer a challenge to the biology student in his contacts with college biology and to assure him that biology is the study of living things rather than, as so many have been led to believe, the consideration of the dead and embalmed, the author has been sending his students into nature in the vicinity of Seward, Nebraska to see for themselves and to collect and to culture insects from galls which they find.

Since the literature on galls is often not available to the student, this paper is designed to make available much of the information needed to identify the galls which he will probably encounter. This paper represents the efforts of the author in collecting through the years from 1938 through 1959, while carrying out other research projects. Daily trips were made to the field during the summers of 1952, 1955, 1957, and 1959. Galls discovered were taken to the laboratory and placed in glass jars or in shoe boxes in the ends of which holes had been made to receive small vials. Since these holes were the only source of light, the emerging insects were attracted to them and soon appeared in the vials.

Most of the insects involved in this study were cultured by the author and identified by the specialists indicated. A few of the insects have not been successfully reared by the author, and in such cases, the literature has been carefully checked; but it is believed that the identifications are quite accurate. However, some uncertainty still prevails with regard to some of the insects. Even in the literature there remain many questions as is indicated by Kinsey and Ayres (1922): "The association of insects with the wrong galls is liable to

occur with our most precautionous methods, and that it has occurred abundantly with many published species is being repeatedly shown." The fact that many parasites, hyperparasites, and guests inhabit the same gall with the gall maker makes it extremely difficult to be sure of the identity of the real gall maker. Also, if clusters of galls are cultured, the fact that at times several different galls are found in one cluster makes it difficult to determine which insect emerged from which gall. The author has some doubts as to the exactness of the identities, especially of some of the wasps listed in the study of *Rosa pratincola* Greene.

GALLS ENCOUNTERED IN THE VICINITY OF SEWARD, NEBRASKA

AMORPHA

Amorpha canescens Pursh. (Lead Plant). (Fig. 1, d, and e.)

"Chimney" gall, 6 mm. tall, on leaflets, petioles or stems, color reddish to green.

Maker: A midge, *Diarthronomyia* sp.

Parasite: A chalcid, *Zatropis nigroaeneus* (Ashmead).

Location: Meadows east of Seward.

Note: This is the first record of this relationship of *Z. nigroaeneus* (Ashmead) with *Diarthronomyia*.

Rachis gall, 15 mm. long, 3 mm. diameter, fusiform thickening of rachis of inflorescence. This gall seems not to have been described nor is the causative insect known. (Fig. 1, e.)

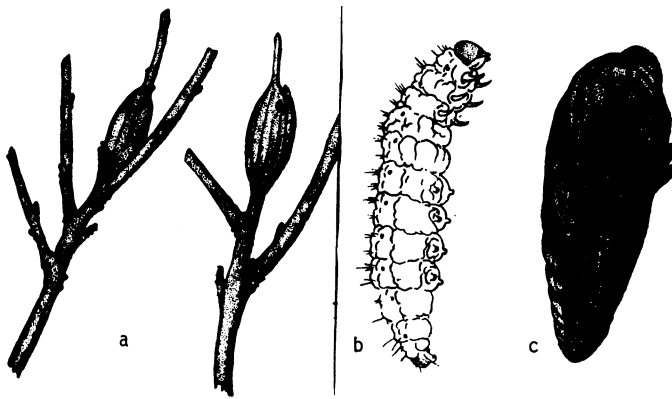
Amorpha fruticosa Linnaeus (False Indigo). (Figure 1, a, b, and c.)

Oval to fusiform stem gall, 8 mm. diameter, 24 mm. long, near tips of stems.

Maker: Lepidopteron, *Walshia amorphella* Clemens.

Parasites: *Phaeogenes walshiae walshiae* Ashm. pupates inside the pupa of *W. amorphella*. *Microgaster eclytolophae* Muesebeck spins silken cocoon inside gall after devouring *W. amorphella*. *Eupelmus* sp.

Note: Old galls are used by many other insects and spiders.



Terminal bud gall, heart-shaped, pubescent, 6 mm. diameter, 8 mm. long.

Maker: A midge, *Itonididae* sp.

Parasites: *Pseudotorymus* sp., *Amblymerus* sp., *Platygaster* sp.

Note: This gall has been found on other asters also.
Location: Roadsides north and east of Seward.

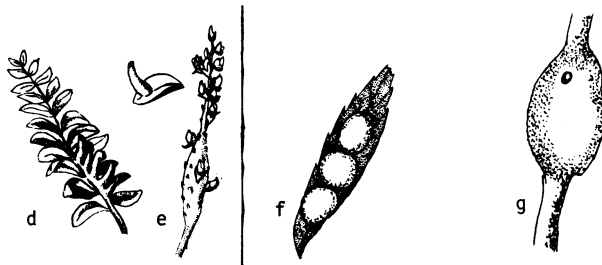


Figure 1. a) *Amorpha fruticosa*—Galls of *Walshia amorphella* Clemens.

b) Larva of *Walshia amorphella*.

c) Pupa of parasite, with *Phaeogenes walshiae* Ashmead inside pupa of *Walshia amorphella*.

d) *Amorpha canescens*, Gall of *Diarthromyia* sp.

e) Rachis gall on *Amorpha canescens* (unidentified).

f) *Solidago canadensis*, Gall of *Asteromyia flavoanulata* Felt.

g) *Solidago canadensis*, Gall of *Gnorimoschema gallaesolidagenis* (Riley).

Location: Second street of Seward, 1 mi. south, along the Blue River.

Watch for galls with a cellophane-like cover over the emergence hole. This is produced by the bee, *Hylaeus cressoni* (Cockerell) (= *Prosopis cressoni* Cockerell, 1907) (Colletidae) which uses the gall as a nesting site.

ASH

Fraxinus campestris Britton (Green ash). (Figure 2, e.) Flowers in deformed masses remain on tree.

Maker: A mite, *Eriophyes fraxiniflora* Felt.

Location: Many on the campus of Concordia Teachers College.

ASTER

Aster multiflorus Aiton (Many-flowered aster). (Figure 2, b.)

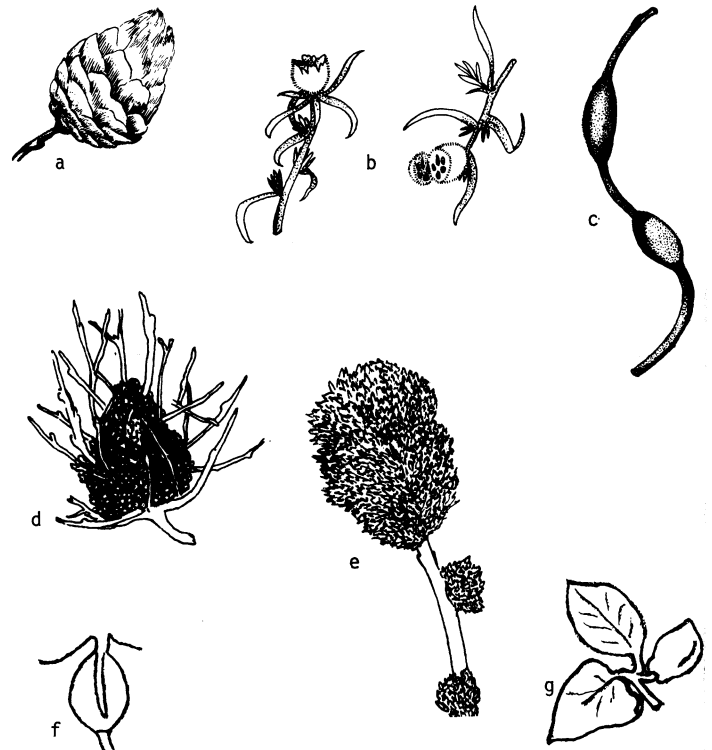


Figure 2. a) Pine cone gall of *Rhabdophaga strobiloides* on *Salix*.

b) Galls of a midge, probably *Rhopalomyia lateriflora* Felt (*Itonididae*).

c) Galls of *Lasioptera convolvuli* Felt on *Convolvulus sepium*.

d) Gall of *Sphaerotheca phytophila* Felt on *Celtis occidentalis*, Linneus.

e) Gall of *Eriophyes fraxiniflora* on *Fraxinus campestris* Britton.

f) Gall of *Pemphigus populitransversus* Riley on *Populus occidentalis* Rhydborg.

g) Gall of *Contarinia virginianiae* Felt on *Prunus virginiana* Linnaeus.

BINDWEED

Convolvulus sepium Linnaeus (Hedge bindweed). (Figure 2, c.)

A fusiform stem gall 14 mm. long, 7 mm. diameter.

Maker: A midge, *Lasioptera convolvuli* Felt.

Note: This can be most easily seen after a frost.

Location: Along Plum Creek.

CEDAR APPLE

Juniperus virginiana Linnaeus. (Red cedar)

Irregular enlargement on twigs, gelatinous in spring rains.

This gall is caused by a fungus: *Gymnosporangium globosum* Farlow.

Several insects may be found in the dry galls.

Location: Common on cedar trees in various areas of the county.

Note: This fungus also causes a blight on apple and pear trees.

CHOKE-CHERRY

Prunus virginiana Linnaeus (Choke-cherry). (Figure 2, g.)

Fruit gall 6 mm. diameter, 14 mm. long, open at one end.

Maker: A midge, *Contarinia virginianiae* Felt.

Inquiline: *Itonida canadensis*, Felt, *Rhizomyia absorbina* Felt, *Dasyneura pregandei* Felt, *Cecidomyia cerasiphila* Felt, *Arthrocnodax apiphila* Felt.

Note: These inquiline are listed by Felt. Several other insects may be found in the old galls.

Location: Concordia Teachers College campus, Seward.

COTTONWOOD

Populus occidentalis (Rhydberg) Britton (Cottonwood). (Figure 2, f.)

Bulbous hollow petiole gall, 15 mm. diameter.

Maker: An aphid, *Pemphigus populitransversus* Riley.

Location: Cottonwoods are common along Plum Creek.

Similar gall at base of leaf, 13 mm. diameter.

Maker: Another aphid, *Pemphigus populicaulis* Fitch.

DOGWOOD

Cornus asperifolia Michaux (rough-leaved dogwood). Club-shaped gall on twigs, 10 mm. diameter, 17 mm. long.

Maker: A midge, *Mycodiplosis alternata* Felt.

Location: Along Clarke Creek (Middle Creek area).

GOLDENROD

Solidago canadensis Linnaeus (Canada goldenrod, State flower). (Figure 1, f, and g.)

Circular blister leaf gall, 8 mm. diameter.

Maker: A midge, *Asteromyia flavoanulata* Felt.

Note: Felt lists *S. squarrosa* as the host for a similar gall with a black border. Such a gall appears also on *S. canadensis* Linnaeus. The insect producing it may be a midge, *Asteromyia squarrosa* Felt, but this is uncertain.

Parasite: *Platygaster solidaginis* (Ashmead).

Apical rosette gall, 65 mm. diameter.

Maker: A midge, *Rhopalomyia solidaginis* Lw.

Inquiline: Numerous, a curculionid beetle; Felt lists also the following which have not been recovered here: *Rhopalomyia albipennis* Felt and *Oligotrophus inquilinus* Felt.

An oval stem gall, 15 mm. diameter, 25 mm. long. (Fig. 1, g.)

Maker: Leptidopteron, *Gnorimoschema gallaesolidaginis* Riley. (Recommended as fish bait)

Parasites: *Zatropis nigroaenus* Ashmead, *Aprostocoetus americanus* Ashmead.

Note: Several additional galls are listed in the literature, but these have not yet been found here.

Location: Roadsides north and south of Seward.

GRAPE

Vitis vulpina Linnaeus (Wild grape).

Leaf gall, wort-like, tuberculate, 4 mm. diameter.

Maker: An aphid *Phylloxera vitifoliae* Fitch.

Location: Plum Creek, Blue River, Clarke Creek.

Note: Destroyed 2,500,000 acres of vineyard in France.

HACKBERRY

Celtis occidentalis Linnaeus (Hackberry).

Nipple-like gall on underside of leaf, 6 mm. diameter, 8 mm. long.

Maker: Psyllid, *Pachypsylla mamma* Riley.

Predator: A neuropteran.

Large sub-globose to reniform petiole gall 12 mm. to 20 mm. diameter. (Fig. 2, f.)

Maker: Psyllid, *Pachypsylla venusta* Osten Sacken.

“Witches’ broom” gall, a mass of twigs 30 mm. in diameter, 60 mm. long or more. (Fig. 2, d.)

Maker: *Sphaerotheca phytophila* Felt.

Location: Four blocks south of Concordia College campus on Columbia Avenue, Seward.

HORSEWEED

Leptilon canadensis (Linnaeus) Britton (Muletail or horseweed).

Apical bud gall 6 mm. to 12 mm. diameter. Rare.

Maker: A midge, *Rhopalomyia erigerontis* Felt.

Fusiform stem gall or thickening of stem 20 mm. long.

Maker: A midge *Neolasioptera erigerontis* Felt.

Location: Plum Creek, Concordia Teachers College campus, Seward.

IRONWEED

Vernonia baldwinii Torrey (Ironweed).

Fusiform stem gall. 8 mm. diameter, 16 mm. long.

Maker: Dipteron, *Lasioptera* sp. or closely related.

Parasites: Braconidae: *Apanteles plathypenae* Muesebeck, *Schizoprymnus* sp. Platygasteridae: *Platygaster vernoniae* Ashmead. Eulophidae: *Tetrastichus* sp. Torymidae: *Torymus* sp., *Torymus* sp.

Pedicle gall, 2 mm. diameter, 6 mm. long.

Maker: Cecidomyia, *Lasioptera* sp. probably *vernoniae* Beutenmueller.

Location: Ironweed may be found abundantly in pasture four miles north of Seward, Highway 15, and other locations.

KNOTWEED

Polygonum lepathifolium Linnaeus (Knotweed—Ladyfinger).

Spindle-shaped to oval stem gall 12 mm. diameter, 20 mm. long.

Maker: Curculionid, *Lixus* sp. (Sp. nov.)

Location: South side of C.B.&Q. R.R. tracks south of Seward.

Polygonum aviculare Linnaeus (Doorweed).

Gall similar to above but about half the size.

Maker: Curculionid, probably *Lixus musculus* Say.

Locations: Concordia Teachers College Campus—very common throughout the area.

LETTUCE

Lactuca ludoviciana (Nuttall) DeCandolle (Wild lettuce).

Bulbous stem gall up to 35 mm. diameter.

Maker: A wasp, *Aulacidea tumida* Bass.

Similar apical gall, often larger.

Maker: A wasp, *Aulacidea annulata* Kinsey.

Location: Roadsides around Seward.

MOSSYCUP OAK

Quercus macrocarpus Michaux (Mossycup).

Spherical, occasionally pointed, gall 14 mm. diameter.

Maker: A wasp, *Disholcaspis mamma* Walsh.

Bulbous petiole gall, 18 mm. diameter.

Maker: *Andricus concolorans* Kinsey.

“Hedgehog” leaf gall, 5 mm. diameter, reddish.

Maker: *Acraspis prinoides* Beutenmueller.

Location: Along creeks and Blue River.

Note: Several additional galls are found on our oaks, but as yet they have not been definitely identified.

Bullet gall similar to first. Spherical or flattened on one or more sides. 12 mm. diameter.

Maker: A wasp, *Disholcaspis globosa* Weld.

Spherical to conical leaf gall 3 mm. diameter, 4 to 5 mm. high.

Maker: A fly, *Cecidomyia* sp.

Midrib cluster gall 7 mm. wide, 12 mm. long, individual cell spherical 2 mm. diameter.

Maker: A wasp, *Cynips dimorphus* Beutenmueller.

PLUM

Prunus americana Marsh (Wild plum).

Irregular terminal bud gall 12 mm. diameter.

Maker: *Cecidomyia* sp. probably *serotina* Osten Sacken.

Location: Plum Creek, Clarke Creek.

PRAIRIE CONEFLOWER

Ratibida columnaris (Sims) Don (Prairie coneflower).

Swelling of torus 2 mm. diameter, 8 mm. long.

This gall has not been described nor have we been able to culture the maker to maturity.

Location: Middle Creek area.

RAGWEED

Ambrosia trifida Linnaeus (Giant ragweed).

Stem gall, oval 14 mm. diameter.

Maker: A midge, *Neolasioptera ambrosiae* Felt.

REDROOT

Ceanothus ovatus Desfontaines (Redroot).

Irregular swelling of stem 6 mm. diameter.

Maker: Lepidopteron, *Stagmatophora ceanothiella* Cosens.

Parasite: A wasp, *Eurytoma* sp.

Location: The gall is found only in an area north of Garland, Nebraska. The plant is found in many meadows near Seward.

ROSE

Rosa pratincola Greene (Prairie rose). (Figures 3 and 4, b.)

Lenticular leaf gall 4 mm. diameter.

Maker: A wasp, *Diplolepis rosaefolii* (Cockerell).

Guest: A wasp, *Periclistus* sp.

Parasites: Wasps, *Ormyrus* sp., *Pteromalini* sp., *Chrysocharis* sp., *Ormyrus* sp.

Spiny-leaf gall, globose, 8 mm. diameter. (Figures 3, c and e.)

Maker: A wasp, *Diplolepis pustulatoides* Beutenmueller.

Parasites: Wasps, *Habrocytus* sp., *Ormyrus* sp., *Eupelmus* sp.

Guest: A wasp, *Periclistus* sp.

Mealy gall, irregularly globose, 10 mm. to 20 mm. diameter.

Maker: A wasp, *Diplolepis ignotus* Osten Sacken.

Parasites: Wasps, *Eurytoma* sp., *Tetrastichus rosae* (Ashmead).

Similar to above, but not mealy type.

Maker: A wasp, *Diplolepis variabilis* Bass. (Figure 4, c.)

Parasites: Wasps, *Eurytoma* sp., *Tetrastichus rosae* (Ashmead), *Eupelmus* sp., *Habrocytus* sp., *Torymus bedeguaris* (Linnaeus), *Eupelmella dryorhizonexi* (Ashmead), *Orthopelma mediator* (Thunberg).

Long spined twig gall 7 mm. to 12 mm. diameter. (Figure 4, h.)

Maker: *Diplolepis fusiformans* Ashmead.

Parasites: Wasps, *Habrocytus* sp., *Torymus bedeguaris* (Linnaeus).

Fusiform stem gall 7 mm. diameter, 10 mm. long. (Figure 4, g.)

Maker: A wasp, *Diplolepis verna* (Osten Sacken).

Parasites: Wasps, *Habrocytus rosae* (Girault), *Ormyrus* sp., *Torymus bedeguaris* (Linnaeus), *Zatropis* sp., *Eurytoma* sp., *Polynema* sp. (egg parasite).

Spiny-leaf gall, globose, 6 mm. to 8 mm. diameter, spines longer than in *Diplolepis pustulatoides* Beutenmueller. (Figure 4, d.)

Maker: A wasp, *Diplolepis bicolor* (Harris).

Guest: A wasp, *Periclistus pirata* (Osten Sacken).

Parasites: A wasp, *Chalcididae*, several species.

Note: *Diplolepis bicolor* was also reared from a gall on *Rosa rugosa* Thunb. This gall has long spines consistently bent or hooked. (Figures 4, e, and f.) From this gall there emerged also the parasites: *Torymus bedeguaris* (Linnaeus) and *Habrocytus* sp.

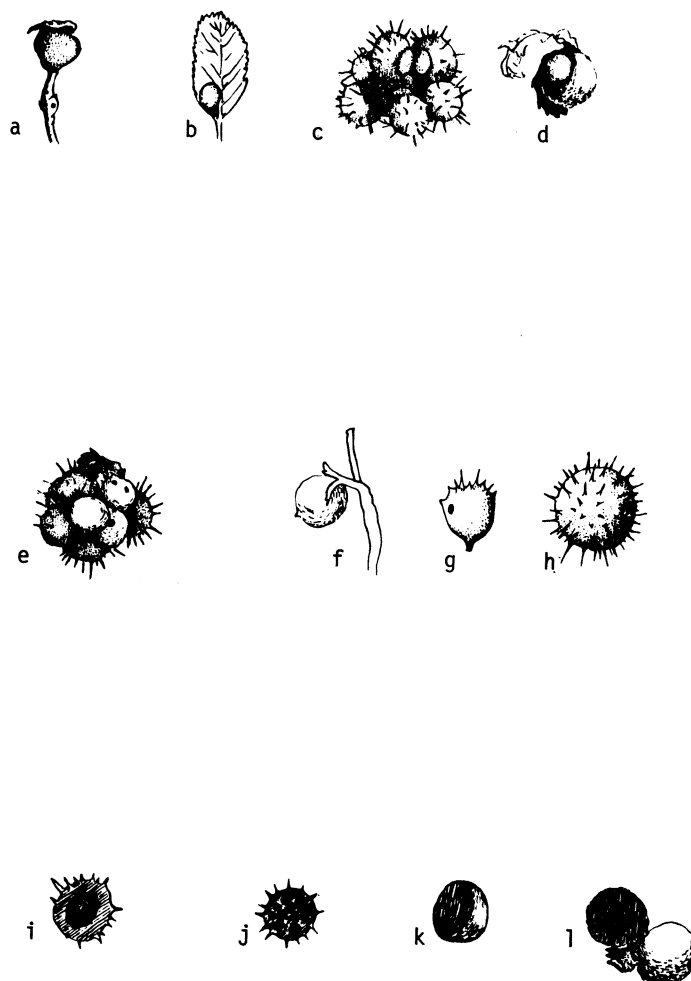


Figure 3. Gall characteristics:

- a) New petiole gall, maker unknown.
- b) Disk gall on leaf.
- c) Disk and spiny galls combined.
- d) Disk and pithy galls combined.
- e) Spiny and pithy galls combined.
- f) Pithy gall.
- g) "Varnished" gall.
- h) Large spiny gall.
- i) Monothalamous spiny gall.
- j) Polythalamous spiny gall.
- k) Polythalamous pithy gall.
- l) Monothalamous pithy gall.

ROSINWEED

Silphium integrifolium Michaux. (Rosinweed)

Ovate flower gall 2 mm. diameter.

Maker: A wasp, *Antistrophus laciniatus* Gillette.

Guest: A wasp, *Eurytoma gigantea* Walsh.

Parasites: Wasps, *Eurytoma* sp., *Tetrastichus* sp.

Location: Blue River, Lincoln Creek, roadsides.

Antistrophus pisum Walsh. The typical gall is pea-shaped; another is a root gall; the third is a stem gall. Parasites: *Antistrophoplex bicoloripes* Crawford, *Eupelmus allynii* French *Tetrastichus bruchophaga* (Gahan)

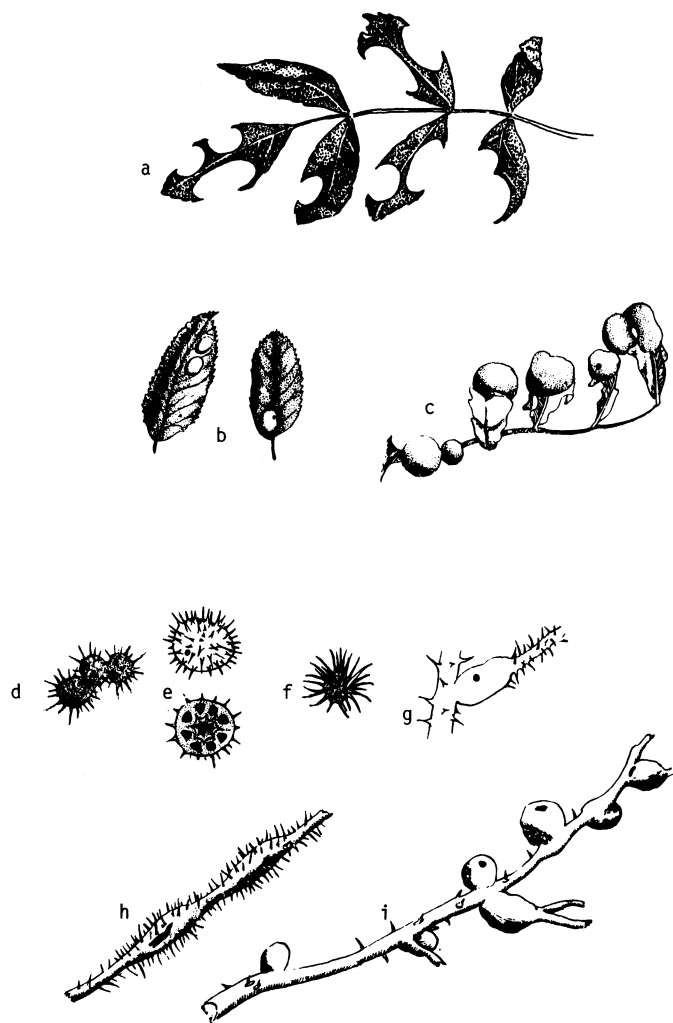


Figure 4. a) Work of the leaf cutter bee, Megachilidae. b) Gall of *Diplolepis, rosaefolii* (Cockerell). c) Gall of *Diplolepis variabilis* Bass. d) Gall of *Diplolepis pustulatoides* Beutenmueller. e) Gall of *Diplolepis bicolor* (Harris). f) Gall of *Diplolepis bicolor* on *Rosa rugosa* Thunberg. g) Gall of *Diplolepis verna* (Osten Sacken). h) Perhaps gall from *Diplolepis fusiformans* Ashmead. No insect recovered. i) Gall of an unknown insect not recovered.

SKELETON WEED

Lygodesmia juncea Pursh (Skeleton weed). (Figure 5, a-h.)

As shown in Fig. 5, three different galls were produced on *Lygodesmia juncea* Pursh by the gall maker,

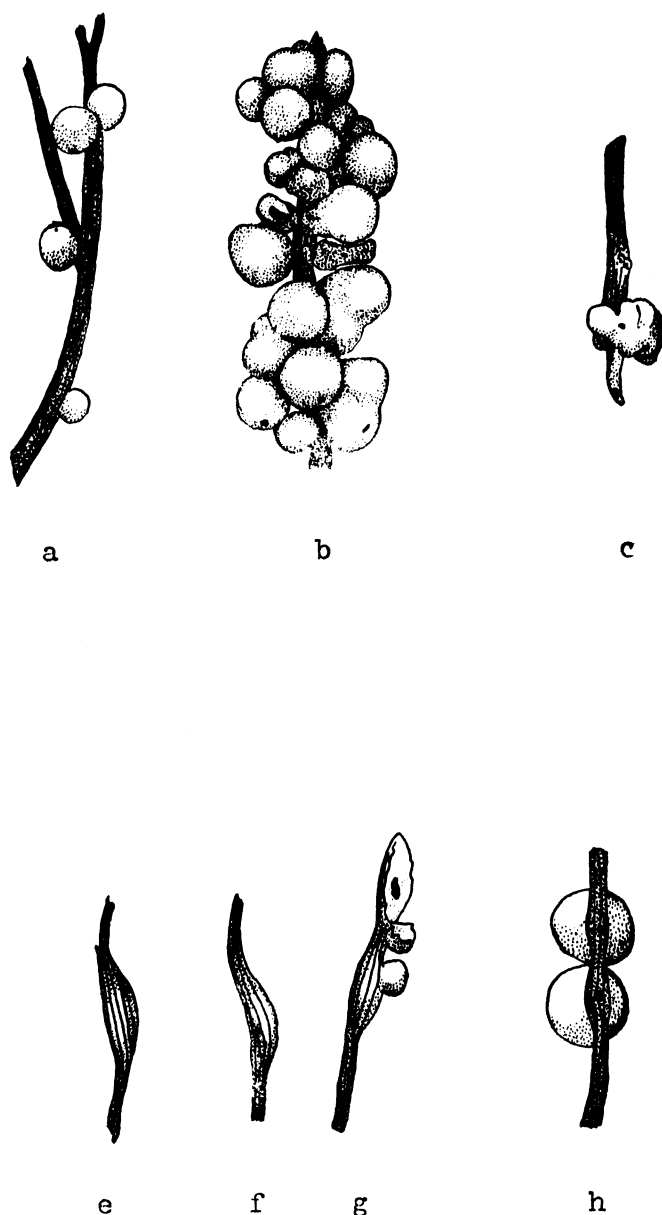


Figure 5. Galls on *Lygodesmia juncea* (Pursh) from which *Antistrophus pisum* Walsh emerged:

- a) Normal condition.
- b) Extreme crowding of galls.
- c) Root gall.
- d) to g) Fusiform galls.
- h) Normal galls with emergence holes through stems.

WILLOW

Salix sp. (willow)

Pine cone gall, 26 mm. diameter, 30 mm. long. (Figure 2, a.)

Maker: A midge, *Rhabdophaga strobiloides* Walsh.

Guest: Several miscellaneous guests live among the "leaves" of the cone-like gall. They have not been successfully cultured, however.

Location: Lincoln Creek near Staplehurst.

ACKNOWLEDGMENTS

Thanks are due the following specialists who made determinations of the insects involved in this study: From the National Museum—Dr. B.D. Burks, Dr. J.F.B. Clark, Dr. R.H. Foote, Dr. Karl V. Krombein, Dr. C.F.W. Muesebeck, Dr. Louise M. Russel, Dr. C.W. Sabrosky, Dr. Luella M. Walkley, and Dr. Lewis B. Weld; Dr. R.C. Dickson, University of California; Dr. C. Frost, Framingham, Massachusetts; and Dr. Vasco M. Tanner, Brigham Young University.

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**MARVINMEYERIA LUCIDA (MOORE, 1954) (ANNELIDA: HIRUDINEA)
A COMMENSAL OF
HELISOMA TRIVOLVIS (SAY) (MOLLUSCA: GASTROPODA) IN NEBRASKA**

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During September, 1974, in the course of examining aquatic snails for larval trematode infections, specimens of *Helisoma trivolvis* (Say) were collected and found to contain one or two specimens of the leech *Marvinmeyera lucida* (Moore, 1954) Soos, 1969 between the shell and mantle. The leeches were identified on the basis of comparison with the original description and with the specific diagnosis given by Soos (1969, Acta Zool. Acad. Scient. 15:397-454). Specimens were observed live with the aid of a stereoscope or compound microscope, then flattened with slight coverslip pressure, fixed with aceto-formo-alcohol (AFA), and stored in 70% ethanol. They were then stained with Mayer's hematoxylin and mounted in Canada balsam for study as whole mounts. Voucher specimens have been deposited in the University of Nebraska State Museum Division of Parasitology.

Marvinmeyera lucida was described from specimens collected in Manitoba, Canada as free-living among plant debris in shallow water (Moore, in Meyer and Moore, 1954; Wassmann, J. Biol. 12:63-96). Moore (1966, Nat. Hist. Pap. Nat'l. Mus. Can. 32:1-11) stated that small snails constitute the principal food source of *M. lucida* in Alberta, Canada and listed *Physa heterostrophus* (Say), *Menetus exacuus* Call, and *Lymnaea marginata* (Say) as prey. When leeches were isolated in aquaria containing only snails, they readily ate the snails, showing a definite preference for *Physa hererostrophus*.

Scudder and Mann (1968, Syesis. 1:203-209) reported *M. lucida* from temporary ponds in British Columbia, Canada. Specimens were said to be free-living among plant debris. Sawyer (1968, Ohio J. Sci. 68:226-228) reported *M. lucida* from southern Michigan and stated that in his rare encounters with the leech species, he usually found them in association with snails of the genera *Physa* and *Lymnaea*, but never observed them feeding upon the snails. Sawyer (1972, Ill.

Biol. Mono., Univ. Ill. Publ., Urbana Ill.) later expressed the opinion that the relationship between *M. lucida* and the snails was other than predator-prey.

In the present study, nine of ten *Helisoma trivolvis* from a pond 2 miles south and 2 miles west of Lincoln and 27 of 30 *H. trivolvis* from a slow-moving stream 2 miles south and 1.5 miles west of Lincoln, Nebraska harbored one or two specimens of *M. lucida*. Specimens of *Physa integra* examined at the same locality were negative. In most cases, when the snail's shell was crushed, the leech (-es) swam rapidly away. In no case was a leech observed feeding on the snail, nor was any pathology evident. Further, examination of stomach contents of mounted specimens revealed the presence of diatoms of the genus *Navicula*, suggesting that the leech's diet is in part composed of plant material. These observations indicate that the relationship between *M. lucida* and *Helisoma trivolvis* in Nebraska may be commensal, the leech utilizing the snail's shell for protection. If, as indicated by the stomach contents, *M. lucida* is a plankton feeder, the leech may serve to partially protect the snail from infection by larval trematodes. None of the snails harboring *M. lucida* was infected by larval trematodes, but the sample was too small to ascertain whether or not that finding is significant. In times of stress, especially if normal food supplies are interrupted, it is conceivable that the leech might consume its snail host [as in Moore's (1966) experiment].

The specimens collected were of two, size classes, with only those specimens of the larger class bearing mature ova. The bimodality of the size distribution may be explained on the basis of studies done by Moore (op. cit.). In studying the reproductive strategy of *M. lucida*, Moore concluded that *M. lucida* overwinters in a pond, then produces one set of progeny in the early spring and another in early summer. Under laboratory conditions, the progeny produced in the early spring were shown to be capable of reproducing in the

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same year. The reproductive state and size distribution of the specimens collected in Nebraska suggest that perhaps the first progeny produced in the spring reproduce in the late summer under natural conditions. The larger, mature specimens correspond to the first set of progeny, and the smaller specimens correspond to the second set of progeny produced in the early summer.

This is the first report of *Marvinmeyeria lucida* from Nebraska and the first report of an association between *M. lucida* and any species of *Helisoma*.

ACKNOWLEDGMENTS

The authors express appreciation to Monte A. Mayes and Mrs. M.H. Pritchard for their aid in this study.

THE IMPACT OF ARTIFICIAL REDUCTION OF LIGHT ON A EUTROPHIC FARM POND

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A novel technique for reducing growth of aquatic macrophytes and decreasing primary productivity in an eutrophic farm pond was evaluated by the addition of commercial blue and brown aniline dyes to pond water isolated from the surrounding pond in experimental boxes. Blue-dyed water completely eliminated all aquatic macrophytes, while brown-dyed water eliminated only *Potamogeton* sp. Primary productivity was reduced, and phytoplankton populations similar to those observed in spring and fall pulses in lakes were present in the dyed water during the summer. Intense thermal stratification, anaerobiosis, and chemical changes were recorded in the enclosed waters after dye addition.

† † †

INTRODUCTION

Accelerated production of plant populations in aquatic ecosystems—one of the consequences of eutrophication—is a problem faced by biologists and engineers wherever lakes and people occur together. Increased production rates, either directly or indirectly, reduce water quality and decrease recreational opportunities in lakes where these increases are occurring.

In the Great Plains region, many small reservoirs have been built and more are being planned. Most often these reservoirs are constructed for flood control with additional benefits for recreation. The reservoirs are located in agricultural settings where intensive crop culture occurs on the fertile soils of their watersheds. The reservoirs depend upon surface runoff as their source of water; such runoff is rich in the nutrients required for the growth of plants. Under these conditions, growth of algae and rooted macrophytes is greater than desired.

Methods for controlling excessive aquatic vegetation vary from harvesting the plants—with problems of disposal of the organic material—to the use of chemical herbicides. Biological controls have been attempted with limited success. Physical controls, such as reservoir drawdown and replacement of substrate, in many cases is inefficient and expensive and may create other problems in fish and wildlife management. In some areas where circumstances allow, advanced treatment of influents to lakes for the removal of nitrogen and phosphorus is being used in an effort to control eutrophication. All of these controls have serious disadvantages—such as high initial operation and maintenance costs or un-

desirable effects on the environment—which make their application to the solution of eutrophication problems in Midwestern reservoirs impractical.

In 1944-1945, George Eicher, a biologist with the Arizona Game and Fish Commission, recognizing the need for some method to control nuisance growths of aquatic plants in hatchery ponds, dyed two ponds with a black aniline dye (Eicher, 1947). His idea of decreasing available light to reduce aquatic plant growth was largely successful; however, he lacked information as to the other biological, chemical, and physical effects of this treatment on the pond water.

Algal and macrophyte photosynthesis is well known to be a function of both light intensity and day length (Ryther, 1956; Chapman and Burrows, 1970; Edwards, 1969; Peltier and Welch, 1970). A reduction of either intensity or duration, regardless of how achieved, should result in lower total production in lakes. This relationship is the basis for the experiments to be described.

Our objective in these experiments was to determine whether the addition of specific colored solutions to a eutrophic pond which supported large populations of both algae and rooted plants could affect a significant decrease in the standing crops of these plants and exert some control on their abundance. Ideally, the added material should persist for at least 4-5 months in the lake (over the growing season), should be aesthetically pleasing, and should have no adverse effects on other components of the environment. Theoretically, it should be possible to add the material in the spring before submerged macrophytes begin their growth and inhibit light penetration during the remainder of the growing season. Furthermore, it should also be possible to add only the amount of dye necessary to achieve a reduction in standing crop but not totally eliminate it. If effective, this method would seem to be a relatively inexpensive and simple way to exert control over excessive plant populations and would be particularly appropriate for small reservoirs in the Great Plains where nutrient removal from inflowing waters is impractical.

It seems prudent for us at this point to inject a note of warning concerning the use of aniline dyes by those who might contemplate using them in research projects similar to ours or who might apply the results we have obtained to their

specific situation. The toxicities of aniline dyes and their degradation products are not well known for most organisms other than man. For humans, the toxicities are thoroughly known; aniline dyes are hazardous chemicals. Our research was designed to determine if the *concept* of eutrophication control by the alteration of the light environment is a feasible alternative to other methods of control. We used aniline dyes because of their availability and convenience. They most likely would not be the chemicals of choice, nor do we advocate their use in eutrophication control. Broad, detailed, long-term studies must be conducted on potential harmful effects of aniline dyes on organisms other than man if dissemination of these chemicals into the aquatic environment is anticipated.

METHODS

Teton Pond, a farm pond draining 59.5 hectares of fertilized cropland north and west of Dunbar in southeastern Nebraska, was selected for the experimental work. The pond met certain characteristics necessary for testing the dye method of treatment. It was generally clear (Secchi disc to 3 m), shallow (mean depth 1.6 m, with the deepest point varying from 2 3/4 to 3 1/2 m), and small (surface area of .96 hectares). A contour map of the pond is shown in Fig. 1. A large population of *Potamogeton foliosus* and *Potamogeton pusillus* grew to the surface of the pond from the shore to the 2 m contour, with lesser growth to the 2 1/2 m contour. An algal mat of *Spirogyra*, *Mougeotia*, and *Cladophora* occurred concurrently with the *Potamogeton*. As a result, an extremely dense canopy of vegetation covered two-thirds of the pond during the summer months.

In order to secure base-line data for the experiment, aquatic macrophytes, plankton, and water samples were taken every two weeks in the summer (May through September) in 1970, and plankton and water samples taken once per month in the fall, winter, and spring of 1970-1971. *In situ* carbon-14 primary productivity tests were conducted monthly during the summer of 1970 to estimate productivity of the phytoplankton.

Three to five samples of macrophytes were removed from the pond each sampling date to determine standing crop. Random sample points were selected from a table of random numbers corresponding to a predetermined grid system superimposed on the pond. A half-square meter, metal quadrat was sunk over the sampling point, and all vegetable matter in the quadrat from the surface to the bottom, including roots, was removed and placed in an opaque polyethylene bag. The bag was iced and returned to the laboratory for analysis (Vollenwieder, 1969).

Water samples for chemical and biological analyses were taken from the surface—1m, 2m and 3m levels—with a Van Dorn water sampler, and composited. A four-liter sample was removed from the composite for chemical analysis, and

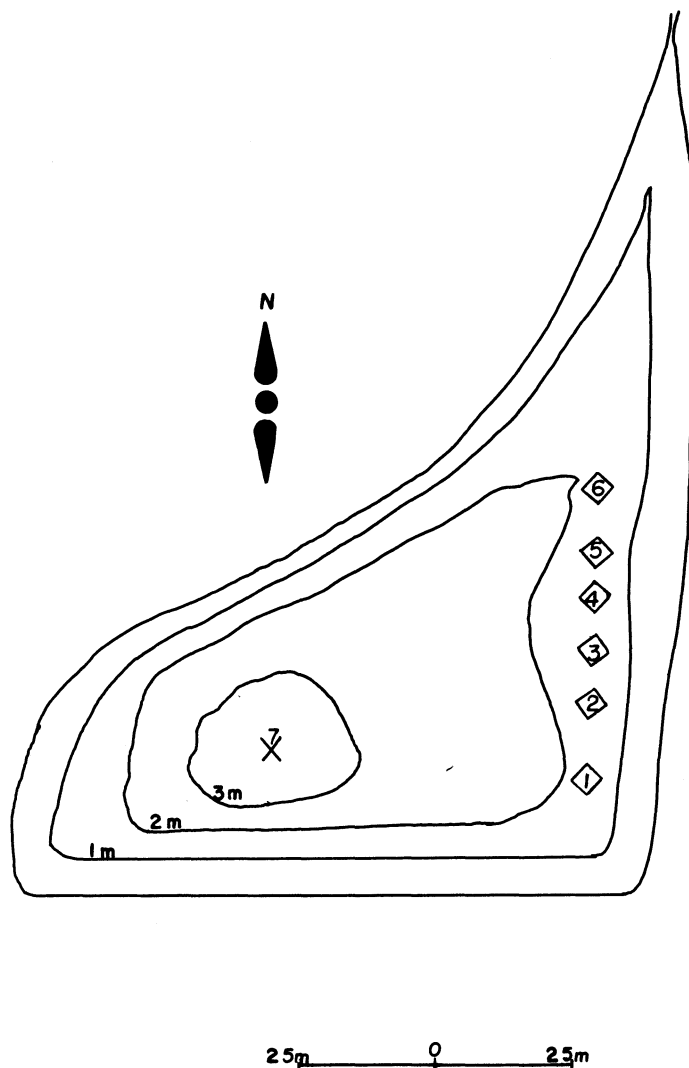


Figure 1. Contour map of Teton Pond showing locations of experimental boxes (1-6) and pond sampling point (7).

the remainder poured through a 35 micron mesh plankton net for identification of the algae present. Temperature and dissolved oxygen were measured in the field with a thermometer/dissolved oxygen meter. Chlorophyll extractions were performed according to the method described by Richards with Thompson (1952), and concentrations calculated using the formula described in a UNESCO (1966) publication. Composited algal samples were preserved on a membrane filter (McNabb, 1960) for counting and volumetric measurements. *In situ* carbon-14 tests were run by the methods described by Goldman et al. (1966), exposed to fuming HCl (Wetzel, 1965), and counted in a thin-window, gas-flow, Geiger-Mueller counter. Other measured water chemistry parameters were determined according to Standard Methods (APHA, 1965).

In April, 1971 an experimental box, 3m x 3m x 2m, constructed of wood and wrapped with translucent polyethylene, was inserted in the pond to test the feasibility of the structure for the dye experiment. After determining that this method of isolation and structural design was adequate for the test, five more experimental boxes were constructed so that the lowermost portion could be sunk into the bottom mud and effectively seal water inside the boxes. Appropriate water and biological samples were taken in each box to determine the macrophyte and algal standing crops. A one-half meter grid system similar to that used for the pond was designed to sample the macrophytes rooted in the boxes.

Sandolan dark brown and Alizanine blue, commercial dyes purchased from the Sandoz Chemical Company (Hanover, New Jersey 07936), were selected for experimental use. Of the variety of colors of dyes received as samples, blue and brown dyes were chosen for the experiment for aesthetic reasons only. Desired limits of Secchi disc visibility, using various concentrations of the dyes in tap water, were determined in the laboratory in a 55 gallon (608.2 liters) aquarium; these concentrations were then calculated for the experimental boxes. Box No. 1, the first box inserted into the pond, was selected as the control enclosure with no dye added. Alizanine blue dye was added to boxes No. 2, No. 4, and No. 6 to bring the Secchi disc depth immediately after addition to 31 cm, 15 cm, and 10 cm, respectively. Boxes No. 3 and No. 5 were brought to Secchi disc visibility limits of 61 cm and 31 cm, respectively, with Sandolan dark brown.

After addition of the dyes, a change in the chlorophyll extraction technique was required. Preliminary evaluation of various techniques in the laboratory indicated that the dyes would adsorb to the membrane filters, rendering the resulting extract unsuitable for pigment analysis. However, it was found that comparable pore-sized glass filters could be rinsed free of dye with distilled water. To determine what effect a substitution of glass filters for membrane filters would have on the results, 113 comparisons of undyed membrane filters and glass fiber filters with dye added to the samples were made using both brown and blue dyes. The resulting correlation coefficient of $r = .97$ between the final pigment concentrations of the membrane and glass filters was determined to be satisfactory for continuation of the pigment analysis.

Appropriate physical, chemical, and biological samples as previously described were taken from each box. *In situ* carbon-14 tests were performed in each box to estimate phytoplankton primary productivity. In addition, water samples from the open pond were incubated at various depths in the boxes, and samples from the boxes were placed in the pond to determine the effect of reduced light on phytoplankton productivity and viability.

RESULTS

Temperature patterns and the intensity of thermal

stratification illustrated in Fig. 2 varied with each experimental box after dye treatment, from basically having the same thermal profile as the pond (box No. 1, control) to a maximum surface-to-bottom temperature differential of $6\frac{1}{2}^{\circ}\text{C}$ in boxes No. 2 and No. 4. Boxes with blue water exhibited greater temperature gradients than those with brown water. Dissolved oxygen concentrations in the boxes fluctuated independently of those in the pond and ranged from oxygen supersaturation conditions before dye treatment to anaerobic conditions after dye treatment. Fig. 3 illustrates the dissolved oxygen concentrations recorded for each experimental box. With time, water clarity as measured with a Secchi disc in experimental boxes No. 2, No. 4 and No. 6 stabilized at approximately 30 cm after dye addition, regardless of the initial dye concentrations added to the boxes. Secchi disc visibility in the brown-water boxes (No. 3 and No. 5) stabilized at about 45 cm. Table I summarizes the ranges of chemical parameters recorded for the pond and for the experimental boxes after dye addition. The boxes with blue water exhibited up to a 6-fold increase in ortho and total phosphate concentrations, while in each case nitrate-nitrogen was essentially eliminated from the water with a corresponding increase in ammonia-nitrogen, presumably due to the anaerobic conditions present in each of the blue-water boxes. The boxes with brown water showed some ortho-phosphate increases and nitrate elimination, but not to the extent as in the blue-water boxes.

Table I:

Ranges of Chemical Parameters Measured in the Experimental Boxes and Teton Pond

Sample Point	pH	PO ₄ (mg/l)	Total P (mg/l)	NH ₃ -N (mg/l)	NO ₃ -N (mg/l)	TDS (mg/l)
Pond (1970-1971)	7.9-9.6	.02-.23	.09-.36	.25-.81	Trace-.60	137-245
Box 1 (control)	8.2-9.8	.02-.16	.12-.29	.15-.84	.10-.38	137-228
Box 2* (blue)	8.0-9.2	.31-.81	.51-1.01	1.40-2.29	Trace-.25	148-230
Box 3* (brown)	8.3-9.2	.08-.20	.13-.50	.52-1.10	Trace-.10	149-197
Box 4* (blue)	8.0-9.2	.15-.72	.23-.81	.89-2.50	Trace-.08	177-236
Box 5* (brown)	9.3-9.4	.08-.25	.10-.36	.15-.44	Trace-.10	160-188
Box 6* (blue)	7.8-9.5	.12-.68	.28-.69	.52-1.58	Trace-.10	152-218

*Parameters after dye addition

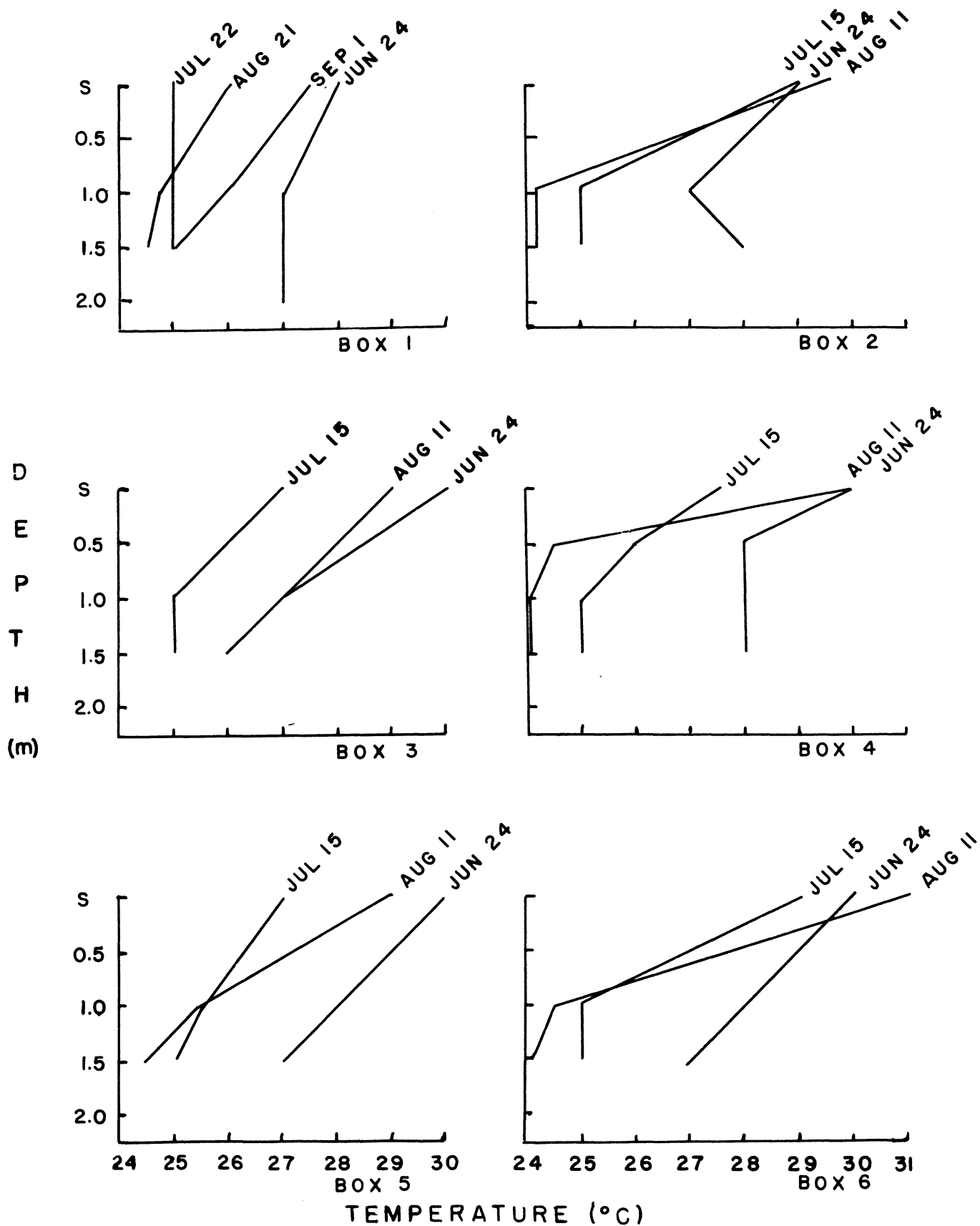


Figure 2. Temperature profiles for experimental boxes 1-6. Box 1 is the control, Box 2, 4 and 6 treated with blue dye, and Box 3 and 5 treated with brown dye.

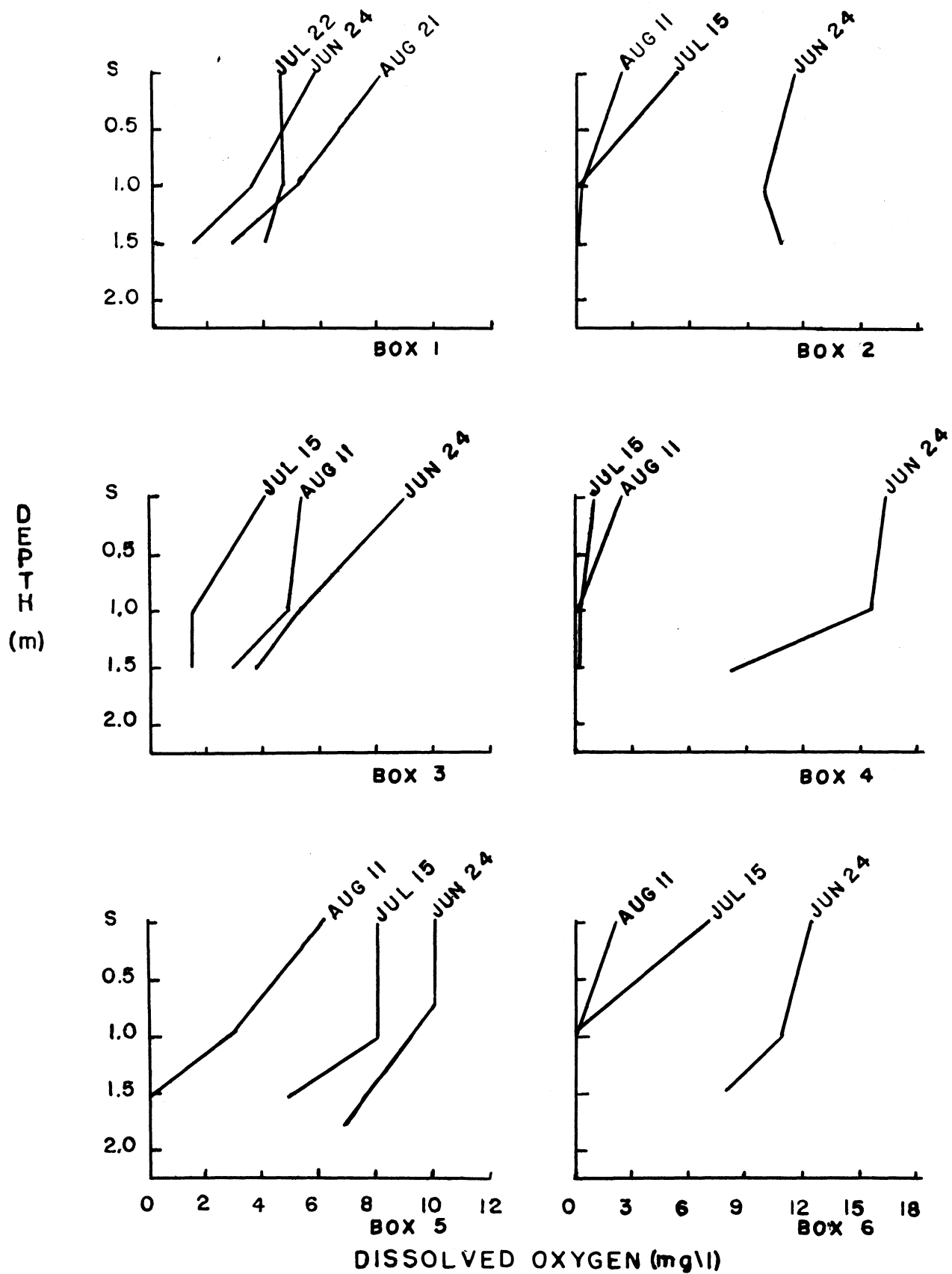


Figure 3. Dissolved oxygen profiles for experimental boxes 1-6.

After installation of the experimental boxes and before the addition of the dye solution, one-time random macrophyte samples were taken to estimate the standing crop in each box. After dye addition, further samples were taken to measure the effect of the dyed water on standing crops of macrophytes. As shown in Table II, aquatic macrophytes were completely eliminated from the blue-water boxes No. 2, No. 4, and No. 6 for the duration of the experiment. No living macrophytes were found in any of these boxes over the next 2 months. Toxicity tests in the laboratory determined that the dye was not toxic to the plants because they maintained their vigor in the presence of the dye if adequate illumination was also provided. It is therefore presumed that reduced light penetration effectively eliminated macrophytes from the experimental boxes. The anaerobic conditions in these boxes probably resulted from the decomposition of the aquatic plants at the bottom of the boxes and the absence of normal wind-induced circulation and aeration which the boxes effectively eliminated, resulting in the rapid death and subsequent decomposition of the plants in the boxes. Somewhat different results were obtained from boxes No. 3 and No. 5 which contained brown water. Before dye addition, *Chara* and *Potamogeton* were sampled in each box. Three weeks after addition of the brown dye, there was a three-fold increase in the standing crop of macrophytes in box No. 5 which consisted exclusively of *Chara*. Although no macrophytes were taken in the random samples in box No. 3, *Chara* was observed growing in the bottom muds, while *Potamogeton* appeared to be eliminated. Unfortunately, the experiment was terminated by the destruction of the boxes during a severe thunderstorm before additional data could be obtained; however, it was evident *Chara* survived and apparently flourished under the light conditions produced by the brown water.

The results of the carbon-14 primary productivity tests are given in Table III. Calculated values for the experimental boxes with blue water were extremely low compared with productivity in the pond. Production rates in the brown water were also reduced markedly, but not always to the same extent as those in the blue water. In order to determine whether the dyes themselves had an inhibitory effect on carbon assimilation or whether their effect was simply due to physical reduction of light, reciprocal exchanges of water samples were made between the pond and the experimental boxes. Samples of pond water were placed at appropriate depths in the boxes and samples of box water were placed at appropriate depths in the pond. As expected, calculated productivities of pond samples placed in the experimental boxes were reduced from 64-94% of those measured in the pond. These samples were, of course, enclosed in bottles, and the algae in them never came in direct contact with the dyes. The results indicate clearly that light reduction was the factor most responsible for the decreased production. Further attesting to this conclusion is the fact that pond samples incubated in the pond in mid-summer characteristically showed the highest production rates at the one-half meter

depth. This suggests that the well-known surface inhibition phenomenon is occurring and is resulting from light intensities which are too high for optimal photosynthesis and which physiologically damage the algal cells. When pond samples were placed in the experimental boxes, the highest production rates usually occurred in the surface bottles, and surface inhibition was no longer present. Clearly, the reduction in available light must be responsible (Table III). In all cases where samples from the experimental boxes were placed in Teton Pond, rates of production greater than those in the boxes were measured.

Table II:
Standing Crop Estimates of Macrophytes

Sample	Date	Number of samples	Grams dry weight per m ²	estimated standing crop in kg dry weight
<i>Before dye treatment</i>				
Teton Pond	17 Jul 1970	5	86	823
	27 Jul 1970	5	237	2262
	6 Aug 1970	5	78	746
	24 Aug 1970	5	101	955
	8 Sep 1970	5	31	300
	22 Sep 1970	3	41	387
	19 Oct 1970	3	52	501
Teton Pond	2 Jul 1971	3	16	154
Box 2	2 Jul 1971	1	83	788
Box 4	2 Jul 1971	1	28	264
Box 6	2 Jul 1971	1	151	1442
Box 3	15 Jul 1971	1	2	15
Box 5	15 Jul 1971	1	46	447
<i>After dye treatment</i>				
Teton Pond	16 Jul 1971	3	34	326
Box 2 (blue)	16 Jul 1971	1	0	0
Box 4 (blue)	16 Jul 1971	1	0	0
Box 6 (blue)	16 Jul 1971	1	0	0
Teton Pond	11 Aug 1971	3	81	776
Box 1 (control)	11 Aug 1971	1	37	356
Box 2 (blue)	11 Aug 1971	1	0	0
Box 3 (brown)	11 Aug 1971	1	0	0
Box 4 (blue)	11 Aug 1971	1	0	0
Box 5 (brown)	11 Aug 1971	1	141	1350
Box 6 (blue)	11 Aug 1971	1	0	0

While at this point it is difficult to know whether the dyestuffs would have a direct inhibitory effect on the algae if mixed directly with them, it is obvious that when the algae are placed in more favorable light conditions (Teton Pond), they respond by fixing carbon at much increased rates.

Table III:

Primary Productivity Estimates with Depth,
Teton Pond and Experimental Boxes 2 through 6, 1971

Sample	Date	Surface (mgC/m ³)	1/2 m (mgC/m ³)	1 m (mgC/m ³)	Calculated 4 hr Productivity (mgC/m ²)
Teton Pond	15 July	15.4	37.4	30.0	77.1
Box 4 (blue)	15 July	9.4	10.6	4.2	8.7
Teton Pond in Box 4	15 July	11.5	3.4	1.0	4.8
Teton Pond	30 July	52.4	127.5	102.3	102.5
Box 2 (blue)	30 July	0	0	0	0
Box 2 in Teton Pond	30 July	0.9	5.7	13.3	6.5
Teton Pond in Box 2	30 July	4.9	14.2	0	8.4
Box 3 (brn)	30 July	445.9	392.0	68.4	324.6
Box 3 in Teton Pond	30 July	556.8	556.9	728.1	599.7
Teton Pond in Box 3	30 July	8.0	12.2	0	8.2
Teton Pond	1 Sept	48.9	119.0	47.0	83.5
Box 5 (brn)	1 Sept	3.4	4.0	2.0	3.4
Box 5 in Teton Pond	1 Sept	5.5	7.0	6.3	6.4
Teton Pond in Box 5	1 Sept	39.6	27.2	2.8	24.2
Box 6 (blue)	1 Sept	2.3	1.7	1.1	1.7
Box 6 in Teton Pond	1 Sept	3.2	2.1	2.4	2.4
Teton Pond in Box 6	1 Sept	96.8	11.4	1.3	30.3

algal volumes as Teton Pond and the control box. After dye treatment, however, significant changes in algal populations occurred. Contrasting with the mixture of blue-greens and diatoms recorded for Teton Pond in the summer, diatoms and greens—mainly *Navicula*, *Nitzschia*, *Stephanodiscus*, *Diploneis*, *Synedra*, *Ankistrodesmus* and *Mougeotia*—dominated the algal populations. These populations were similar to the spring and fall algal pulses observed in Teton Pond which consisted of *Navicula*, *Dinobryon*, *Stephanodiscus*, *Synedra*, *Diploneis*, *Oocystis* and *Sphaerocystis*. Figures 4, 5, and 6 compare the volumes of algae present in the pond and in each of the experimental boxes before and after dye treatment. A comparison of algal numbers graphed in similar fashion yields comparable results. In both brown- and blue-water boxes, blue-green algae were reduced or completely eliminated from the algal populations during the summer bloom period (except in box No. 4), while blue-green algae were the dominant algal type observed in Teton Pond. The five most abundant genera for Teton Pond and each experimental box are listed both prior to and after dye treatment in Table 4. Green algae, practically nonexistent in Teton Pond during the summer bloom period, contributed 20% to 40% of the total algal volume observed in the experimental boxes. Diatom auxospores formed mats at the surface of the water in the blue-water boxes, and resembled in appearance the blue-green algae mats characteristic of highly eutrophic lakes.

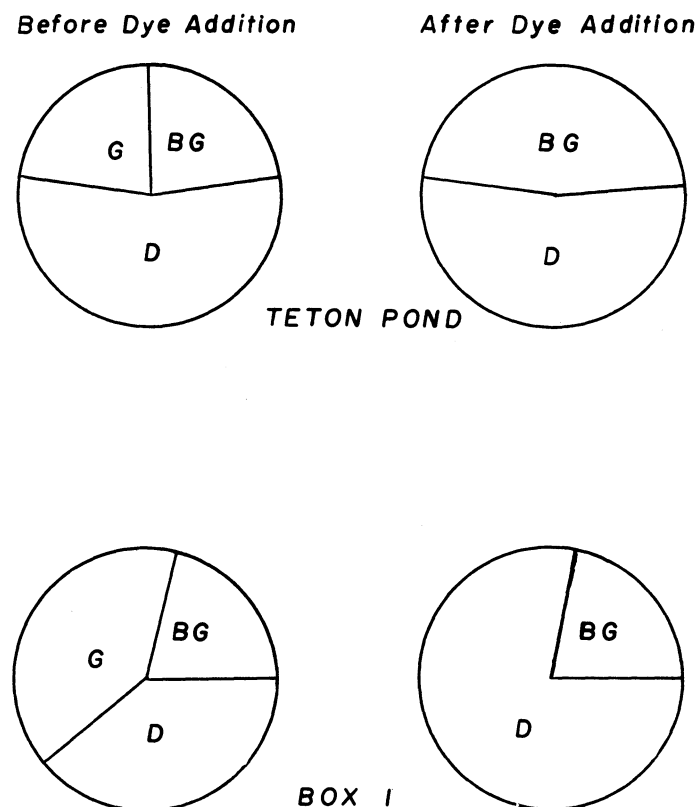


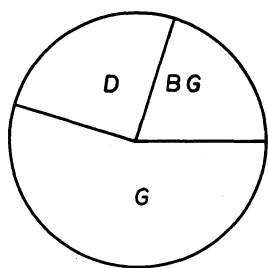
Figure 4. Comparative algal volumes recorded for Teton Pond and Box 1 (control) before and after dye treatment. G-Green Algae; D-Diatoms; BG-Blue-green Algae.

Chlorophyll "a" concentrations did not correlate well with either calculated algal volumes or algal counts in either the pond or the experimental boxes. Instead, total chlorophyll (chlorophyll "a" + chlorophyll "b" + chlorophyll "c") correlated significantly ($r = .53$) with macrophyte biomass. This seemed to indicate the presence of extracellular chlorophylls in the pond and box waters.

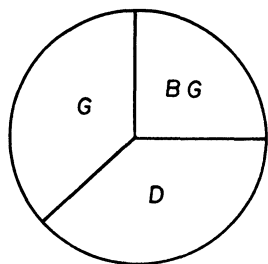
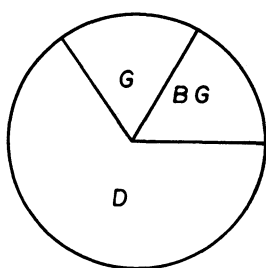
During the period 24 April – 2 July 1971 in Teton Pond, diatoms comprised a majority of the algal volume, with green and blue-green algae present in smaller but equal amounts. The period 15 July – 1 September, the summer bloom period, consisted of approximately equal amounts of diatoms and blue-green algae. Green algae were present but in insignificant numbers or volume. The control experimental box, box No. 1, contained populations similar to the pond for the spring period, but during the summer period the diatom fraction was larger in the box than in the pond. The experimental boxes, prior to dye treatment, contained comparable

Before Dye Addition

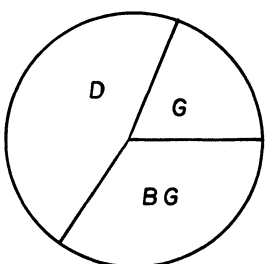
After Dye Addition



BOX 2

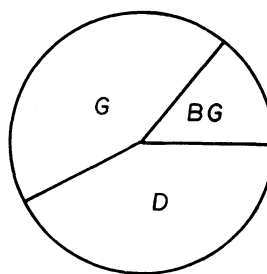


BOX 4

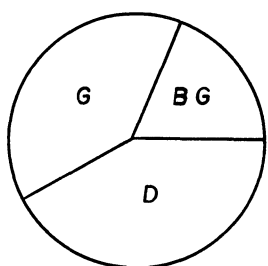
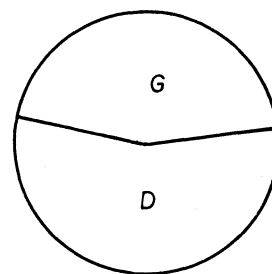


Before Dye Addition

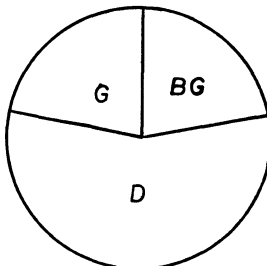
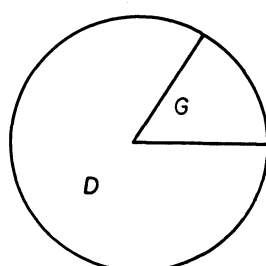
After Dye Addition



BOX 3



BOX 6



BOX 5

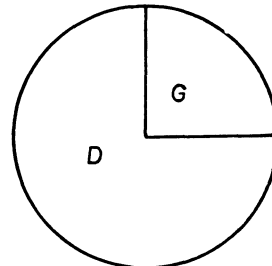


Figure 5. Comparative algal volumes recorded for blue dye treatment water, before and after dye treatment. G- Green Algae; D-Diatoms; BG-Blue-green Algae.

Figure 6. Comparative algal volumes recorded for brown dye treatment water, before and after dye treatment. G- Green Algae; D-Diatoms; BG-Blue-green Algae.

Table IV:

The Five Most Abundant Algal Genera in Teton Pond and Experimental Boxes

Sample	Before Treatment		After Treatment	
	Period	Genera	Period	Genera
Teton Pond	24 Apr – 2 July	<i>Aphanizomenon</i> <i>Chodatella</i> <i>Dinobryon</i> <i>Oocystis</i> <i>Synedra</i>	15 July – 1 Sep	<i>Aphanizomenon</i> <i>Microcystis</i> <i>Navicula</i> <i>Oscillatoria</i> <i>Radiococcus</i>
Box 1 (control)	24 Apr – 2 July	<i>Aphanizomenon</i> <i>Coelastrum</i> <i>Dinobryon</i> <i>Navicula</i> <i>Synedra</i>	15 July – 1 Sep	<i>Diploneis</i> <i>Microcystis</i> <i>Navicula</i> <i>Nitzschia</i> <i>Oscillatoria</i>
Box 2 (blue)	24 June – 2 July	<i>Aphanizomenon</i> <i>Asterococcus</i> <i>Navicula</i> <i>Oocystis</i> <i>Schroederia</i>	15 July – 1 Sep	<i>Coelastrum</i> <i>Gomphonema</i> <i>Microcystis</i> <i>Navicula</i> <i>Nitzschia</i>
Box 3 (brown)	24 June – 15 July	<i>Aphanizomenon</i> <i>Coelastrum</i> <i>Oocystis</i> <i>Sphaerocystis</i> <i>Stephanodiscus</i>	22 July – 1 Sep	<i>Ankistrodesmus</i> <i>Coelastrum</i> <i>Navicula</i> <i>Stephanodiscus</i> <i>Synedra</i>
Box 4 (blue)	24 June – 2 July	<i>Aphanizomenon</i> <i>Asterococcus</i> <i>Cosmarium</i> <i>Navicula</i> <i>Synedra</i>	15 July - 1 Sep	<i>Ankistrodesmus</i> <i>Dictyosphaerium</i> <i>Microcystis</i> <i>Navicula</i> <i>Synedra</i>
Box 5 (brown)	24 June – 15 July	<i>Aphanizomenon</i> <i>Dinobryon</i> <i>Navicula</i> <i>Oocystis</i> <i>Sphaerocystis</i>	22 July – 1 Sep	<i>Ankistrodesmus</i> <i>Diploneis</i> <i>Fragillaria</i> <i>Mougeotia</i> <i>Navicula</i>
Box 6 (blue)	24 June – 2 July	<i>Aphanizomenon</i> <i>Fragillaria</i> <i>Oocystis</i> <i>Sphaerocystis</i> <i>Stephanodiscus</i>	15 July – 1 Sep	<i>Asterococcus</i> <i>Diploneis</i> <i>Euglena</i> <i>Navicula</i> <i>Nitzschia</i>

DISCUSSION

By reducing the intensity of available light in water through the use of dyes, not only was a decrease of algal photosynthesis and a change in the dominant algal genera achieved, but also elimination of aquatic macrophytes was accomplished. Primary productivity tests indicated a major reduction of algal photosynthesis in the experimental boxes. Not only was low productivity observed in most samples, but water samples taken from the pond and placed in the dyed water of the boxes showed substantial reduction in primary productivity. This result was in keeping with our original hypothesis: any reduction of light below the saturation intensity would influence productivity. The more heavily dyed, blue boxes reduced primary productivity to a greater extent than the brown-water boxes.

Average total chlorophylls and the average of chlorophyll "a" plus chlorophyll "b" decreased with increasing dye concentration for both blue- and brown-water boxes. Figure 7 suggests a very approximate upper and lower limit for the concentration of blue and brown dye required to achieve a maximum limitation of algal and macrophyte growth. Further experimentation with this technique for predicting chlorophyll concentration from dye concentration is warranted.

Our experimental results indicate that a dye method of treatment will alter summer algal populations from those containing largely blue-green algae to those characteristic of spring or fall algal pulses in lakes. Populations of rooted aquatic macrophytes can be either completely eliminated from a lake system, as was suggested by the results of the blue-dye treatment, or altered to a selected macrophyte type, as was observed in the brown-dye treatment.

Chara seemed to thrive in the reduced-light environment of the brown water, but is generally considered a clear-water alga (Macan, 1970; Smith, 1950). Our results suggest that *Chara* is able to grow under reduced light conditions as well. The massive elimination of *Potamogeton* and *Chara* in blue water suggests that these plants would not have even begun growing if the waters had been dyed prior to their emergence in the spring.

No attempt was made physically to mix the isolated water columns treated with dye. What effect continued mixing would have had is speculation; however, a further decrease in primary productivity could have resulted by forcing the more productive algae at the surface into the light-limiting depths of the experimental boxes. Anaerobiosis may not have occurred with adequate mixing, and aeration of the water would have altered the chemical composition we observed after dye treatment and elimination of macrophytes.

This research has demonstrated that the concept of

controlling excessive plant production through the reduction of available light is valid and feasible. Research should be initiated: (1) to find the most suitable substance for coloring lake water; (2) to learn the most appropriate season for addition of the substance for control of aquatic weed and algal productivity; and (3) to investigate in more detail the over-all environmental effects.

It should be noted that recently a product (Aquashade, from Aquashade, Inc., Dobbs Ferry, New York) has come onto the commercial market. It employs the same principle of eutrophication control through light reduction that we demonstrated in this research. We do not know any specifics about its chemical composition or effectiveness, or whether it has any unanticipated environmental effects.

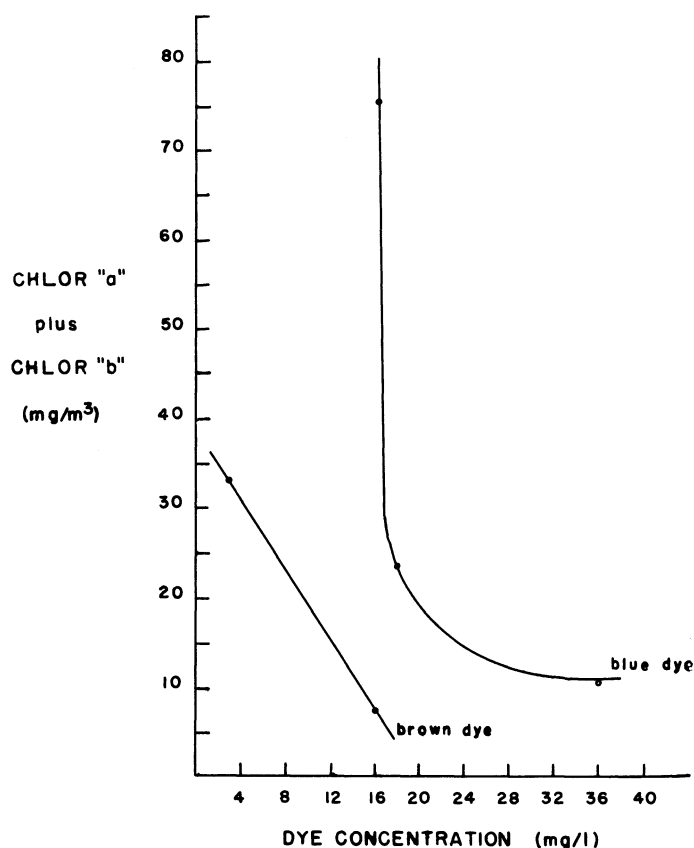


Figure 7. Average chlorophyll "a" plus chlorophyll "b" versus dye concentration.

ACKNOWLEDGMENTS

Credits. This Master's Thesis research was supported by the Office of Water Resources Research, Department of the Interior, under the Public Law 88-379 Program. About the authors—Gary L. Hergenrader is Professor of Zoology, University of Nebraska, Lincoln, Nebraska; Eugene G. Buglewicz is an Aquatic Biologist with the U.S. Army Corps of Engineers, Walla Walla, Washington. At the time of this research, the latter was a graduate student at the University of Nebraska-Lincoln.

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CHROMOSOME ANALYSIS OF *BIDENS POLYLEPIS* AND *BIDENS CORONATA* (Compositae)

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The closely related species *Bidens coronata* (L.) Britt. and *B. polylepis* Blake are morphologically similar and may hybridize readily. Sympatric eastward, the species are allopatric in Nebraska and adjacent states. Karyotype analysis of the two species revealed not only a number of similarities but also some significant differences. Chromosomal analysis of the awn forms of *B. polylepis* (designated as varieties by some) revealed no significant differences, indicating, along with morphological evidence, that *B. polylepis* is a single taxonomic entity, although phenotypically highly plastic.

† † †

INTRODUCTION

The primary objectives of this study were: (A) to provide a karyotypic nomenclature by describing quantitatively the chromosomes of *Bidens coronata* (L.) Britt. and *B. polylepis* Blake; and (B) to define chromosomal similarities and differences between the karyotypes of these two plant species.

The species—sometimes called “Beggarticks,” “Stick-tights,” or “Tickseed Sunflowers”—are morphologically similar and are often difficult to identify. *B. coronata*, a native of eastern North America, displays the distributional pattern of an arc northward and westward around the southern half of the Great Plains, by occurring in east to north-central Iowa and east-central Minnesota, disjunct then to the Sand Hills and adjacent areas of Nebraska and South Dakota. *B. polylepis* continentally is an interior species entering the Great Plains from the east. Hall (1967) speculated that these species and other North American representatives of the Section *Meduseae* were fragmented by Pleistocene events into four ecogeographically isolated populations, perhaps from a single, original, pre-Pleistocene ancestral species. He further speculated that the situation may very possibly break down again due to secondary contacts brought on recently by white man to create a single variable entity. On the other hand, Figures 1 and 2 indicate that the Sand Hills of Nebraska may act as a refuge for *B. coronata*, both because its western limit of distribution is distinctly separate from that of *B. polylepis*, and because *B. polylepis* may not be able to become established in the unique habitats of the Sand Hills. The establishment of a karyotype for each of the two species would, thus, be very helpful in determining the potentiality of secondary merger in the evolution of these two species.

The diploid (2n) chromosome number of *B. coronata*

has been reported to be 24 (Weedon, 1973). Also, the three awn forms of *B. polylepis*, known as varieties by some (*B. polylepis* “*polylepis*,” *B. polylepis* “*antrorsa*,” and *B. polylepis* “*retrorsa*”), have been reported to be 24 (Weedon, 1973). The haploid number for each of these species is $n=12$ (Weedon, *et al.*, 1974; Weedon and Butler, 1976). Thus, to classify the plants on the basis of chromosome analysis, one must turn to possible differences in chromosome morphology.

MATERIALS AND METHODS

Mature achenes from greenhouse progeny of plants collected in the Great Plains region (voucher specimens at CSCN) were placed in tap water and allowed to germinate. These achenes were harvested from specimens having a pollen grain viability of approximately 98%, as confirmed by the Buffalo black staining technique of Jackson (1973). Actively growing root tips were placed in saturated 8-hydroxyquinoline at room temperature for 3 hours, transferred to a fixative consisting of 100% ethanol and acetic acid (3:1) for at least 3 hours, and stored until used in 70% ethanol at 4°C by techniques similar to those used by Merritt and Burns (1974).

Microscope slides were prepared by transferring the root tips to 10% HCl and hydrolyzing for 8 minutes at 60°C. The terminal one millimeter portions of the root tips were placed on clean microscope slides and stained with acetocarmine for a few minutes. The cover slips were put in place, and then, by the use of a pencil eraser, the cells were flattened by the squash technique. Finally, the slides were heated for one to three seconds over a low-flame Bunsen burner to aid in spreading the chromosomes.

Slides were scanned by using a phase-contrast microscope with a built-in camera. Suitable metaphase chromosome spreads with attached satellites were photographed at 1000x magnification. The film used was 4 x 5 inch Kodak, Kodalith, Ortho Film, Type 3. Karyotypes were prepared from the 8 x 10 inch enlargements by cutting out the individual chromosomes, pairing apparently homologous chromosomes, and

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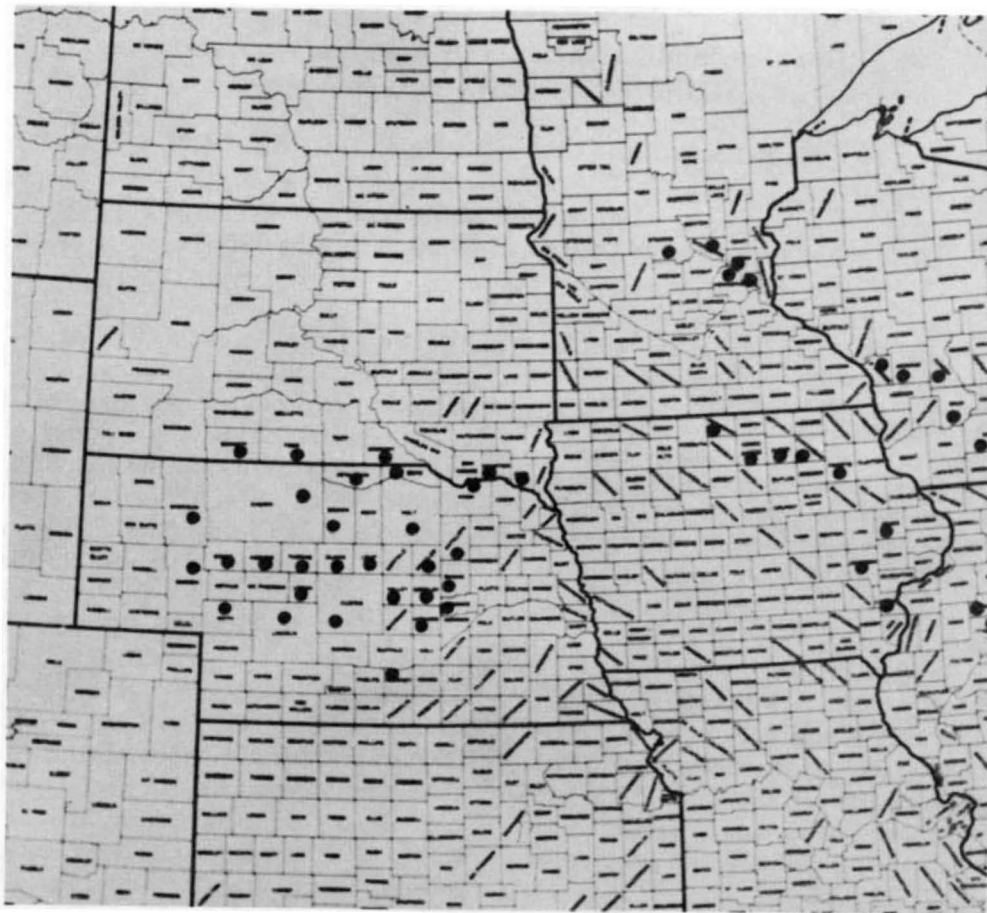


Figure 1. *Bidens coronata* (L.) Britt.

mounting them on white cardboard in a manner similar to the approach used by Rary, *et al.* (1968).

Spreads suitable for karyotype analyses were photographed, and karyotypes were prepared from the prints. These spreads included three karyotypes of *B. coronata*, three of *B. polylepis* "*polylepis*," three of *B. polylepis* "*antrorsa*," and two of *B. polylepis* "*retrorsa*." All three of these awn forms are often detected in a given population of *B. polylepis* (Weedon, 1973). The length of each arm of the individual chromosome and the total length of the chromosomes were measured with a vernier caliper, and the chromosomes were measured directly from the microscope slide by the use of an ocular micrometer. Heterochromatic regions of the chromosomes of the taxa were studied utilizing techniques of Merritt (1974).

RESULTS AND DISCUSSION

An organized system for karyotypic preparation in plant cytogenetics is needed for the arrangement of chromosomes. This system would be instrumental in establishing a method of chromosome identification and quantitative analysis. The

following system was used in the preparation of karyotypes for this study of *B. coronata* and *B. polylepis*. In making the karyotype, the apparently homologous chromosomes were placed in three rows of eight. The chromosomes were placed visually in decreasing order of size with the apparent metacentric chromosomes composing the second and third rows. The first row was composed of chromosomes with attached satellites and also containing submetacentric and subtelocentric chromosomes to complete the row of eight chromosomes. The chromosomes were paired visually as homologous or morphologue chromosomes. Due to possible contraction out of phase for individual chromosomes and the degree of mitotic activity, some chromosomes may appear to have the same shape and appearance, but, actually, a chromosome pair may not be homologous. Figures 3, 4, 5, and 6 show the arrangement of the chromosomes within the karyotypes studied.

Numbers were assigned to the chromosomes within the rows for the purposes of analysis and measuring. The homologous pairs of chromosomes were numbered from one through twelve for the karyotypes of *B. coronata* and the karyotypes of *B. polylepis*.

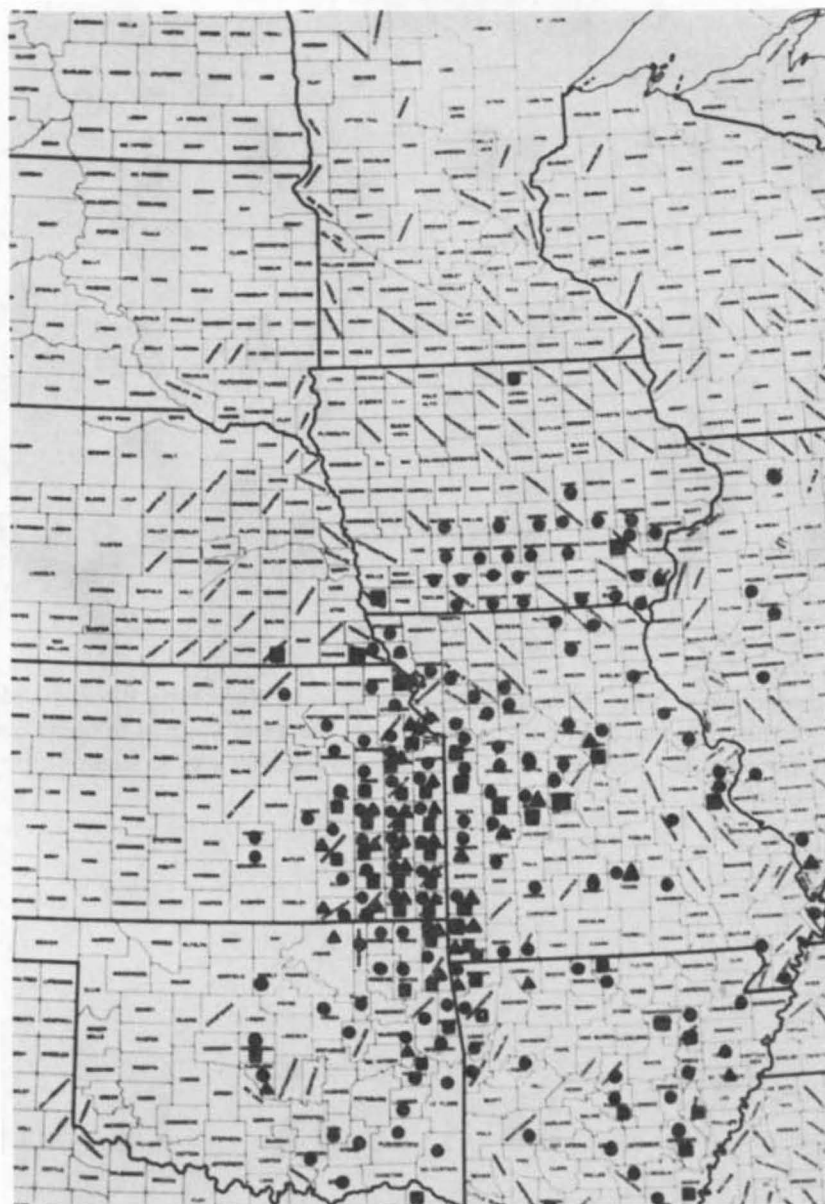


Figure 2. *Bidens polylepis* Blake.

- awnless to very short awns
- ★ awns long, retrorse
- awns long, antrorse

The long-arm/short-arm ratio, centric index, length of the chromosome in percent of total cell chromatin, and the chromosome type were calculated for each chromosome (Tables I, II, III and IV). The system proposed by Levan, *et al.* (1964) for designating individual chromosomes has been used in this karyotypic analysis. The SAT-chromosomes were measured without including the length of the satellites in the arm length. For example, chromosome numbers 3 and 4 of row 1 of *B. coronata* (Fig. 3) would be termed subtelocentric (st-type) with L/S ratios of 2.91 and 3.09, respectively; chromosome numbers 1 and 2 would be termed submetacentric (sm-type)

with L/S ratios of 2.02 and 1.72, respectively; and chromosomes of rows 2 and 3 were determined to be near-metacentric (m-type) or metacentric (M-type) with a L/S ratio range of 1.34 to 1.00.

The karyotype of *B. coronata* shows 4 satellites attached to chromosome pairs, numbers 2 and 3. The karyotypes of each of the three awn forms of *B. polylepis* (Figs. 4-6) show 6 satellites attached to three pairs of subtelocentric or submetacentric chromosomes. Therefore, the major gross difference of the karyotypes of the two species was the number of satellites present.

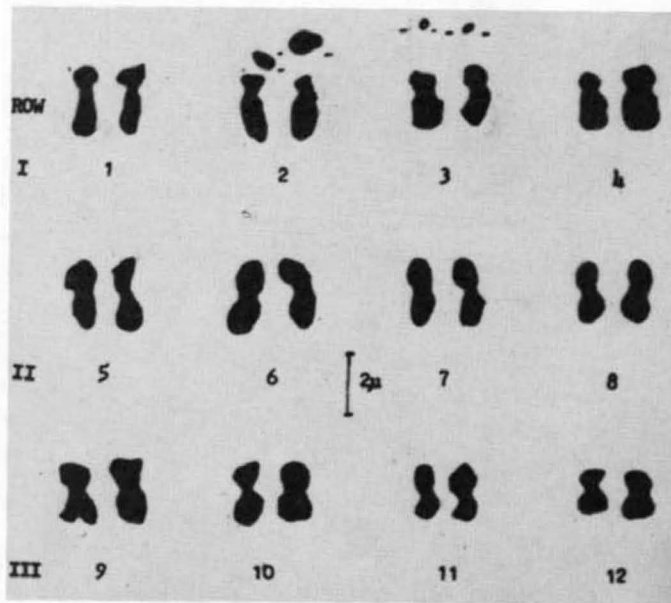


Figure 3. Karyotype of *B. coronata* with the numbers assigned to homologous pairs of chromosomes. Satellites can be seen on chromosome pairs 2 and 3.

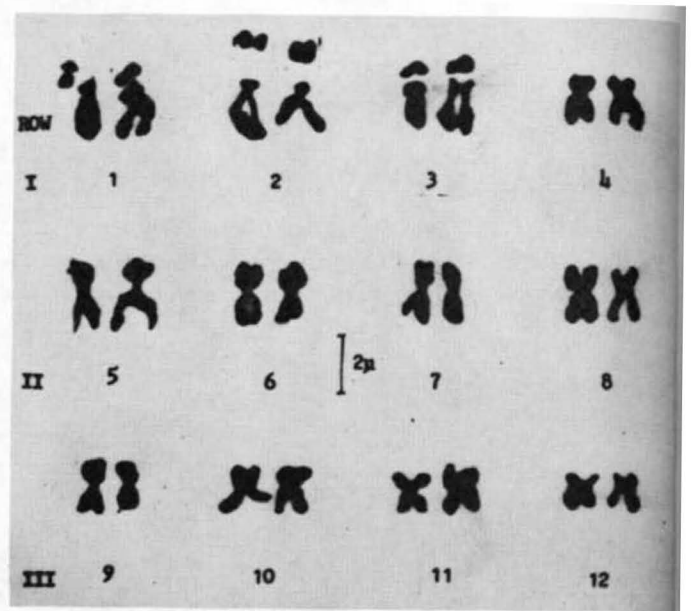


Figure 5. Karyotype of *B. polylepis* "antrorsa" with the numbers assigned to homologous pairs of chromosomes. Satellites can be seen on chromosome pairs 1, 2, and 3.

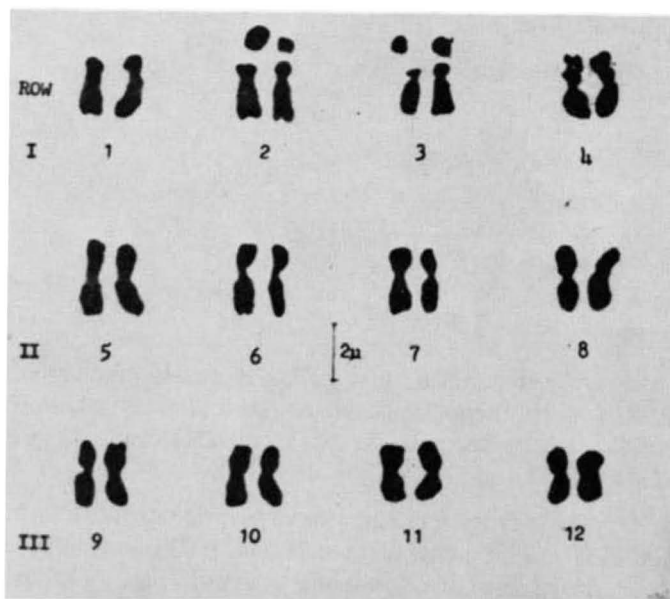


Figure 4. Karyotype of *B. polylepis* "polylepis" with the numbers assigned to homologous pairs of chromosomes. Satellites can be seen on chromosome pairs 2, 3, and 4.

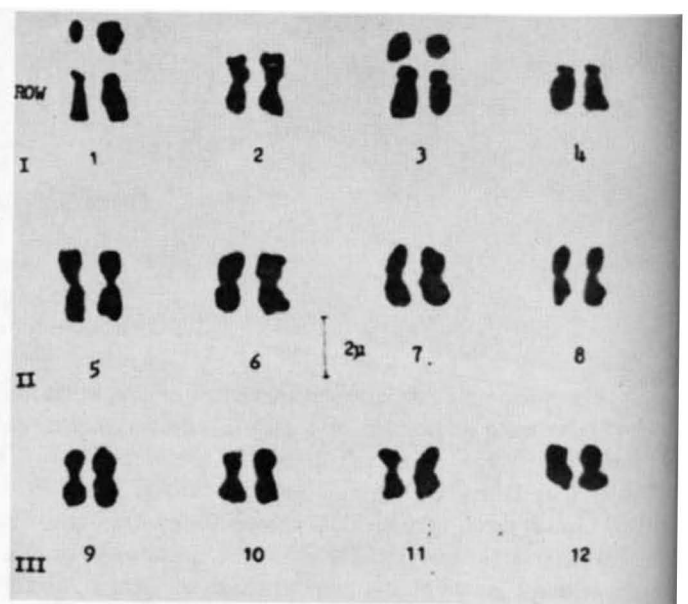


Figure 6. Karyotype of *B. polylepis* "retrorsa" with the numbers assigned to homologous pairs of chromosomes. Satellites can be seen on chromosome pairs 1, 2, and 3.

Table I:

Lengths of Chromosomes in Percent
of Total Cell Chromatin (L%),
Long-arm/Short-arm Ratios (L/S),
Centric Indices (L^c), and
Chromosome Types Calculated for *Bidens coronata*

Chromosome Number	L% ⁺	L/S	L ^c *	Chromosome Type [†]
1	4.66	2.02	33.1	sm
2	4.50	1.72	36.7	sm
3	4.15	2.91	25.5	st
4	4.24	3.09	23.9	st
5	3.89	1.62	38.2	sm
6	4.08	1.71	36.9	sm
7	3.83	2.00	33.3	sm
8	3.95	2.07	32.5	sm
9	4.67	1.26	44.2	m
10	4.86	1.34	42.7	m
11	4.73	1.00	50.0	M
12	4.70	1.01	49.7	m
13	4.56	1.08	48.0	m
14	4.50	1.13	46.9	m
15	4.24	1.11	47.4	m
16	4.24	1.07	48.2	m
17	4.18	1.04	48.9	m
18	4.24	1.07	48.2	m
19	4.28	1.09	47.8	m
20	3.95	1.02	49.6	m
21	3.57	1.33	43.0	m
22	3.63	1.27	44.0	m
23	3.13	1.26	44.2	m
24	3.25	1.27	44.1	m

* $L^c = \frac{\text{length of the short-arm}}{\text{total length of the chromosome}} \times 100$ After Kaul and Ansari (1975)

⁺ After Torres (1968)

[†] After Levan, *et al.* (1964)

Table II:

Lengths of Chromosomes in Percent
of Total Cell Chromatin (L%),
Long-arm/Short-arm Ratios (L/S),
Centric Indices (L^c), and
Chromosome Types Calculated for
Bidens polylepis "polylepis"

Chromosome Number	L% ⁺	L/S	L ^c *	Chromosome Type [†]
1	3.92	2.61	27.7	sm
2	4.21	2.45	29.0	sm
3	3.88	2.97	25.2	st
4	4.25	3.03	24.8	st
5	3.26	3.04	24.8	st
6	3.59	2.97	25.2	st
7	3.32	2.15	31.7	sm
8	3.36	2.28	30.5	sm
9	5.17	1.12	47.3	m
10	4.87	1.17	46.2	m
11	4.80	1.17	46.1	m
12	4.94	1.28	44.0	m
13	4.58	1.25	44.4	m
14	4.51	1.20	45.5	m
15	4.48	(1.01)	49.7	m
16	4.54	1.10	47.6	m
17	4.48	1.03	49.3	m
18	4.34	1.04	48.9	m
19	4.18	1.01	49.6	m
20	4.05	1.05	48.9	m
21	3.95	1.03	49.2	m
22	4.02	1.06	48.4	m
23	3.69	1.05	48.7	m
24	3.62	1.11	47.4	m

* $L^c = \frac{\text{length of the short-arm}}{\text{total length of the chromosome}} \times 100$ After Kaul and Ansari (1975)

⁺ After Torres (1968)

[†] After Levan, *et al.* (1964)

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A BOTANICAL SURVEY OF CUMING COUNTY: PART I, THE VASCULAR PLANTS

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A botanical survey of the vascular plants of Cuming County, Nebraska, recognizes 4 major vegetation zones and a total of 491 species representing 270 genera and 83 families.

† † †

INTRODUCTION

This is the first systematic botanical survey for a north-eastern Nebraska county and the second published county flora survey for Nebraska. The first published botanical survey was that of Urbatsch and Eddy (1973) for Dawes County, Nebraska. Part I of this study presents the vascular flora—Equisetophyta, Polypodiophyta, Pinophyta and Magnoliophyta—of Cuming County. Work is now under way on Part II of the bryophyte flora.

The study of the vascular flora of Cuming County was conducted for the flowering seasons of 1972 through 1974. The objective was to survey and document with plant specimens all known species, native and introduced, that were not under cultivation within the county. In addition to collecting, species' associations and vegetation zones were recorded. Approximately 12 visits were made throughout the flowering season for each of the 3 years. Sixty-three sites were studied; several were sampled throughout the season; and all possible vegetation zones were surveyed.

Four hundred ninety-one species, 7 subspecies or varieties, and 4 hybrids—representing 270 genera and 83 families—were recorded; and 1,000 specimen were collected and are deposited at the Nebraska State Herbarium (NEB). A duplicate set of nearly all species of the author's collections is deposited at the Missouri Botanical Garden (MO).

BOTANICAL HISTORY

The first botanical record from Cuming County was noted by a mixed collection of *Cystopteris fragilis* and *Adiantum pedatum* made by L. Bruner from West Point in July, 1880. Bessey (1890) listed 38 species of grasses from Cuming County exhibited at the 1889 Nebraska State Fair. These grasses were collected by Artman and were examined and listed by H. Webber. None of Artman's collections is contained in the Nebraska State Herbarium. All but 5 of these grasses

have been collected by the author. Those grasses not verified by specimen are here excluded from the annotated list. These include: *Bromus ciliatus*, *Schedonnardus paniculatus*, *Muhlenbergia cuspidata*, *Sporobolus asper*, and *Aristida purpurea*.

Collectors and the number of specimen contained in the Nebraska State Herbarium from Cuming County are: L. Bruner (2); H. Webber (2); N. Peterson (1); A. Burke (1); W. Tolstead (5); S. Churchill (1,000). Recently, the University of Kansas, in its survey of the Great Plains, has added a number of collections from Cuming County by H.A. Stephens, some of which are additions to the author's collections and are cited in the annotated list.

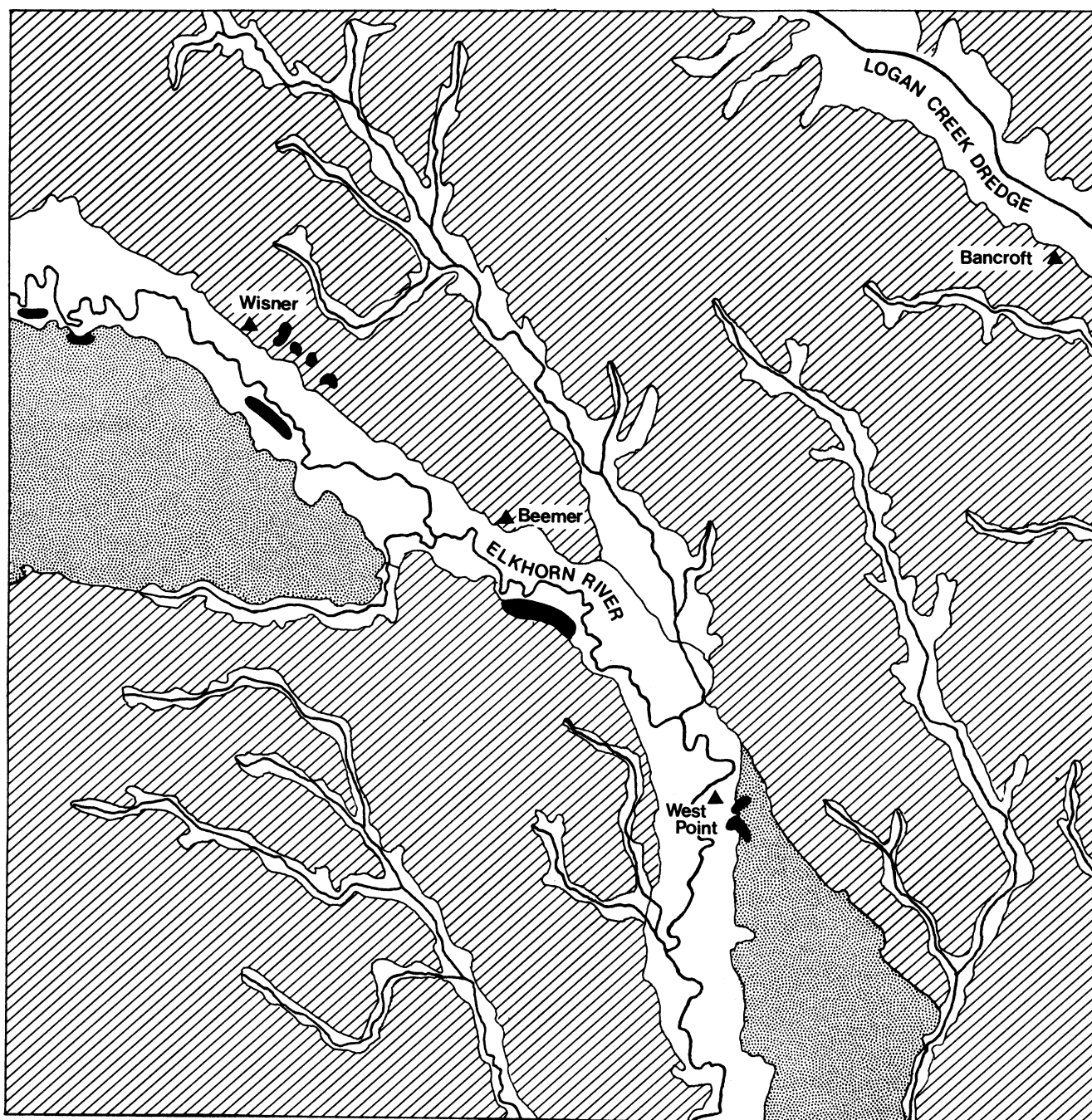
LOCATION

Cuming County is in the second tier of counties west of the Missouri River in northeastern Nebraska. With an area of about 570 square miles or 365,440 acres (Nebraska Conservation Needs Committee, 1969), Cuming County is located in that general area known as the "eastern prairie" of the Great Plains and forms a portion of the vast central lowlands in the interior of North America (Raisz, 1957).

GEOLOGY AND SOILS

All of the geologic bedrock of Cuming County is covered by mantle rock (soils and unconsolidated sediments). From west to east, the bedrock forms are: Carlile, Greenhorn-Graneros, and Dakota, all of the Cretaceous period (Elder, 1969). Both the Nebraskan and Kansan glacial stages covered Cuming County.

Five soil associations have been recognized within the county: Nora-Moody-Judson, Colo-Calco-Kennebec, Moody-Nora-Belfore, Zook-Leshara-Wann, and Thurman-Leisy-Moody associations (DaMoude, 1973). Soil types generally coincide with the major vegetation zones (Fig. 1): silty soils on the uplands (eastern tallgrass prairie); clayey, silty, loam soils on the bottomlands (floodplain prairie and forest); and sandy upland (sandhills prairie).



Vegetation of Cuming County, Nebraska

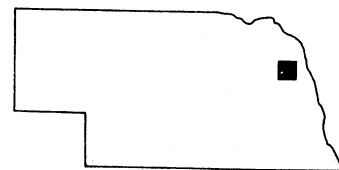
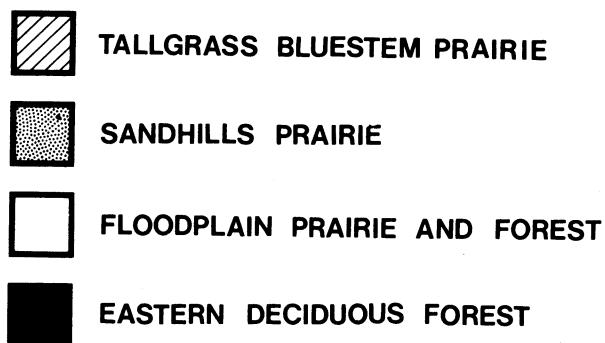


Figure 1. Vegetation of Cuming County, Nebraska.

TOPOGRAPHY AND DRAINAGE

The maximum topographic relief (highest elevation) in Cuming County is approximately 1600 feet in the western portion and 1100 feet (the minimum) in the eastern portion of the county. The uplands are marked by level-to-rolling plains and the lowlands with minor- and major-level floodplains. The general slope and drainage is to the south and east. The largest drainage systems are the Elkhorn River and its major tributaries: Logan, Cuming, Plum, Rock, and Pebble Creeks (Bentall, *et al.*, 1971).

CLIMATE

The mean annual precipitation based on the period from 1931-1955 for West Point ranged from 24 to 28 inches. The mean temperature ranged from 21 to 79 degrees during the same period. The number of frost-free days based on the period from 1921-1950 at West Point ranged from 159 to 236 days. The mean dates of the last spring frost ranged from 03-21 to 05-02, and from 10-08 to 11-13 for the first fall frost (Stevens, 1959).

PAST AND PRESENT VEGETATION

Since no botanical accounts were ever kept for Cuming County, it is difficult to assess the original vegetation. Compiled data concerning present relict tracts of vegetation zones and their components, plus available early historical accounts, aid in postulating the probable vegetation of Cuming County.

The historical settlement of Cuming County from the period of first settlement in the early 1850's through the mid-1870's is given by Sweet (1876), whose account provides several clues to the original vegetation. Rich floodplain forest and tall grass areas are described for the lowlands, while the uplands were vast areas of prairie. However, there is seldom a year when Sweet does not mention flooding of the Elkhorn River and/or its major tributaries, or the extensive prairie fires on the uplands. Such accounts testify to the natural conditioning that gave the prairie and floodplain their apparent richness before the influence of European man.

The vegetation map (Fig. 1) of Cuming County is a compromise between past and present vegetation. All but the eastern deciduous forest generally conform to the original vegetation. The eastern deciduous forest was probably more extensive than depicted on the map.

Four major vegetation zones can be recognized in Cuming County: floodplain prairie and forest; tallgrass bluestem prairie; sandhills prairie; and eastern deciduous forest. These zones generally conform to the recent vegetation map of Nebraska by Kaul (1975). Only small remnants of the zones are in existence today due to the intense agricultural use of the land in Cuming County. Present land use in Cuming County in percentage of total land acres is: 79% cropland,

14% pasture, 1% range, 2% forest, and 4% miscellaneous—e.g. farmstead, town, road, etc. (Nebraska Conservation Needs Committee, 1969).

As a result of this study, two notable facts concerning the vegetation zones in Cuming County are reported. First, Churchill *et al.*, (1976) reported the eastern-most extension of sandhills vegetation for Nebraska occurring in Cuming County. Second, eastern deciduous forests are native to the Elkhorn River valley area. The question as to whether this eastern deciduous forest vegetation zone in Cuming County is native has been raised by the University of Nebraska Conservation and Survey Division. I think several facts support the contention that the oak woods are native to the region. First, Sweet's account, mentioned previously, states that a lumber mill was in operation at West Point and harvested much of the local cottonwood and oak. Second, much of the oak woods contain "typical" eastern deciduous forest vegetation, e.g., *Quercus macrocarpa*, *Tilia americana*, *Xanthoxylum americanum*, *Gymnocladus dioica*, *Menispermum canadensis*, *Aquilegia canadensis*, *Dicentra cucullaria*, *Sanguinaria canadensis*, *Carex convoluta*, *Adiantum pedatum*, *Botrychium virginianum*, and *Cystopteris fragilis*. Third, the common presence of oak seedlings suggests their adaptability to the area of the Elkhorn River bluffs and sandy floodplain. Thus, it must be assumed that many years would be involved in the establishment of such a zone, and therefore, it did not just come into being after the presence of European man.

It is not difficult to assess the future of the relict vegetation tracts in Cuming County. The rich eastern deciduous forest flora contained on the bluffs south of Beemer (Sec. 1, T22N, R5E) is slowly being eroded by the local garbage dump, and the sandhill prairies southwest of Wisner and southeast of West Point are slowly being stabilized through so-called management programs. This study, and especially the collections made which contain labelled location and habitat information, will aid in the assessment of future changes in vegetation zones and components of those zones within the county.

ANNOTATED LIST

The following list is arranged according to Cronquist (1968) as modified by McGregor *et al.* (1977) for the vascular plant families. Within each of the families, genera and species are arranged alphabetically. Nomenclature generally follows that of McGregor *et al.* (1977) for the treatment of genera and species. Subspecies and varieties are recognized only if the author considers them distinct enough for recognition.

To conserve space, symbols have been employed for each of the vegetation zones that are given for each taxon. In addition, symbols are used to describe particular habitats in a vegetation zone. For the vegetation zones, those symbols are: tallgrass bluestem prairie (TBP); sandhills prairie (SP); floodplain forest (FF); floodplain prairie (FP); and eastern

deciduous forest (EDF). For the habitats they are: aquatic (A); marsh (M); meadow (MW); riparian (R); disturbed ground (DG). For the origin of the plants, they are either introduced or adventive, most of which have become naturalized now (I). Taxa with no notation of "(I)" are here considered native to the county.

All taxa listed were collected or verified by the author. Specimens of each taxon are deposited in the Nebraska State Herbarium (NEB) except those indicated are at the University of Kansas (KANU).

ACKNOWLEDGMENTS

Several individuals assisted with the verification or determination of specimens and are gratefully acknowledged: Mr. Robert Albert, Drs. Ole Kolstad, Ronald McGregor, and David Sutherland. Ms. Martha Haack, illustrator for the University of Nebraska State Museum, prepared the fine map illustration. Special thanks are extended to Dr. Greg Anderson for help in the initiation of this study and to Dr. Robert Kaul for support throughout the study. I would like to thank my wife, Katherine, for accompanying and assisting on many of the field trips.

I wish to acknowledge financial support from the Jessie Lee Fund for several summers of field work.

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ANNOTATED LIST

EQUISTEOPHYTA

Equisetaceae

- Equisetum arvense* L. (FF) *E. laevigatum* A. Br. (SP)
E. hyemale L. (M, R)

POLYPODIOPHYTA

Ophioglossaceae

- Botrychium virginianum* (L.) Sw. (EDF)

Polypodiaceae

- Adiantum pedatum* L. (EDF) *Cystopteris fragilis* (L.) Bernh. (EDF)

PINOPHYTA

Cupressaceae

- Juniperus virginiana* L. (DG-SP)

MAGNOLIOPHYTA

LILIATAE

Alismataceae

- Alisma plantago-aquatica* L. (M) *S. latifolia* Willd. (M-FF, R)
A. subcordatum Raf. (M) *S. montevidensis* Cham. et Schlect
Sagittaria engelmanniana J. G. Sm. ssp. *calycina* (Engelm.) Bogin (R)
ssp. *brevirostra* (Mack. et Bush) Bogin (M)

Hydrocharitaceae

- Elodea nuttallii* (Planch.) St. John (A)

Potamogetonaceae

- Potamogeton foliosus* Raf. (A) *P. pectinatus* L. (A)

Zannichelliaceae

- Zannichellia palustris* L. (A)

Fagaceae		Ceratophyllaceae	
<i>Quercus macrocarpa</i> Michx. (EDF)		<i>Ceratophyllum demersum</i> L. (A)	
Ulmaceae		Ranunculaceae	
<i>Celtis occidentalis</i> L. (EDF, MW-FP)	<i>U. pumila</i> L. (DG-TBP; I)	<i>Anemone canadensis</i> L. (MW-FP)	<i>Ranunculus abortivus</i> L. (FF, EDF)
<i>Ulmus americana</i> L. (FF, EDF)	<i>U. rubra</i> Muhl. (FF, EDF)	<i>A. cylindrica</i> Gray (EDF)	<i>R. pensylvanicus</i> L. (FF)
Moraceae		<i>Aquilegia canadensis</i> L. (EDF)	<i>R. sceleratus</i> L. (R)
<i>Cannabis sativa</i> L. (DG; I)	<i>Morus alba</i> L. (EDF), FF. I)	<i>Clematis virginiana</i> L. (MW-FP)	<i>Thalictrum dasycarpum</i> Fisch.,
<i>Humulus lupulus</i> L. (DG)		<i>Delphinium virescens</i> Nutt. (SP)	Mey., et Ave-Lall. (MW-FP, FF)
Urticaceae		Menispermaceae	
<i>Boehmeria cylindrica</i> (L.) Sw. (FF)	<i>Urtica dioica</i> L. ssp. <i>gracilis</i>	<i>Menispermum canadense</i> L. (EDF)	
<i>Laportea canadensis</i> (L.) Gaud. (FF)	(Ait.) Selander (EDF, FF)	Papaveraceae	
<i>Pilea fontana</i> (Lunell) Rydb. (EDF)		<i>Argemone polyanthemom</i> (Fedde)	<i>Sanguinaria canadensis</i> L.
Santalaceae		G. Ownbey (SP)	(EDF)
<i>Comandra umbellata</i> (L.) Nutt. ssp. <i>umbellata</i> (FP)		Fumariaceae	
Polygonaceae		<i>Dicentra cucullaria</i> (L.) Bernh. (EDF)	
<i>Eriogonum annuum</i> Nutt. (SP)	<i>P. ramosissimum</i> Michx. (DG)	Brassicaceae	
<i>Polygonum achoreum</i> Blake (DG)	<i>P. scandens</i> L. (FF)	<i>Arabis hirsuta</i> (L.) Scop. (FP)	<i>Lepidium densiflorum</i> Schrad. (DG)
<i>P. arenastrum</i> Jord. ex Bor. (DG)	<i>Rumex acetosella</i> L. (DG-SP)	<i>Brassica juncea</i> (L.) Coss. (DG; I)	<i>Lesquerella ludoviciana</i> (Nutt.)
(<i>P. aviculare</i>)	<i>R. altissimus</i> Wood. (M)	<i>B. nigra</i> (L.) Koch. (DG; I)	Wats. (SP)
<i>P. coccineum</i> Muhl. (M, A)	<i>R. crispus</i> L. (M-FF)	<i>Camelina microcarpa</i> Andr.	<i>Rorippa austriaca</i> (Crantz.) Bess. (M-DG)
<i>P. convolvulus</i> L. (DG-FF; I)	<i>R. maritimus</i> L. var. <i>fueginus</i>	(DG; I)	<i>R. palustris</i> (L.) Bess. ssp. <i>glabra</i> (Schulz)
<i>P. lapathifolium</i> L. (M-FF; I)	(Phil.) Dusen. (R)	<i>Capsella bursa-pastoris</i> (L.)	Stuckey var. <i>fernaldiana</i> (Butt.
<i>P. pensylvanicum</i> L. (M-FF)	<i>R. stenophyllum</i> Ledeb. (M; I)	Medic. (DG; I)	et. Abbe) Stuckey (R, M; I)
<i>P. punctatum</i> Ell. (M-FP)	<i>R. venosus</i> Pursh (SP)	<i>Cardaria draba</i> (L.) Desv. (DG; I)	<i>R. sinuata</i> (Nutt.) Hitchc. (DG-M)
Chenopodiaceae		<i>Descurainia pinnata</i> (Walt.) Britt. var.	(Stephens 21121; KANU)
<i>Chenopodium album</i> L. (DG; I)	<i>Cycloloma atriplicifolium</i>	<i>brachycarpa</i> (Richards.) Fern. (DG)	<i>Sisymbrium altissimum</i>
<i>C. desiccatum</i> A. Nels. (DG-SP)	(Spreng.) Coult. (R)	<i>Draba reptans</i> (Lam.) Fern. (SP)	L. (DG; I)
<i>C. hybridum</i> L. (DG-EDF)	<i>Kochia scoparia</i> (L.) Schrad. (DG; I)	<i>Erysimum cheiranthoides</i> L. (EDF; I)	<i>S. loeselii</i> L. (DG; I)
<i>C. standleyanum</i> Aellen (EDF)	<i>Salsola iberica</i> Sennen et Pau.	<i>Hesperis matronalis</i> L. (DG; I)	<i>Thlaspi arvense</i> L. (DG; I)
<i>Corispermum nitidum</i> L. (SP)	(DG; I) (<i>S. kali</i>)	Crassulaceae	
Amaranthaceae		<i>Penthorum sedoides</i> L. (M, R)	
<i>Amaranthus graecizans</i> L. (DG)	<i>Froelichia floridana</i> Nutt. var.	Saxifragaceae	
<i>A. retroflexus</i> L. (DG)	<i>campestris</i> (Small) Fern. (SP)	<i>Ribes missouriense</i> Nutt. (FF, EDF)	
<i>A. tamariscinus</i> Nutt. (DG)	<i>F. gracilis</i> (Hook.) Moq. (DG-SP)	Rosaceae	
Nyctaginaceae		<i>Crataegus mollis</i> (T. et G.)	<i>Prunus americana</i> Marsh (FF)
<i>Mirabilis albidia</i> (Walt.)	<i>M. nyctaginea</i> (Michx.) MacM.	Scheele. (EDF)	<i>P. besseyi</i> Bailey (SP)
Heimerl. (SP)	(DG, FF)	<i>Fragaria virginiana</i> Duchn. (FP)	<i>P. virginiana</i> L. (FF)
Aizoaceae		<i>Geum canadense</i> Jacq. (FF)	<i>Rosa arkansana</i> Porter (FP, TBP)
<i>Mollugo verticillata</i> L. (DG-SP; I)		<i>Potentilla norvegica</i> L. (FF, R)	<i>Rubus occidentalis</i> L. (EDF)
Caryophyllaceae		<i>P. recta</i> L. (SP; I)	
<i>Cerastium vulgatum</i> L. (EDF; I)	<i>S. dichotoma</i> Ehrh. (DG; I) (Peter-	Fabaceae	
<i>Saponaria officinalis</i> L. (DG; I)	son s.n. 3 July 1908; NEB)	<i>Amorpha canescens</i> Pursh	<i>A. crassicaupus</i> Nutt. (TBP)
<i>Silene antirrhina</i> L. (DG-FP)	<i>S. stellata</i> (L.) Ait. f. (MW-FP)	(TBP, SP, FP)	<i>Cassia fasciculata</i> Michx. (DG-FP)
		<i>A. fruticosa</i> L. (R, M-FF)	<i>Crotalaria sagittalis</i> L. (M)
		<i>Amphicarpaea bracteata</i> (L.) Fern. (SP)	
		<i>Apios americana</i> Fabricus (FF)	<i>Desmodium canescens</i> (L.) DC. (TBP)
		(Stephens 36401; KANU)	<i>D. glutinosum</i> (Muhl.) Wood.
		<i>Astragalus canadensis</i> L. (FP)	(EDF)
			<i>D. illinoense</i> Gray (TBP)

Apocynaceae		Bignoniaceae	
<i>Apocynum cannabinum</i> L. (DG)	<i>A. sibiricum</i> Jacq. (DG)	<i>Catalpa speciosa</i> Warder (FF; I)	
Asclepiadaceae		Plantaginaceae	
<i>Asclepias amplexicaulis</i> Sm. (SP)	<i>A. tuberosa</i> L. ssp. <i>interior</i> Woods. (SP)	<i>Plantago patagonica</i> Jacq. var. <i>patagonica</i> (SP, TBP, DG) (<i>P. purshii</i>)	<i>P. rugelii</i> Dcne. (FF)
<i>A. arenaria</i> Torr. (SP)			<i>P. virginica</i> L. (DG)
<i>A. incarnata</i> L. (M)	<i>A. verticillata</i> L. (TBP, FP, SP)		
<i>A. sullivantii</i> Engelm. (FP)	<i>A. viridiflora</i> Raf. (SP)		
<i>A. syriaca</i> Vail. (DG)		Rubiaceae	
Convolvulaceae		<i>Cephalanthus occidentalis</i> L. (M-FF) (Webber 5090; NEB)	<i>G. obtusum</i> Bigel. (FP)
<i>Convolvulus arvensis</i> L. (DG; I)	<i>C. polygonorum</i> Engelm. (R)	<i>Galium aparine</i> L. (FF, EDF)	<i>G. trifidum</i> L. (M-FP)
<i>C. sepium</i> L. (DG)	<i>Ipomoea purpurea</i> (L.) Mey. (DG; I)	Caprifoliaceae	
<i>Cuscuta cephalantha</i> Engelm. (DG)		<i>Sambucus canadensis</i> L. (FF)	<i>Symphoricarpos occidentalis</i> Hook. (SP, TBP, EDF)
Polemoniaceae		Cucurbitaceae	
<i>Phlox pilosa</i> L. (FP)		<i>Echinocystis lobata</i> (Michx.) Greene (DG)	
Hydrophyllaceae		Campanulaceae	
<i>Ellisia nyctelea</i> L. (DG)		<i>Campanula americana</i> L. (FF)	<i>Triodanis perfoliata</i> (L.) Nieuw. (SP)
Boraginaceae		Lobeliaceae	
<i>Hackelia virginiana</i> (L.) I.M. Johnst. (FF)	<i>L. carolinense</i> (Walt.) MacM. (SP)	<i>Lobelia siphilitica</i> L. (M)	
<i>Lithospermum canescens</i> (Michx.) Lehm. (FP)	<i>L. incisum</i> Lehm. (SP)	Asteraceae	
Verbenaceae		<i>Achillea millefolium</i> L. ssp. <i>lanulosa</i> (Nutt.) Piper. (TBP)	<i>C. ramosissima</i> Cronq. (DG)
<i>Phyla lanceolata</i> Michx.) Greene (M)	<i>V. urticifolia</i> L. (MW-FP; FF)	<i>Ambrosia artemisiifolia</i> L. (DG)	<i>Dyssodia papposa</i> (Vent.) Hitchc. (DG)
<i>Verbena bracteata</i> Lag. et Rodr. (DG-SP)	<i>V. x illicita</i> Moldenke (MW-FP) (<i>V. urticifolia</i> X <i>V. stricta</i>)	<i>A. psilostachya</i> DC. (DG)	<i>Echinacea angustifolia</i> DC. var. <i>angustifolia</i> (TBP, SP)
<i>V. hastata</i> L. (M)		<i>A. trifida</i> L. (DG; I)	<i>Eclipta alba</i> (L.) Hassk. (R)
<i>V. stricta</i> Vent. (TBP, SP, FP)		<i>Antennaria neglecta</i> Greene (SP, TBP)	<i>Erigeron philadelphicus</i> L. (FP)
Lamiaceae		<i>Artemisia dracunculus</i> L. (DG)	<i>E. strigosus</i> Muhl. (TBP, SP)
<i>Agastache nepetoides</i> (L.) O. Ktze. (FF)	<i>Nepeta cataria</i> L. (EDF; I)	<i>A. ludoviciana</i> Nutt. var. <i>ludoviciana</i> (SP)	<i>Eupatorium maculatum</i> L. var. <i>bruneri</i> (Gray) Breitung. (FP)
<i>Hedeoma hispida</i> Pursh (SP)	<i>Physostegia virginiana</i> (L.) Benth. (M)	<i>Aster ericoides</i> L. (TBP)	<i>E. perfoliatum</i> L. (FP)
<i>Leonurus cardiaca</i> L. (M-FF; I)	<i>Prunella vulgaris</i> L. (FF; I)	<i>A. novae-angliae</i> L. (EDF)	<i>E. rugosum</i> Houtt. (FF, EDF)
<i>Lycopus americanus</i> Muhl. (M)	<i>Scutellaria lateriflora</i> L. (M-FP)	<i>A. oblongifolius</i> Nutt. (SP)	<i>Gnaphalium obtusifolium</i> L. (SP)
<i>L. asper</i> Greene (M)	<i>S. parvula</i> Michx. var. <i>leonardi</i> (Epl.) Fern. (DG-M)	<i>A. pansus</i> (Blake) Cronq. (FP) (Stephens 44729; KANU)	<i>Grindelia squarrosa</i> (Pursh) Dun. var. <i>squarrosa</i> (TBP)
<i>L. virginicus</i> L. (M)	<i>Teucrium canadense</i> L. var. <i>occidentale</i> (Gray) McCl. et Epl. (M)	<i>A. praealtus</i> Poir. var. <i>nebrascensis</i> (Britt.) Wieg. (M)	<i>Haplopappus spinulosus</i> (Pursh) DC. (SP)
<i>Mentha arvensis</i> L. (M)		<i>A. simplex</i> Willd. var. <i>ramosissimus</i> (T. et G.) Cronq. (M)	<i>Helianthus annuus</i> L. (DG)
<i>Monarda fistulosa</i> L. (MW-FP)		<i>Bidens cernua</i> L. (M)	<i>H. grosseserratus</i> Martens (FP)
Solanaceae		<i>B. comosa</i> (Gray) Wieg. (M)	<i>H. maximiliana</i> Schrad. (FP)
<i>Physalis heterophylla</i> Nees. (SP)	<i>Solanum americanum</i> Mill. (DG, FF)	<i>B. frondosa</i> L. (M)	<i>H. petiolaris</i> Nutt. (SP, FP)
<i>P. virginiana</i> Mill. var. <i>virginiana</i> (FP)	<i>S. rostratum</i> Dun. (DG)	<i>B. vulgata</i> (Greene) (M)	<i>H. rigidus</i> (Cass) Desf. ssp. <i>rigidus</i> (SP, FP)
<i>P. virginiana</i> Mill. var. <i>sonorae</i> (Torr.) Waterfall (FP) (<i>P. longifolia</i>)	<i>S. triflorum</i> Nutt. (DG?) (Webber 5619; NEB)	<i>Carduus nutans</i> L. (DG; I)	<i>H. tuberosus</i> L. (FP)
Scrophulariaceae		<i>Chrysanthemum leucanthemum</i> L. (DG; I)	<i>Heliopsis helianthoides</i> (L.) Sweet. var. <i>scabra</i> (Dun.) Fern. (FP)
<i>Agalinis tenuifolia</i> (Vahl.) Raf. (R)	<i>Verbascum thapsus</i> L. (DG; I)	<i>Chrysopsis villosa</i> (Pursh) Nutt. (SP)	<i>Hymenopappus tenuifolius</i> Pursh (SP)
<i>Lindernia dubia</i> (L.) Penn. (R)	<i>Veronica peregrina</i> L. var. <i>peregrina</i> (DG-M)	<i>Cirsium altissimum</i> (L.) Spreng. (FF)	<i>Kuhnia eupatorioides</i> L. var. <i>corymbulosa</i> T. et G. (TBP)
<i>Mimulus ringens</i> L. (M)	<i>V. peregrina</i> L. var. <i>xalapensis</i> (H.B.K.) St. John et Warren (DG-M)	<i>C. canescens</i> Nutt. (SP)	<i>Lactuca canadensis</i> L. (DG)
<i>Penstemon albidus</i> Nutt. (SP)		<i>C. flodmani</i> (Rydb.) Arthur (SP)	
<i>P. grandiflorus</i> Nutt. (SP)		<i>C. vulgare</i> (Savi) Ten. (DG; I)	
<i>Scrophularia lanceolata</i> Pursh (FF)		<i>Conyza canadensis</i> (L.) Cronq. (DG)	

<i>L. oblongifolia</i> Nutt. (EDF)	<i>S. canadensis</i> L. var. <i>scabra</i> T.
(<i>L. pulchella</i>)	et G. (MW-FF) (<i>S. altissima</i>)
<i>L. serriola</i> L. (FF; I)	<i>S. gigantea</i> Ait. var. <i>serotina</i> (O.
(<i>L. scariola</i>)	Ktze.) Cronq. (FP)
<i>Liatris aspera</i> Michx. (TBP)	<i>S. graminifolia</i> (L.) Salisb. var.
<i>L. glabrata</i> Rydb. (SP)	<i>gymnospermoides</i> (Greene) Croat (SP)
<i>L. pycnostachya</i> Michx. (FP)	<i>S. missouriensis</i> Nutt. (SP, TBP)
<i>Lygodesmia juncea</i> (Pursh) D.	<i>S. rigida</i> L. var. <i>rigida</i>
Don. (SP)	(SP, TBP)
<i>Matricaria matricarioides</i> (Less)	<i>S. rigida</i> L. var. <i>humilis</i>
Porter. (DG)	Porter (SP)
<i>Ratibida columnifera</i> (Nutt.) Woot.	<i>Taraxacum officinale</i> Weber (DG; I)
et Standl. (SP, FP)	<i>Thelesperma filifolium</i> (Hook.)
<i>R. pinnata</i> (Vent.) Barnh. (FP)	Gray var. <i>intermedium</i> (Rydb.)
<i>Rudbeckia hirta</i> L. (MW-FP)	Shinners (SP)
<i>R. laciniata</i> L. (M-FF)	<i>Tragopogon dubius</i> Scop. (DG; I)
<i>Senecio plattensis</i> Nutt. (SP, TBP)	<i>Vernonia baldwini</i> Torr. var. <i>interior</i>
<i>Silphium integrifolium</i> Michx. (FP)	(Small) Schub. (TBP)
<i>S. laciniatum</i> L. (FP)	(Stephens 44729; KANU)
<i>S. perfoliatum</i> L. (FP)	<i>V. fasciculata</i> Michx. var.
<i>Solidago canadensis</i> L. var.	<i>fasciculata</i> (FP, DG)
<i>hargerii</i> Fern. (TBP, EDF)	<i>Xanthium strumarium</i> L. (DG, R; I)

WOOD DUCK PRODUCTION IN THE SALT CREEK WATERSHED OF EASTERN NEBRASKA

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Counts of Wood Ducks made during the spring and summer of 1970 on the creeks and reservoirs of the Salt Creek watershed in south-eastern Nebraska yielded a conservative estimate of 40 breeding pairs; 16 broods were counted. Estimates of production are biased by numerous variables, including intrinsic sampling problems.

† † †

INTRODUCTION

In eastern Nebraska the Wood Duck (*Aix sponsa*) is an uncommon migrant (Rapp *et al.*, 1958) and breeds in limited numbers in the eastern one-half, and mainly the eastern one-fourth, of the state (Nebraska Game and Parks Comm., 1972). Its abundance in Nebraska apparently mirrors the steady increase of these animals throughout the United States from the near extinction levels of the early 1900's (Bellrose, 1976a). Although the species was listed as a local breeder in almost every one of the United States in 1930 (A.O.U., 1931), Kortwright (1942) did not include Nebraska within its breeding range. It now breeds as far west as Hastings, Nebraska in the south and Springview in the north (Bellrose, 1976b), and its breeding population has been estimated at 4,000 (Sutherland, 1971). Very little has been published, however, to document the distribution of the state's Wood Duck population or the annual natality within this population. During the summer of 1970, I attempted to estimate how frequently Wood Ducks breed and how many young are produced in the Salt Creek watershed of eastern Nebraska (Lancaster County and portions of Butler, Cass, Saline, Saunders, and Seward counties). The number of breeding pairs and young produced on creeks in the watershed was compared with those on reservoirs in the same watershed.

CREEK STUDY AREAS

Sampling units consisted of five-mile lengths of creek, considered reasonable given the time limitations of foot travel. Starting at the Platte River, non-overlapping, five-mile segments were marked off along Salt Creek and its tributaries on a topographic map. No segments were marked off where Salt Creek is channeled through the city of Lincoln, where reservoirs were present on a given stretch of creek, or where a segment was less than five miles long. Creeks passing

through concentrations of human population (e.g., Antelope Creek in Lincoln) were also avoided. Forty segments met the criteria for possible study areas and were assigned a number in random order. Of these, ten segments were randomly selected (table of random numbers) for the census. The study areas were numbered 1-10 for reference (for locations see Fig. 1).

Table I:

Results of the Watershed Creek Censuses

Study Area	May		June
	Number of Pairs	Number of Broods	Number of Broods
1	1		1
2			
3			
4	1	1	
5	1		
6			
7			
8	1		1
9	2	1	1*
10	1	—	1
Totals	7	2	4

*denotes a brood possibly seen on an earlier census.

The creek banks were variously forested. This variable wasn't considered in the selection of study areas in order that the samples be representative of the entire watershed. Generally, where a creek had numerous oxbows, stands of trees from 2-10 acres persisted in spite of agricultural practices. Where the creek bed was straight, cultivation extended nearly to the bank, and only occasionally would a row of scattered trees persist. Species composition varied, but American elm

(*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), and cottonwood (*Populus deltoides*) usually predominated. Bur oaks (*Quercus macrocarpa*) were usually found in the drier sites. Understory varied from almost none in heavily grazed woods to impenetrable rank vegetation (for quantitative description see Cink, 1970).

RESERVOIR STUDY AREAS

The reservoirs studied included the ten largest in the watershed (average size—429 acres) and 20 additional impoundments under 100 acres selected randomly from a total of 60 suited to study (impoundments devoid of emergent vegetation and/or with surrounding cover trampled by livestock were considered unsuitable for waterfowl). Figure 1 shows the distribution of reservoirs in the Salt Creek watershed.

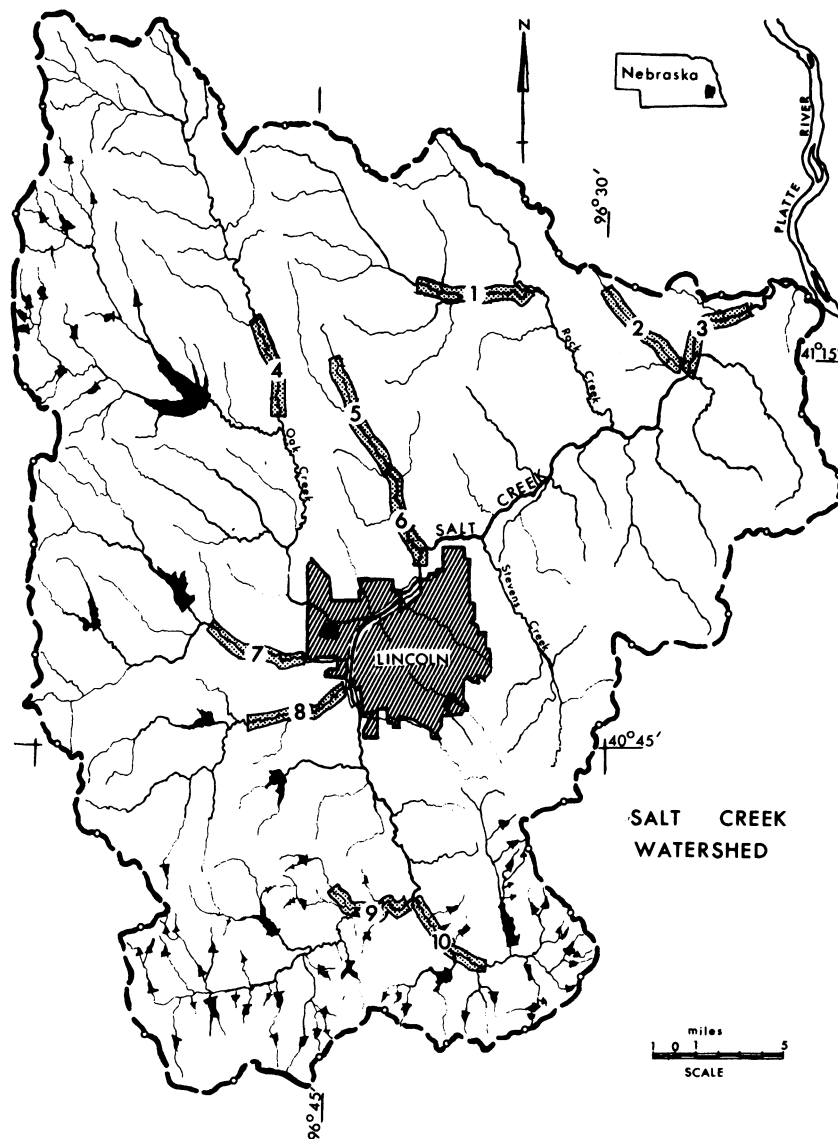


Figure 1. The Salt Creek watershed in southeastern Nebraska (the ten sample study areas stippled).

METHODS

A census of breeding Wood Ducks is difficult because of the wooded habitats preferred. Both flight counts and counts made by floating down inhabited streams have been employed as indices to the abundance of nesting Wood Ducks (Hein, 1966). However, because most of the creeks in the Salt Creek watershed are not navigable, counts of all Wood Ducks seen by walking along the creek banks were used. Brood counts in this type of habitat are especially difficult because the female has ample time to hide the brood when the approach of humans is heard. Although several broods were observed and numbers of young counted, it is likely that some broods were missed. Broods were sometimes discovered from their tracks in the mud along the creek. Broods were aged using the criteria of Dreis (1954). Each creek study area was surveyed in early May for breeding pairs and broods, and in June for broods. Usually, only one study area could be traversed during a morning's work, but on two occasions, adjoining areas were walked on the same day. Searches for breeding pairs and broods were made around the peripheries of the reservoirs during late May, June, and July.

RESULTS AND DISCUSSION

The results of the creek census are shown in Table 1. No breeding pairs or broods were seen in the three study areas that were close to the cities of Lincoln and Ashland. Perhaps these areas had more than the usual amount of human disturbance or simply had less suitable habitat along the creek. The average number of breeding pairs per study area was 0.7. If the average number of breeding pairs on all streams in the watershed could be extrapolated from this figure using the 40 possible study areas, the result would be approximately 28 pairs of Wood Ducks. Considering the low frequency with which this species is encountered in the field, this estimate seems reasonable. All methods used to achieve a census for Wood Ducks seem to underestimate actual population sizes (Stewart, 1958), and, thus, an estimate of 28 pairs may be conservative.

A total of six broods was seen. Based on age and locality, one of these broods was probably the same one seen on a previous count, and, therefore, the correct total is probably five broods. The two broods discovered in May were estimated to be 10 days old, which would place their hatching date about the first week in May or the last week in April. Two of the broods discovered in June were 3-4 weeks old (hatched near the second week in May), and one brood discovered in June was about one week old (hatched in early June). The average brood size was 9.2 (range 5-14). The average number of ducklings produced per study area was 4.6. For the watershed as a whole, this indicates that as many as 184 ducklings could have been produced in 1970. However, nesting habitat along each five-mile segment is not the same, and there is no way of knowing how many of these young were lost to predation. The greatest mortality of young usually comes in the

age classes seen (1-2 weeks) according to Grice and Rogers (1965). Although the Wood Duck is sometimes known to raise two broods to flight stage during the same season (Hester, 1965), there was no evidence of this during my study.

Results for the census of Wood Ducks on the largest reservoirs are given in Table 2. Nine pairs were observed for an average of 0.9 pairs per reservoir. It appears that a large reservoir may have more breeding pairs than a five-mile segment of creek. Reservoirs provide larger resting pools and flooded timber that are attractive to Wood Ducks. In addition, nesting boxes have been provided on several of the reservoirs (e.g. Twin Lakes) by the Nebraska Game and Parks Commission. Probably, however, Wood Ducks are just more easily observed on reservoirs than on creeks. Only two pairs were observed on the smaller impoundments. Usually, the smaller reservoirs have less flooded timber and surrounding cover than do the larger reservoirs.

Ten broods were seen on the large reservoirs, but, of these, three recorded broods may have been the same one

Table 2:

Results of the Watershed Reservoir Censuses

Study Areas ¹	May		June	July
	Number of Pairs	Number of Broods	Number of Broods	Number of Broods
Branched Oak	1		1	1*
Pawnee				
Bluestem	1	1		1*
Wagon Train	1		1	
Twin Lakes	2	1	1	1*
Conestoga	1			
Yankee Hill	1		1	
Stage Coach	1			
Olive Creek	1	1		
Sprague	—	—	—	—
Totals	9	3	4	3

¹ in order of decreasing size.

*denotes a brood possibly seen on an earlier census.

observed earlier in the season. This leaves seven broods, which is still considerably more than might be expected from often disturbed reservoirs. The three broods discovered in May were estimated as 1-2 weeks old (hatch date: April 15-30). Two broods in June were estimated as 3-4 weeks old (hatch date: May 1-7). And the other two broods were estimated as about one week old (hatch date: May 25-31). All three broods found in July were estimated as 5-6 weeks old. The average complement was 7.6 (range 4-10). July broods were all smaller than earlier ones. The actual number of ducklings in some broods may well have been larger than counted, especially where small young were involved, because the broods were usually concealed when the hen was flushed from shore, and it took some work to get the young to flush into the open. Production of young on the ten reservoirs averaged 5.7 per reservoir. No broods were observed on the small impoundments.

These data indicate that the Wood Duck is a low-density breeding bird in the Salt Creek watershed. There may be nearly 28 breeding pairs on the creeks and another 12 pairs on the reservoirs. The sampling technique used in this study would tend to give a conservative estimate of actual numbers. The estimated figures for production of young (184 for creeks and 57 for reservoirs) are undoubtedly biased by such unknown variables as predation, differences in habitat between sample areas and the watershed as a whole, and the intrinsic sampling problems of brood counts in this species. Also, the distinction between creeks and reservoirs is an artificial one: they are in the same drainage system, and Wood Ducks move freely between them. Young hatched along a creek can easily be escorted by their parents to a distant reservoir. Because young Wood Ducks may hatch some distance from water, this type of census will miss some of these individuals. These data are also for one year only, and there may be large differences in production between years.

This study does, however, give some idea of the abundance of breeding Wood Ducks in the Salt Creek watershed and of their productivity in the early 1970's. This could serve as a basis for more intensive study in the future and a baseline for measurement of future population trends.

ACKNOWLEDGMENTS

I thank Paul A. Stewart for the use of his copy of a now out-of-print paper and Paul A. Johnsgard and Robert M. Mengel for their helpful criticism of the manuscript.

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SANDHILL CRANE DANCING DURING THE SPRING MIGRATION

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The role, intensity, and frequency of Lesser Sandhill Crane (*Grus canadensis*) dances were interpreted from observations of 1,167 dance sequences from March 6, 1975, to April 15, 1975. The observations were from 27 sites in Kearney and Hall Counties, Nebraska.

Nineteen variables, selected as possible determinants of dance frequency (dances/minute), were recorded on field observation forms along with a description of each dance and the approximate duration.

The 19 variables were regressed against the dance frequency of the total dances as well as 6 subgroups—courtship display, emotion or tension-release, aggression-related activity, pre-flight and pre-walk communication, and response to possible danger. Primary factors selected as influencing the dance frequencies of all the dances collectively included: relative density, distance to the nearest road, date, time, flock size, circular flock shape, and grazing in corn stubble. Primary predictors were also selected for each of the 6 dance types.

The intensity (duration) of each dance was recorded. As the migratory season progressed, the dance frequency increased, whereas, the intensity decreased. This was primarily due to an increase in tension-release and aggression-related dances of which nearly 97% lasted less than 30 seconds.

† † †

INTRODUCTION

Heineman (1954) wrote that the dance display of the lesser Sandhill Crane was a "sight to behold" and a "joy for nature lovers." Several investigators felt that this avian phenomenon was more than a pleasure for bird watchers, so they devised studies to determine the value of the behavior to the cranes.

Fey (1965) and Schaffer (1968) referred to the dance as a curious courtship display; however, many investigators have reported this to be only part of the value. Functions also ascribed to the dances were: aggressive maintenance of an individual territory (Farrar, 1975; Keith, 1962; and Walkinshaw, 1949); pre-flight communication (Walkinshaw, 1949); response to a possible danger (Keith, 1962); an emotional outlet or tension-release activity (Farrar, 1975; Keith, 1962;

McNulty, 1966; and Walkinshaw, 1949). Thus, 5 functions have been proposed as roles of crane dancing.

In this study, research was conducted to determine the frequency (dances/minute of observation), intensity (time duration of individual dance sequences), and the role of this behavior during the spring migration of Sandhill Cranes through central Nebraska.

MATERIALS AND METHOD

The dancing behavior of Sandhill Cranes was observed for two periods during the spring migration: March 6, 1975-March 18, 1975, and March 31, 1975-April 15, 1975. Listed in Table I are the dates of field observations, the length of time spent at each site, the total number of dances recorded per site, and the dance frequency for each of the 27 sites.

In Kearney County, Nebraska, the study was bordered on the west by Nebraska Highway 44; on the south by a county road 1 mile south and running parallel to Nebraska Link 50A connecting Nebraska Highways 10 and 44; on the east by a county road 2 miles east and running parallel to Nebraska Highway 10; and on the north by the Platte River. In Hall County, all observations were within a 1-mile radius of the intersection of Nebraska Highway Link 40C and Platte River Drive, with two exceptions—one observation on Shoemaker Island and another approximately 1 mile south of the south channel of the Platte River and .3 miles west of Nebraska Highway 281.

Approximately one hour was spent at each site (\bar{X} = 58.15 minutes/site). Observations were recorded on tape and later transcribed onto a form devised for the study which provided space for recording individual bird behavior during and following a dance. Included in this section were the actions of the dancers and responses of surrounding birds, plus an approximate duration of each dance sequence, i.e., a = 1 to 30 seconds, b = 30 to 60 seconds and c = more than 60 seconds.

Table I:

Date, Duration, Number of Dances and Dance Frequency
For the 27 Observation Sites

Date of Observation	Time at Site (minutes)	Total Number of Dances	Dance Frequency
March 6, 1975	20	1	.0500
March 6, 1975	80	11	.1375
March 8, 1975	56	28	.0500
March 8, 1975	30	2	.0667
March 8, 1975	29	5	.1724
March 11, 1975	81	73	.9012
March 11, 1975	45	26	.5778
March 13, 1975	40	25	.6250
March 13, 1975	49	35	.7143
March 15, 1975	32	1	.0312
March 15, 1975	25	7	.2800
March 18, 1975	30	7	.2333
March 18, 1975	60	36	.6000
March 31, 1975	51	45	.8824
March 31, 1975	40	9	.2250
March 31, 1975	61	42	.6885
March 31, 1975	138	289	2.0942
April 1, 1975	60	18	.3000
April 1, 1975	72	93	1.2917
April 1, 1975	40	4	.1000
April 3, 1975	120	62	.5166
April 5, 1975	86	158	1.8372
April 6, 1975	40	70	1.7500
April 8, 1975	42	30	.7142
April 8, 1975	60	11	.1833
April 12, 1975	123	75	.6098
April 15, 1975	60	4	.0667
	1570	1167	.7668

The following is a hypothetical Part II of the recording form indicating the 6 dance types that the author determined were roles of crane dancing: emotional outlet, aggression-related activity, courtship display, response to possible danger, pre-flight and pre-walk communication. The dances are recorded in a long form and on an abbreviated form adopted by the author as the study progressed.

DESCRIPTION OF DANCES

Bird A flapped and jumped twice and then ran around Bird B with small steps. Bird A then threw sticks into the air. Birds A and B then alternated jumps; A stopped jumping, but B jumped one more time. Both birds bobbed their heads, alternating the bobs with sigmoid neck postures. Bird A "craned" its neck and appeared to sing for about 10 seconds. Both birds returned to grazing. The dance sequence lasted longer than 30 seconds, but less than 60. [A f + j 2x, A small steps B, A sticks. AB alt. j, B j. AB alt. bob and sigmoid. A sing 10 secs. (b)].

Bird A flapped twice, then it flapped and jumped into the air. After a pause of 10 seconds, it flapped and jumped twice, running to a point about 15' outside of the flock. It jumped one more time and then returned to grazing. The dance sequence lasted between 30 and 60 seconds. [A f 2x, A f + j, 10 secs., A f + j 2x, flock ↔ 10'. j. (b)].

Bird A pecked at Bird B; the latter flapped and jumped into the air and then ran about 10' from Bird A. The sequence lasted less than 30 seconds. [A → B, B f + j, B → 10'. (a)].

Bird A flapped and jumped into the air three times. After a pause of 5 seconds, Bird A and 4 other birds flew from the flock and out of the sight of the observer. The dance sequence lasted less than 30 seconds. [A f + j 3x, 5 secs., A + 4 fly. (a)].

Bird A flapped and jumped. Immediately Bird A and 35 birds walked 35' to the west of the flock and began grazing. The sequence lasted longer than 60 seconds. [A f + j, A + 35 walk → 35' W. (c)].

As the observer's car approached, all birds within 100 yards of the road flew away; 15 birds remained flapping and jumping for more than 30 seconds. [Car, all < 100 yards fly, 15 f + j 30 secs. (b)].

Supplementary recording sheets were used to record only the individual dancing section. A change in the first section required using Parts I and II, e.g. abrupt wind changes, commencement of precipitation, or large additions to the flock.

RESULTS AND DISCUSSION

The dance frequency at each of the 27 sites was determined by dividing the total number of dances by the time spent at each site. The word "dance" was used to describe a particular action of the Sandhill Cranes, specifically the act of leaping into the air and flapping the wings. This definition was the same as that used by Keith (1962) when describing a similar activity of the Japanese Crane (*Grus japonensis*). In the preceding section, the dances were referred to as "f + j" in the author's notation. By Keith's definition, each "f + j"

was actually a dance, such that if 6 cranes flapped and jumped, then 6 dances occurred. However, in this study, each individual bird was not counted, but rather the entire dance sequence was referred to as one dance with one-to-several participants. The number of dance sequences observed was 1,167, but the total number of participants was more than 5,000.

Each of the dance sequences was classified as one of 6 dance types: courtship (Type I), emotion or tension-release (Type II), aggression-related (Type III), pre-flight communication (Type IV), pre-walk communication (Type V), and a response to possible danger (Type VI). The dance types will be discussed separately following a review of the factors affecting all the dances collectively.

The frequencies of the 27 sites were correlated with 19 variables by a forward selection step-wise multiple regression analysis (IBM, 1975). The simple linear correlation of each variable to the dance frequency is shown in Table 2. It was considered unlikely that a single factor would be the sole primary predictor of dance frequency; therefore, in order to determine the importance and selection order of the independent variables, a forward selection step-wise regression was considered appropriate. The variables were adapted for computer programming as follows:

1. dependent variable: dance frequency (f = dances/minute of observation).
2. date: March 6, 1975 = 1 to April 15, 1975 = 40.
3. latitude: degrees, minutes, and seconds were converted to degrees.
4. longitude: same method as latitude.
5. distance from the nearest road: in yards. Observations were always from the nearest road to the flock, but not necessarily from the nearest point on that road.
6. time of day: 9:00 A.M. = 0 to 7:00 P.M. = 660.
7. alfalfa field: 1 = yes, 0 = no.
8. corn stubble field: 1 = yes, 0 = no.
9. pasture: 1 = yes, 0 = no.
10. temperature: 15° = 0 to 52° = 37.
11. precipitation: 1 = yes, 0 = no.
12. cloud cover: 0% to 100%.
13. wind direction: in degrees.

14. wind speed: 0 = 4 mi/hr to 11 = 15 mi/hr.

15. flock size: number of cranes.

16. relative density: 0 = well-spaced to 3 = dense.

17. middle of field: 1 = middle, 0 = nearer perimeter than middle.

18. rectangular flock shape: 1 = rectangular, values from 0 to 1.

19. barbell flock shape: 1 = barbell shape, values from 0 to 1.

20. circular flock shape: 1 = circular flock shape, values from 0 to 1. There were 18 different shapes for the 27 sites, but they were encompassed by these 3 forms.

The simple linear correlations indicated separately the relationships of the 19 variables to the dance frequency. For example, variable 16 had a relatively high correlation, .468; variable 4 had a low positive correlation, .025; and variable 11 had a negative correlation, -.145. One would deduce from these values that density and precipitation were relatively more important in explaining dancing than longitude; that is, as the relative density increased or as the precipitation decreased, the likelihood of dancing increased.

When the observed values for both the independent and dependent variables were entered into the regression, the resulting correlation coefficient was .772. The order of variable selection is included in Table II.

The multiple regression analysis provided two analyses of the effect of the variables upon dance frequency. Without mathematical transformations, it provided an index of the relationship of the interaction of the 19 variables to the dance frequency. The multiple correlation coefficient indicated the combination of variables that affected the observed activity, providing an initial assessment of the primary factors which accounted for the dancing. By transforming the variables mathematically, a more accurate predictor of dance frequency was developed. The better model was attained by deleting the least important predictors in the initial trial and entering higher order terms of the selected predictors, such as square roots, squares, and natural logarithms (Table III). Introduction of these terms permitted the development of an equation that better approximated the actual dance frequency. The partially transformed data yielded a multiple correlation coefficient of .972.

Fritts (1960), in discussing the validity of the step-wise multiple regression analysis for analyzing field observations, stated that beyond predicting the dance frequency, transformed variables afford some indication of those factors that

Table II:
Simple Linear Correlations of the 19 Untransformed Variables to the 6 Dance Types
And to all the Dances Collectively

Variable	Dance Types						All Dances
	I	II	III	IV	V	VI	
1*	Dependent Variable: Dance Frequency						
2	-.313(3)**	.453(2)	.326(2)	-.132(3)	-.036(15)	.108(10)	.333(2)
3	-.007(10)	.212(15)	.096(8)	.028(8)	.260(11)	-.490(1)	.124(6)
4	.276(14)	-.154(14)	.077(15)	.124(11)	-.254(10)	-.210(9)	.025(14)
5	.083(8)	.010(13)	.244(3)	.147(7)	-.291(3)	-.341(4)	.189(7)
6	.331(17)	.526(1)	.235(4)	.140(13)	-.152(16)	-.110(17)	.360(11)
7	-.202(19)	-.252(18)	-.232(9)	-.188(2)	.114(8)	-.206(7)	-.276(13)
8	.207(5)	.114(19)	.003(17)	-.025(12)	-.342(19)	-.076(18)	.042(17)
9	-.104(18)	-.024(12)	.130(16)	.134(14)	.296(12)	.199(5)	.114(18)
10	.010(4)	.331(7)	.218(7)	.063(10)	.071(18)	.052(13)	.255(15)
11	-.145(6)	-.113(4)	-.159(18)	-.096(5)	.135(5)	-.075(6)	-.165(19)
12	-.201(13)	-.191(3)	-.283(10)	-.010(9)	-.246(9)	.230(12)	-.296(4)
13	.110(11)	-.144(5)	.006(19)	.081(15)	-.394(1)	-.096(19)	-.072(9)
14	-.049(8)	.315(9)	.148(14)	.202(4)	.136(2)	-.158(15)	.154(8)
15	.303(7)	.073(8)	.150(12)	.259(1)	-.051(6)	-.374(3)	.158(10)
16	.573(1)	.334(6)	.434(1)	.233(17)	-.141(4)	-.341(11)	.468(1)
17	.238(12)	.189(10)	.093(13)	-.016(16)	.090(13)	.467(2)	.124(12)
18	-.300(14)	-.160(17)	-.194(11)	.139(19)	.136(17)	-.047(16)	-.237(16)
19	.371(2)	-.101(11)	.163(5)	.049(18)	-.047(7)	-.190(14)	.159(5)
20	.020(16)	.298(16)	.164(6)	-.198(6)	-.137(14)	.150(8)	.414(3)

* The variables are listed according to explanation in the Results and Discussion section.

** In parenthesis is the selection order of the variables by the regression analysis.

were the most influential in controlling the activity. Only 5 variables and their transformations and 4 untransformed variables were selected to provide the .972 correlation coefficient. Thus, factors indicated as being primary predictors of dancing were relative density, distance to the nearest road, date, time of day, temperature, flock size, barbell flock shape, and a central position in a corn stubble field.

The selection of 8 of these 9 variables was not unex-

pected since the simple linear correlation coefficients of all except corn stubble was greater than .158. Corn stubble was highly correlated with density and the distance to the nearest road which could account for its selection.

The same variables used in the first analysis were used in a step-wise multiple regression analysis for each of the 6 dance types. Table 4 lists the dance frequency for the 6 dance types for each site.

Table III:

Simple Linear Correlations of the Transformed and Untransformed Variables for the 6 Dance Types
And all the Dances Collectively

Variable	Dance Types						All Dances
	I	II	III	IV	V	VI	
(2)*	-.181(3)**	.247(6)	.232(20)	-.134(9)	-.131(3)		
(2) ^{1/2}	-.299(9)	.451(2)	.363(2)				.373(2)
(2) ²	-.321(6)	.410(10)	.244(21)				.252(14)
(2) ³		.342(9)					.170(12)
(3)						-.490(4)	
(5)	.083(*)		.329(5)		.341(5)	-.341(12)	.189(17)
(5) ^{1/2}	.079(10)		.199(11)	.176(8)			.150(18)
ln(5)			.155(12)	.200(14)			.112(*)
1/(5)			-.076(*)	-.225(15)			-.045(*)
(5) ²	.093(11)		.244(6)	.043(7)			.264(5)
(5) ³						-.270(5)	.330(4)
(6)		.526(19)	.235(15)				.360(3)
ln(6)		.281(5)	.184(16)				
(6) ^{1/2}		.412(13)	.217(7)				
(6) ²		.656(1)					
1/(6)		.089(18)	.100(10)				
(7)					.114(10)	-.206(15)	
(8)	.207(5)		.003(13)				.042(9)
(9)					.296(8)		
(10)	.010(12)	.331(7)	.218(17)	.063(*)			.255(16)
(10) ^{1/2}	.082(4)						.186(15)
(10) ²				.042(11)			.313(13)
(10) ³				.101(10)			.338(11)
(11)	-.145(7)	-.113(8)		-.096(*)	.135(12)	-.075(9)	
(12)		-.191(*)		-.010(16)			-.296(*)
(13)		-.140(11)	.006(18)		-.394(1)		
(13) ^{1/2}					-.386(*)	-.063(8)	
ln(13)					-.368(*)		
(13) ²				.152(*)	-.376(*)		
(13) ³				.203(12)	-.334(*)		
1/(13)					.324(4)		
(14)	-.049(*)	.315(*)	.148(19)	.202(*)	.136(2)		

Table III (Continued)

Variable	Dance Types						All Dances
	I	II	III	IV	V	VI	
(14) ^{1/2}				.126(6)			
(14) ²				.164(18)			
(14) ³				.286(3)			
(15)	.307(*)	.073(12)		.259(13)	-.051(16)	-.374(14)	.158(10)
(15) ^{1/2}		.141(16)		.314(*)	-.021(11)	-.363(6)	
ln(15)	.383(8)	.216(17)		.345(1)	.018(9)	-.302(1)	
1/15		-.304(14)		-.311(17)	-.083(7)	.076(3)	
(15) ²	.164(14)			.140(4)	-.084(15)	-.333(13)	
(15) ³				.048(2)	-.098(14)		
(16)		.334(4)	.434(14)		-.140(6)		
(16) ^{1/2}	.573(1)	.364(3)	.421(3)			-.346(11)	.469(2)
(16) ²	.482(18)	.267(*)	.452(4)			-.322(10)	
(16) ³		.207(15)	.460(1)				.423(6)
(17)					.096(17)	-.467(2)	.124(8)
(19)			.164(8)		-.047(13)		.159(7)
(20)			.163(9)	-.198(5)		.150(7)	
a	.860	.907	.745	.831	.731	.873	.963
b	.048	.075	.284	.016	.012	.010	.161

* The numerals upon which the transformations are being performed refer to the explanation in the Results and Discussion Section.

** In parentheses, following the correlation coefficients, is the selection order of the variable by the step-wise multiple regression analysis. Variables rejected at a constant to limit variables = .001 are denoted by an asterisk (*).

a Final multiple correlation coefficient adjusted for degrees of freedom.

b Standard error of estimate.

Table IV:

Frequencies and Percentage of Total Dances
of the 6 Dance Types

Site	Dance Types					
	I	II	III	IV	V	VI
1	.0500	.0000	.0000	.0000	.0000	.0000
2	.2727	.0750	.0008	.0909	.0000	.0000
3	.0357	.1964	.1964	.0178	.0357	.0178
4	.0000	.0333	.0000	.0000	.0333	.0000
5	.0345	.0345	.0345	.0000	.0000	.0690
6	.3210	.0864	.4815	.0123	.0000	.0000
7	.1111	.0889	.3111	.0667	.0000	.0000
8	.2000	.1500	.2250	.0500	.0000	.0000
9	.2449	.1428	.3265	.0000	.0000	.0000
10	.0000	.0000	.0312	.0000	.0000	.0000
11	.0400	.0800	.1200	.0000	.0000	.0400
12	.0000	.0667	.0333	.0667	.0333	.0333
13	.2000	.1167	.2500	.0000	.0333	.0000
14	.0588	.1765	.5686	.0196	.0588	.0000
15	.0500	.0750	.0750	.0000	.0000	.0250
16	.0820	.2131	.2951	.0820	.0000	.0164
17	.1304	.3913	1.5362	.0217	.0145	.0000
18	.1000	.0000	.2000	.0000	.0000	.0000
19	.0278	.3472	.8889	.0000	.0000	.0278
20	.0000	.1000	.0000	.0000	.0000	.0000
21	.0250	.2500	.2083	.0083	.0278	.0139
22	.1628	.4186	1.2210	.0116	.0116	.0116
23	.1250	.7750	.7750	.0250	.0250	.0250
24	.0714	.2143	.3810	.0000	.0000	.0476
25	.0000	.0667	.0000	.0167	.0000	.0500
26	.0488	.2846	.2764	.0000	.0000	.0000
27	.0000	.0500	.0167	.0000	.0000	.0000
Total	.0928	.2039	.4389	.0151	.0099	.0112

Percentage of total number of dances:

I	12.08
II	26.56
III	56.64
IV	1.97
V	1.28
VI	1.46

Type I. Courtship Dances

Allen (1932), speaking for Sandhill Cranes, said "We feel some strange desire to dance as the nesting season approaches" and "in these dances there is no prize and no winner, and they are in no sense a marathon, but we dance merely for the pleasure it gives us to demonstrate to others of our kind our superior abilities." This bit of teleology captures the predominant interpretation of crane dancing through the years, a courtship display for pair-formation and bond-cementing.

Keith (1962) described a generalized courtship dance as including head-bobbing, sigmoid neck postures, flapping and jumping, and perhaps a dance flight. Keith was discussing the Japanese Crane, but the display is not unlike that of the Sandhill Crane. Two other components of the courtship dance were stick-throwing and duet calling. Often in courtship displays, one of the two cranes would pick up a stick, corn cob, or other available material and throw it into the air. Keith explained this behavior as a possible conflict between two drives or as an action related to nest building due to the bird's heightened emotional state and the presence of suitable nesting materials. The duet was often seen after a particularly intense dance by the two birds. Often, it involved both birds calling simultaneously; sometimes just the bird that initiated the dance sequence called. The duet calling was commonly followed by a return to grazing. The first dance included in the dance description section was an actual sequence that contained several of the gestures described by Keith.

Of the 6 types of dances, courtship was the third most common in number and frequency—141 dances and a frequency of .0928.

Interpretations of the simple linear correlations indicated that courtship dances were more likely to occur in dense, irregular-shaped flocks as the day progressed. The flock size was relatively important, perhaps providing, in larger flocks, an increased opportunity for bond-attempting interactions. The dance frequency was negatively correlated with the date, indicating that the amount of this type of dancing decreased as the migratory season progressed.

The circular and barbell flock shapes were generally mid-field shapes appearing not to have been influenced by surrounding physical features, such as fencerows and creeks. Rectangular flocks were more often formed by the boundaries of the field or were linearly arranged near the side of a field along a hedgerow or shelterbelt. The Type I dance frequency was positively correlated with the first two shapes and negatively with the latter, indicating that the cranes tended to court near the center of the field. A more direct interpretation leading to the same conclusion is that courtship dances were correlated positively with flock positioning in the middle of the field.

The variables temperature, density, date, flock size, and distance to the nearest road were transformed and selected by the program in the second regression analysis as primary predictors of courtship dance frequency, along with barbell flock shape, corn stubble, and precipitation.

Type II. Emotion or Tension-release Dances

There were several dances in which the cranes appeared to be dancing without a stimulus. The author felt justified in classifying these dances as tension-release dances because of the lack of observable stimuli and because of documentation by other observers. Keith (1962) quoted R. Allen as stating that mating-season increases in dance behavior might have been due to a nervous and emotional condition brought about by a seasonal development of the gonads. This hormonal condition resulted in a lowered threshold in spring that might have been triggered without a stimulus. This type of *in vacuo* activity, according to Wallace (1973) occurred in cases where a pattern had become ritualized. It is quite likely, therefore, that the ritual courtship display of the Sandhill Crane often manifested itself as an emotional outlet at apparently inappropriate times without a stimulus.

Type II dances often involved large sections of a flock. Brooks and Allen (1937) wrote that many times 6 to 8 cranes would climb to the top of a hill and have an "old-fashioned barn dance." The largest number of cranes observed by the author in an infectious communal dance was 15. There were several cases in which a car would come near the flock and 2 or 3 birds would begin dancing followed within seconds by several hundred other cranes dancing. In this study, these dances were considered as Type VI and not Type II dances. The correlation of Type II dance frequency to the distance to the nearest road supported this contention since this dance type had a very small positive correlation. This indicated that the distance to the nearest road and vehicle interference were not stimulatory. In Table II, high positive correlations to date and time are shown, indicating that this kind of dance increased both during the day and during the migration period.

Since there was a rather high positive correlation to circular flock shape and a large negative correlation to rectangular flock shapes, one would have expected a relatively high positive correlation to positioning in the middle of the field, which was the case. The field type did not seem to have a stimulating effect, but in the case of alfalfa, not a common feeding area, it was possibly limiting.

Time, date, cloud cover, precipitation, wind direction, wind speed, relative density, temperature, and flock size were selected as variables to be entered into a series of regressions. Cloud cover and wind speed were rejected at the limit imposed; therefore, the 7 remaining variables and their transformations were selected as primary predictors with a standard error of estimate of .075. The importance of relative density and flock size as primary predictors might indicate that the author was unable to recognize stimuli detected by the cranes.

Type III. Aggression-related Dances

Keith (1962) stated that when Japanese Cranes came together in a flock, a good deal of aggressive behavior took place and there was obviously some established hierarchy among them. These cranes displayed, in a manner similar to that of the Sandhill Cranes, either an "arched-over" or an "arched-under" posture, both of which showed the red crown patch of the aggressor to the aggressed. This posture was often observed in the aggressive encounters of the Sandhill Cranes. Both Keith (1962) and Walkinshaw (1949) stated that they never saw the aggressor unsuccessful, i.e., the aggressed crane failed to run away or it turned on the aggressor. This author found the aggressor to be successful in many cases but, by no means, all cases. In some cases, Bird A would chase Bird B in an arched-under posture; Bird B would run about 10', turn, and return at Bird A with the same posture, chasing it away.

Farrar (1975) wrote that the cranes generally kept just beyond the striking range of their neighbors. This seemed to be the case with the observed birds since there was a high correlation between relative density and the aggressive dance frequency (.434). Nearly 57% of all the dances were aggression-related. Type III dances increased as the day and migration period progressed, as the flock became more crowded, and as the temperature increased. Density was clearly a contributing factor since, in many instances, a crane would dance or lunge at another crane which would jump from the first crane's striking range. This would begin a series of lunges at the original aggressed bird by several other birds when it apparently entered each of their individual territories.

In the final regression, the highest adjusted value for the number of degrees of freedom was after the twelfth step. Therefore, the 6 variables providing the most accurate estimate of Type III dance frequency were relative density, date, time, distance to the nearest road, circular and barbell flock shapes.

Type IV. Pre-flight Communicatory Dances

There is little information concerning the communication activity of Sandhill Cranes. Walkinshaw (1949) wrote that the birds would begin dancing at dawn, and the frequency would increase until about 7:30 A.M. when the birds would leave the roosting area for the feeding areas. Twenty-three of the dances observed involved the dancing of 1 or 2 birds which were joined by as many as 15 birds. In no case did more than the original bird(s) dance, but the action was continuous. The birds, upon stopping their dancing, would take 2 or 3 steps and fly away with the remainder of the non-dancers. Each time, the birds flew from the flock and out of the view of the observer.

In the 23 Type IV dances, most took place on pasture areas that were not primary feeding areas. In observation number 23—the only evening observation—5 of the 70 dances

were Type IV. It appeared that these dances—more than 20% of all Type IV dances—were for birds going to the roosting areas.

All simple linear correlations were less than .300. It should be noted that other than the birds dancing in response to the author's car, no dances were recorded for the first 10 minutes at each site. Thus, one would not expect the distance to the nearest road to be a limiting factor, such that all dances could be explained as responses to the observer's recent approach.

In the final regression, 8 variables and 14 transformations provided an equation with a standard error of estimate of .024. The factors selected were flock size, wind speed, circular flock shape, distance to the nearest road, date, temperature, wind direction, and cloud cover.

Type V. Pre-walk Communicatory Dances

The action of this dance type was similar to that of the Type IV dances, i.e., usually only 1 or 2 birds danced, but these birds were joined by a larger group of between 5 and 50 birds. Generally, the birds walked to the periphery of the flock and remained there or walked beyond it up to 50'.

In both pasture and alfalfa fields, which were not primary grazing areas, the cranes most commonly exhibited Type V dance behavior; whereas, this behavior was rarely observed in disced corn fields. This dance type occurred only 15 times, but it was quite unmistakable. In one example, a single bird jumped several times, nearly circling its small flock of 26 other birds. As soon as it stopped dancing, the 27 birds walked approximately 50 yards to the other side of the field. The flock continued grazing for 40 minutes before 15 cranes landed near them and the original 27 flew away.

This was the only dance type positively correlated with precipitation. There was a relatively high negative correlation to the distance to the nearest road, indicating the dances occurred more commonly near the road than the center of the field. It is possible that despite the 10 minute adjustment period the birds, after a time, walked away from the observer's position. In only 2 cases, the cranes walked from the flock to a point nearer the observer, and both times the original distance to the observer was greater than 250 yards.

Eleven variables and transformations provided a multiple correlation coefficient of .906 with a standard error of estimate of .012. Wind direction, flock size, and their transformations contributed 8 of the 17 predictors; the other 9 predictors (wind speed, distance to the nearest road, relative density, alfalfa, pasture, precipitation, barbell flock shape, date, and position in the field) were not transformed.

It is interesting to note that flock size had a simple linear correlation of only .051, yet it was selected as a primary

predictor for this dance type. This variable correlated highly with density (.410) and precipitation (.513), and as Fritts (1960) stated, it is often the interrelation of variables that accounts for the most accurate multiple regression correlation coefficient.

Type VI. Response to Possible Danger Dances

Farrar (1975) quoted P. Johnsgaard as saying that Sandhill Crane dances might be a response to agitation by man. In this study, however, cranes only responded to the approach of the observer's car by dancing in 12 of 27 cases. This would appear to remove man as the sole factor.

Apparently cranes became habituated to vehicles rather rapidly. The simple linear correlations indicated that one would expect birds in the southeast portion of the study range to dance less frequently in response to vehicles as possible danger. The sites in the southeast quadrant were most often along Nebraska Highway Link 40C in Hall County, a more travelled road than the county roads running north from Nebraska Highway Link 50A in Kearney County. The birds danced more commonly in response to cars in Kearney County; this was the case in 11 of the 17 dance sequences.

When the cranes were within approximately 150 yards of the road, they would dance and then fly—or fly immediately; whereas, those cranes beyond this distance did not appear to react to the car's approach. If birds were nearer the perimeter of the field, they were more responsive to possible danger stimuli, dancing in different cases when approached by cars, tractors, dogs, and even a flock of Canada Geese. There was one observation on the last day of the study period where the author was able to park no more than 75 yards from a flock of cranes in corn stubble.

Following a series of transformations, 9 variables plus transformations were selected as primary predictors: flock size, field position, latitude, distance to the nearest road, circular flock shape, wind direction, relative density, precipitation, and alfalfa.

DANCE INTENSITY AND FREQUENCY

Intensity is defined as the time, in seconds, per dance sequence. The intensity classifications were a = less than 30 seconds, b = between 30 and 60 seconds, and c = more than 60 seconds. In Table V the dance classes are listed for each of the dance types as well as all of the dances collectively; whereas, in Table VI, the dances are grouped according to the dates of observation. Of the total dances, 92.37% lasted less than 30 seconds; and of these, 86.5% were Type II and Type II dances which generally involved only 1 or 2 birds.

It was quite uncommon for a dance to last longer than 60 seconds (19/1167, 1.63%). In both Type V and Type VI dances, the duration included the time spent walking away

Table V:

Dance Intensity (Duration) for the 6 Dance Types

Dance Type	Intensity Classes						Total Number of Dances
	a*	% of "a" Dances	b	% of "b" Dances	c	% of "c" Dances	
I	118	10.95	18	25.71	5	26.32	141
II	290	26.90	15	21.43	5	26.32	310
III	643	59.65	15	21.43	3	15.29	661
IV	12	1.11	9	12.86	2	10.53	23
V	10	.93	3	4.28	2	10.53	15
VI	5	.46	10	14.28	2	10.53	17
Total	1078		70		19		1167
% all dances		92.37		6.00		1.63	

* a = less than 30 seconds.

b = between 30 and 60 seconds.

c = more than 60 seconds.

from the flock or potential danger. Thus, the time consumed was not always spent in actual dancing. In no case was Allen's (1932) "several hours continuous dancing" observed; although at observation site No. 17, the dance frequency (2.0942) indicated that the birds remained quite active for the 138 minutes of observation. However, the dances did not seem to be interrelated, nor did they appear to be of the infectious type exclusively.

Five courtship dances were observed that lasted more than a minute. These dances were quite involved, employing many of the gestures discussed previously. However, neither the number nor the intensity was that expected after reviewing the previously published literature.

According to Keith (1962), the Japanese Crane began dancing more frequently as migration approached and continued with increasing agitation until nesting time. Farrar (1975) stated that the Sandhill Cranes began elaborate displays during the migratory period nearly 2 months prior to the actual nesting period. Thus, one might expect an increase in the frequency and intensity of dances as the cranes became

sexually aroused. The increase was quite substantial in the second period over the first, particularly for Type II and Type III dances. If proper stimuli were not present, an inappropriate display might have been manifested *in vacuo*, or if the proper stimuli were present, possibly the reaction was an increased number of protective dances of individual territory.

The frequency of Type I dancing decreased during the second period. Possibly because bonds were completed, emotional dances were performed for bond maintenance, i.e., Type III dances were actually protection for newly formed or revowed pairs.

The frequency for Types IV, V, and VI dances remained nearly the same for both periods. The dance frequency of the cranes increased as the breeding season neared, primarily due to the increased frequency of Type II and Type III dances. The intensity decreased during the same period for primarily the same reason, an increase in "a" class dances for Types II and III. However, in all dance types, except Type V, there was an increase in the shorter dance sequences and a decrease in the longer.

Table VI:

Intensity and Frequency for the Two Observation Periods

Dance Type	Intensity Classes and Frequency						Total Number of Dances
	a	f	b	f	c	f	
I *	57	.099	11	.019	3	.005	71
**	61	.061	7	.007	2	.002	70
II *	47	.081	5	.009	2	.003	54
**	243	.245	10	.010	3	.003	256
III *	102	.177	4	.007	3	.005	109
**	541	.545	11	.011	0	.000	552
IV *	6	.010	4	.007	0	.000	10
**	6	.006	5	.005	2	.002	13
V *	3	.005	1	.002	2	.003	6
**	7	.007	2	.002	0	.000	9
VI *	0	.000	3	.005	2	.003	5
**	5	.005	7	.007	0	.000	12
Total *	217	.376	28	.048	12	.021	257
**	861	.867	42	.042	7	.007	910

* March 6, 1975, to March 18, 1975. 577 minutes of observation, 13 sites.

** March 31, 1975, to April 15, 1975. 993 minutes of observation, 14 sites.

f = frequency

a = less than 30 seconds

b = between 30 and 60 seconds

c = more than 60 seconds

CONCLUSIONS

The dances of the Lesser Sandhill Cranes during their spring migration were divided into 6 types: courtship display (I), emotion or tension-release activity (II), aggression-related dance (III), pre-flight (IV) and pre-walk (V) communication, and response to possible danger (VI).

Primary factors affecting dance frequency were determined by analysis of simple linear correlations and untransformed and transformed variables selected by a step-wise multiple regression analysis. Variables selected as primary predictors included:

- Type I: temperature, relative density, date, flock size, distance to the nearest road, barbell flock shape, precipitation, and corn stubble.
- Type II: time, date, relative density, distance to the nearest road, precipitation, wind direction, flock size, and temperature.
- Type III: relative density, date, distance to the nearest road, time, circular and barbell flock shapes.
- Type IV: flock size, wind speed, wind direction, distance to the nearest road, cloud cover, and circular flock shape.
- Type V: flock size, wind speed, wind direction, distance to the nearest road, circular flock shape, relative density, pasture, alfalfa, precipitation, and middle of the field.

- Type VI: flock size, wind direction, middle of the field, latitude, distance to the nearest road, circular flock shape, relative density, precipitation, and alfalfa.
- All relative density, distance to the nearest Dances: road, circular flock shape, date, time, flock size, and corn stubble.

The intensity (duration) of each dance was recorded. As the migratory season progressed, the dance frequency increased, whereas, the intensity decreased. This was primarily due to an increase in Type II and Type III dances of which nearly 97% lasted less than 30 seconds.

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A TAXONOMIC INVESTIGATION OF SOME RHIZOMATOUS SPECIES OF THE GENUS *MUHLENBERGIA* (GRAMINEAE)

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Seven species of the grass genus *Muhlenbergia* were studied using gross morphological and anatomical characters. The anatomical criteria proved to be of limited taxonomic value. A key to the species of the east-central plains was developed.

† † †

INTRODUCTION

The genus *Muhlenbergia* is a large, widely distributed group of grasses, encompassing numerous species and various growth forms. The subgenus *Muhlenbergia*, comprised of mesic, broad-leaved, usually rhizomatous species, can easily be separated from the rest of the genus on the basis of growth habit and habitat preferences (Pohl, 1969). Species of the subgenus are widely distributed in North America but are most abundant in the deciduous forests of the eastern part of the continent. All of the species included in this study are perennials and possess well-developed scaly rhizomes. Seven species were studied: *M. bushii* Pohl, *M. frondosa* (Poir.) Fern., *M. mexicana* (L.) Trin., *M. racemosa* (Michx.) B.S.P., *M. sobolifera* (Muhl.) Trin., *M. sylvatica* (Torr.) Torr. and *M. tenuiflora* (Willd.) B.S.P.

Morphological similarity among members of the subgenus makes them difficult to separate using conventional taxonomic characteristics. The intent of this study is to explore these taxonomic difficulties using both anatomical and gross morphological characters.

METHODS AND MATERIALS

The majority of the plants used in this study were collected from an area which included seven southeastern Nebraska counties and two southwestern Iowa counties; field collections were made from August through mid-October, 1975. Additional specimens used were borrowed from the University of Nebraska-Lincoln herbarium.

All measurements of 10 mm or less were made with a stereoscopic binocular microscope with an ocular micrometer calibrated to 0.1 mm intervals. Lemma, glume, and anther measurements were obtained from mature spikelets. The larger basal leaves were chosen for ligule measurements and for making transverse sections of the blade and sheath. Blade sections were taken at a point midway between the tip of the blade and ligule; sheath sections were taken from a point not

more than 1.0 cm below the ligule. Sections were made free-hand from both fresh material and herbarium specimens; dried leaves were soaked in a softening solution (Pohl, 1965). Hoyer's solution was used to clear the sections and also as a mounting medium (Humason, 1972). Cellulose acetate casts were made to study epidermal characteristics (Payne, 1968).

RESULTS AND DISCUSSION

Anatomical Characters

Epidermal leaf anatomy and transverse blade anatomy proved to be of limited taxonomic value. Only minor differences were noted among the species. Transverse sheath anatomy provides a reliable character to separate *M. mexicana* and *M. sylvatica* since it clearly shows the degree to which the sheath is keeled (Fig. 1). *M. mexicana* has prominently keeled sheaths in contrast to the rounded sheaths of *M. sylvatica*.

Species Differences and Key Characters

Comparisons between certain species pairs were made using ligule, anther, lemma, and glume measurements. The species pairs selected were chosen because of their similarity to each other or because they tend to be paired in the keys.

M. mexicana – *M. sylvatica* (Table I):

These species are difficult to separate and have often been confused, probably because two distinct forms of *M. mexicana* exist. The form with slender elongate inflorescences, not unlike those of *M. sylvatica*, is common in eastern Nebraska; while the typical form with dense lobulate inflorescences appears to be common in western Nebraska. Average ligule length of *M. sylvatica* is twice that of *M. mexicana*. The ligule of *M. sylvatica* also projects well above the summit of the sheath, in contrast to the ligule of *M. mexicana* which is barely visible from the side. Additional differences noted include: (1) mean anther length which is 50% greater in *M. sylvatica* than in *M. mexicana*; and (2) an abruptly keeled leaf sheath in *M. mexicana* in contrast to the rounded sheaths of *M. sylvatica*.

M. mexicana – *M. racemosa* (Table I):

Several characters are needed to separate these species.

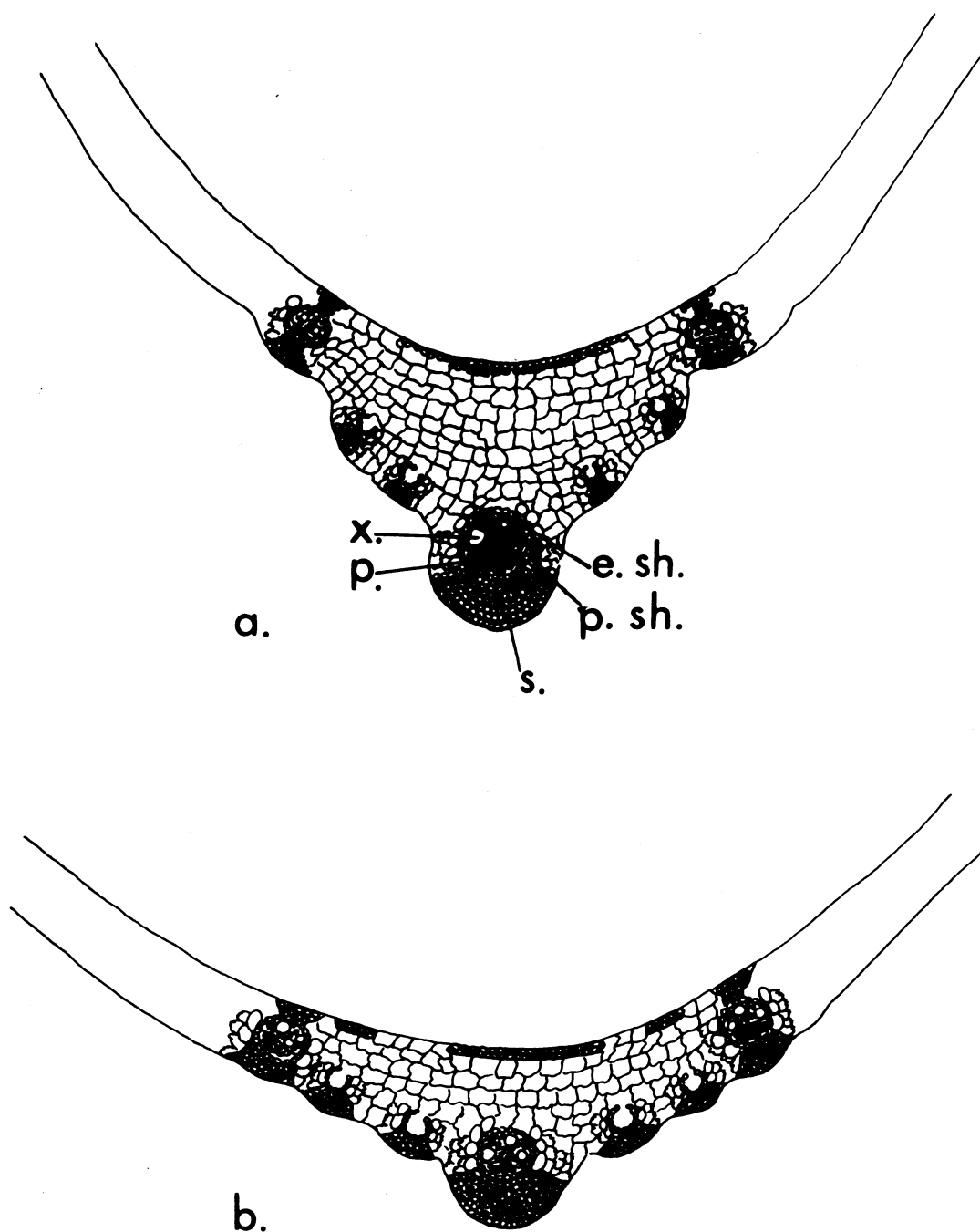


Figure 1. a) *M. mexicana* — cross section of sheath

x. — xylem

p. — phloem

e. sh. — endodermal sheath

p. sh. — parenchyma sheath

s. — sclerenchyma

b.) *M. sylvatica* — cross section of sheath

Table I:
Comparison of Species Using Six Key Characters
Lengths are Given in mm

	Ligule	Anther	Lemma	Glumes	Internodes	Panicles
<i>M. bushii</i>	0.2-0.8 $\bar{x} = 0.6$	0.3-0.6 $\bar{x} = 0.4$	2.4-3.3 $\bar{x} = 2.8$	1.5-2.4 $\bar{x} = 2.0$	smooth and shining	numerous included panicles
<i>M. frondosa</i>	0.8-1.5 $\bar{x} = 1.1$	0.3-0.6 $\bar{x} = 0.4$	2.8-3.5 $\bar{x} = 2.9$	1.9-3.2 $\bar{x} = 2.7$	smooth and shining	numerous included panicles
<i>M. tenuiflora</i>	0.4-0.9 $\bar{x} = 0.6$	1.1-2.2 $\bar{x} = 1.2$	2.9-3.4 $\bar{x} = 3.1$	1.5-3.0 $\bar{x} = 2.1$	puberulent	panicles long exserted
<i>M. sobolifera</i>	0.4-1.0 $\bar{x} = 0.6$	0.4-0.8 $\bar{x} = 0.7$	1.7-2.1 $\bar{x} = 1.9$	1.3-2.0 $\bar{x} = 1.6$	smooth and shining	panicles long exserted
<i>M. sylvatica</i>	1.3-2.5 $\bar{x} = 2.0$	0.5-0.8 $\bar{x} = 0.8$	2.2-3.5 $\bar{x} = 2.6$	1.6-3.0 $\bar{x} = 2.0$	puberulent or glabrous	panicles long exserted
<i>M. mexicana</i>	0.4-1.2 $\bar{x} = 0.8$	0.3-0.6 $\bar{x} = 0.5$	2.0-3.1 $\bar{x} = 2.3$	1.5-2.8* $\bar{x} = 2.1$	puberulent	panicles long exserted
<i>M. racemosa</i>	0.6-1.5 $\bar{x} = 1.2$	0.5-1.0 $\bar{x} = 0.6$	2.3-3.5 $\bar{x} = 3.1$	4.0-6.0 $\bar{x} = 4.7$	glabrous to puberulent roughened	panicles usually exserted

*occasionally over 3.0

Individuals were occasionally encountered which were intermediate between the two species with respect to internodal pubescence and glume length. Recent keys indicate that *M. racemosa* invariably has smooth, shining internodes, but many individuals of this species were found to have puberulent, roughened internodes similar to those of *M. mexicana*. Furthermore, individuals of *M. mexicana* were encountered with relatively long awn-tipped glumes similar to those of *M. racemosa*. The following are valuable when atypical plants are encountered: (1) glumes of *M. racemosa* are much longer than the lemmas on all spikelets of a given plant. In *M. mexicana* glume length is more variable, not exceeding the lemmas in all of the spikelets; (2) anthers and ligules of *M. racemosa* are longer than those of *M. mexicana* although some overlap occurs; (3) the lemmas of *M. racemosa* are never awned in contrast to the occasionally awned lemmas of *M. mexicana*;

(4) grains of *M. racemosa* are usually longer than 1.5 mm, while those of *M. mexicana* are less than 1.5 mm.

M. bushii – *M. frondosa* (Table I):

Glumes and ligules of *M. frondosa* are much longer than those of *M. bushii*, but individuals were occasionally encountered which were intermediate with respect to these characters. Three other characters are valuable with such individuals (Mitchell, 1962): (1) the terminal panicle of *M. bushii* tends to be more exserted than in *M. frondosa*; (2) the leaves of *M. bushii* tend to be positioned at right angles to the stem, unlike those of *M. frondosa*; (3) the leaves of the side branches in *M. bushii* are relatively shorter and narrower than are the leaves of the main culm; such an obvious difference does not exist in *M. frondosa*.

M. sobolifera – *M. tenuiflora* (Table I):

These two species are usually paired in keys because each has short, broadly ovate glumes. Lemma and anther length are sufficient to separate the two.

Key

The following key was constructed using observations made in the course of this study combined with some of those characteristics used by Pohl (1969), Gleason and Cronquist (1965), Fernald (1943), and Mitchell (1962).

1. Glumes with stiff awn-tips, both one-third longer than the awnless lemma in the majority of the spikelets; anther 0.5 mm or longer; grain usually longer than 1.5 mm; internodes often smooth and shining, occasionally puberulent-roughened *M. racemosa*
Glumes awnless or awn-tipped, usually shorter than the lemma, occasionally longer; lemma awned or awnless; anthers, grain, and internodes variable. 2
2. Internodes of culm glabrous, sometimes slightly puberulent near the summit 3
Internodes of culm puberulent, especially near the summit 6
3. Plants with numerous axillary inflorescences, many of these included in the leaf sheath 4
Plants with few axillary inflorescences, but if present their peduncles long and exserted. 5
4. Glumes much shorter than the lemma, mostly under 2.2 mm; ligules 0.7 mm or less; leaves positioned at right angles to the stem, those of the secondary branches often shorter and narrower than the leaves of the main culm; terminal panicle often well exserted *M. bushii*
Glumes nearly as long as the lemma, the second sometimes exceeding the lemma; ligule 0.8 mm or more; leaves not conspicuously positioned at right angles to the stem and with little difference in size between the leaves of the branches and the main culm; terminal panicle not usually long exserted *M. frondosa*
5. Ligules conspicuous, 1.4-2.5 mm, projecting above the summit of the sheath, lemma 2.4 mm or more *M. sylvatica*

Ligules not conspicuous, 1.0 mm or less; lemma 2.2 mm or less. *M. sobolifera*

6. Glumes much shorter than the lemma, broadly ovate and overlapping; anthers longer than 1.0 mm *M. tenuiflora*
Glumes as long as the lemma (occasionally shorter), lanceolate, not overlapping; anthers 0.8 mm or less 7
7. Ligules conspicuous, 1.4-2.5 mm, projecting above summit of sheath; inflorescences slender; anthers 0.6-0.8 mm; leaf sheaths rounded *M. sylvatica*

Ligules not conspicuous, 1.2 mm or less; inflorescences from very dense and lobulate to very slender; anthers 0.5 mm or less; leaf sheaths abruptly keeled. *M. mexicana*

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PROPRANOLOL: A SPECIFIC ANTAGONIST TO SUB ACUTE COCAINE INTOXICATION

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INTRODUCTION

In the clinical treatment of over fifty cases of "over-dose" with cocaine, the authors have become aware of the strikingly specific antagonistic effects of propranolol HCl (Inderal^R) on the manifestations of central cardiovascular hypermetabolism.

Time after propranolol (min.)	Blood pressure (mm. Hg)	Pulse rate (min. ⁻¹)	Respiration (min. ⁻¹)
3	130/90	118	28
5	130/88	110	26
15	120/80	90	24
30	110/70	84	20

CASE-REPORT: A

The patient was a 28-year-old, well-developed, Caucasian blue-collar, outdoor, heavy laborer. Past medical history revealed childhood "asthma" and several episodes of childhood "pneumonia." There had been no further history of problems of this nature for over ten years. History of drug habits revealed a rather heavy intake of beer, consisting of from six to twelve bottles per day. When seen at a "rock concert" he reported that he had drunk over six bottles of beer that day, had smoked two "joints," and had just done two amyl nitrite "poppers." He appeared rather giddy, was pale, sweaty, and obviously intoxicated. He was reported to have just snorted several "lines" of "good coke" (translated here as 200 mg. cocaine), after which he became tremulous, nauseous, and faint. When initially seen, his blood pressure was 140/90 mm. Hg; his pulse rate was 130/min., and his respirations, 36/min. He was notably tremulous and anxious at this time. After a further two minutes, he was given 2 ml. of propranolol hydrochloride intravenously. Subsequent blood pressure readings and pulse and respiration rates 2 ml. (2 mgm.) of propranolol hydrochloride intravenously and 80 mgm. p.o. Subsequent blood pressure readings and pulse and respiration rates were:

He reported that he was much more relaxed but was still "high on coke." He was released to the care of his friends. At this time he appeared visibly calm, rational, and in control of his motor and sensory facilities. He was subsequently seen on several occasions in the crowd, dancing to the music, and apparently in need of no further medical intervention.

OBSERVATIONS: This patient was noted to reflect the typical lytic effects of Inderal on blood pressure and pulse as noted with other case reports. The Inderal appeared to have little effect on pupil size or upon degree of "wiredness". The patient remained quite active although not unduly apprehensive until about 1:20 A.M. at which time he retired and experienced a good night's sleep.

CASE-REPORT: B

The subject was a 34-year-old, white male who worked at heavy, outdoor labor. Past drug history revealed frequent marijuana and alcohol usage; his intake of beer was approximately six to twelve bottles a day; his intake of grass was about two to three joints per day. When seen, he was "hung over"; he had taken two joints of grass and about three or four beers that afternoon. He appeared slightly intoxicated. He gave

a past history of childhood asthma, which he stated he had overcome by his own will power. When first examined, he had been running on the beach and appeared somewhat out of breath and diaphoretic. At 6:10 P.M. when first examined, his BP was 160/90; his pulse was 100; his respirations were 32. At 6:12 he snorted 200 milligrams of cocaine. At 6:15 his BP was reported as 150/100; his pulse rate 120; his respirations were 32. At 6:25 his BP was noted as 120/70; his pulse rate, 120; his respirations were 30. At 6:33 his BP was noted as 140/76; his pulse rate, 120; respirations, 28. At 6:37 his BP was 140/100; his pulse rate, 120; his respirations, 28. At 6:38 he received 2 ml. of Inderal I.V. At 6:45 his BP was 126/90; his pulse rate was 100; his respirations were 28. At 6:50 his BP was 120/80; his pulse rate was 84; his respirations were 24. At 7 P.M. his BP, 120/80; his pulse rate was 84; his respirations were 24.

OBSERVATIONS: This patient would appear to have been slightly "out of shape" and slightly intoxicated with beer prior to the experiment. His personal observations were that it was "pretty good coke," but he missed the "wired" effect which contributed to his own subjective high.

CASE-REPORT: C

The subject was a 28-year-old, white male who worked as a heavy, outdoor laborer, but who displayed extreme craftsmanship with wood. Past medical history revealed a childhood asthma and several episodes of childhood pneumonia, which he stated were life-endangering. Current drug habits consisted of a rather heavy intake of beer, mainly in the evening and consisting of six to twelve bottles. When seen, he reported that over the last twelve hours he had drunk over six bottles of beer, had smoked two joints, and had done two amyl nitrite "poppers." He appeared rather light-hearted, but not euphoric and not intoxicated. At 6 P.M. in the resting state, his blood pressure was 130/90; pulse was 120; respirations, 14. At 6:04 he snorted 200 milligrams of cocaine. At 6:05, his pulse was 126. At 6:10 his blood pressure was 140/90; his pulse was 130; his respirations were 30. At 6:15 his BP was 130/94; his pulse rate, 140; respirations, 36. At 6:25 his BP was 140/90; his pulse rate, 140; his respirations, 36. At 6:29 his pulse rate was 135. At 6:30 he received 2 ml. of Inderal. At 6:32 his blood pressure was 130/90, his pulse 118, his respiration 28. At 6:35 his BP was 130/88, pulse rate 110, respirations 26. At 6:43 his BP was 120/80, his pulse rate 100, his respiratory rate was 26, he developed a "pounding headache". At 6:47 he received an additional 2 ml. of Inderal. At 6:50 his BP was reported as 120/80; his pulse was 96. At 6:50 his BP was 120/80; his pulse was 90; his respirations were 24. At 7 P.M. his BP was 110/72; his pulse was 84; his respiratory rate was 24.

OBSERVATIONS: At 7 P.M. the patient was noticed to be relatively relaxed, but reported subjectively that he was really "high" on "coke."

CASE-REPORT: D

The subject was a 26-year-old, white female who worked at a clerical job. Past medical history was unremarkable. Current drug intake consisted of daily alcohol and grass in moderate amounts. She reported having several beers and a joint that day, but did not appear in any way intoxicated. At 6:15 P.M. her BP was reported as 120/88; her pulse rate was 84; her respirations were 18. At 6:17 she snorted approximately 200 milligrams of cocaine. At 6:20 her BP was 130/90; her pulse rate was 100; her respirations were 28. At 6:25 her BP was 120/90; her pulse rate was 100; her respirations were 28. At 6:34 her BP was 120/70; her pulse rate was 80; her respirations were 26. At 6:40 she was to receive 2 ml. of Inderal. She expressed some apprehension at receiving an intravenous shot at that time. Her vital signs were: BP 120/80, pulse rate 120, respirations 28. At 6:41 she received 2 ml. of Inderal I.V. At 6:45 her BP was 110/80; her pulse rate was 84; her respirations were 24. At 6:52 her BP was 110/80; her pulse rate, 84; her respirations, 22. At 7 P.M. her BP was 110/70; her pulse rate, 80; her respirations were 18.

OBSERVATIONS: This subject felt that having her vital signs monitored took away somewhat from the pleasure of a cocaine high. She also reported that she was a cocaine snorter and that the appearance of the needle was very frightening to her.

CASE-REPORT: E

The subject was a 44-year-old unemployed artist of medium build and good general health. Drug habits included moderate alcohol intake and occasional marijuana in social situations. He was a non-smoker. At 6:05 P.M., blood pressure was noted to be 132/90; pulse, 64; respirations, 16. At 6:10 P.M. 200 milligrams of cocaine were taken by way of the nasal route. At 6:18 a blood pressure of 142/94, a pulse of 60, and respirations of 20 were noted. At 6:30 blood pressure was 142/98; pulse, 68; respirations, 24. The patient was noted to be euphoric, in a high and excited mood, and talkative. His feelings were reported to be sharp and alert. There was no nausea and no urge to defecate or urinate. At 6:40 the blood pressure was 148/94; pulse was 68; respirations, 26. At 6:50 the blood pressure was 150/96; pulse, 60; respirations, 20. The pupils were noted to be dilated to 6 millimeters. The hands were cold; feet were cold; and mouth was dry. At 6:55 an additional 100 milligrams of cocaine was taken by nasal route. At 7:00 P.M. the patient was noted to be jittery; a foot tapping was noted. A slight headache was reported. A non-intention tremor of the right hand was noted. At 7:05 blood pressure was 150/98; pulse was 60; respirations, 20. At 7:15 the blood pressure was 178/112; the pulse was 70. The patient reported that he felt psychically lifted, that he felt euphoric and excited. Rapid eye movements were noted, as were rather random and rapid mouth movements. The nailbeds were blanched; the skin was pale and dry. At 7:25 the blood pressure was 170/110; the pulse was 56; respirations,

24. At 7:25 an amyl nitrite vaporole was inhaled. At 7:26 the blood pressure was reported as 180/90; the pulse was weak and thready and sporadic at approximately 160 per minute. It was not palpated well, peripherally. At 7:28 the pulse was 140 and bounding. At 7:29 the pulse had returned to 64. The patient did not lose consciousness but appeared to be quite euphoric and high during this interval. At 7:30 visual patterns of a paisley nature were reported; patient reported that these were not as clear as seen with mushrooms or acid. At 7:35 the blood pressure was 146/90; the pulse was 60. At 7:35 100 milligrams of cocaine was given intravenously. At 7:40 the patient reported that his ears were ringing and that there was a dizzy rush. His feet were noted to be moving in a tapping motion. Pulse was 72. At 7:40 the blood pressure was 160/100; the respirations were 28. The mouth was reported as quite dry. The patient reported that he was unable to do anything; he could only sit; he was too dizzy to get up and move about. The right hand was noted to be involuntarily shaking. The patient was generally noted to be tremulous. The legs were moving. The patient appeared unable to focus his eyes; the pupils remained dilated at 6 millimeters. The patient reported that he was slightly queasy. He stood up, moved about, appeared sweaty. He reported colored spots before his eyes. There was little ataxia, and his gait was relatively normal. At 7:47 the blood pressure was 180/112; pulse, 60. The patient reported that his throat was so dry that speech was quite difficult. He also reported a need to hyperventilate at this time. Respirations were 16. The patient reported that the "zang" rush was decreasing. The eyes were then able to focus and to read newsprint. The headache was reported to persist. There was slight teeth grinding noted. The jaw was reported to ache. Feet were noted to be tapping, and hands and fists were clenched. Colors were reported to be intense. The patient was questioned about thoughts of sex, and reported that there was none. He further reported that as his attention was brought to this subject, his thoughts were increasing and he felt a pelvic rush of blood. A slight sick headache and slight nausea were reported at this time. At 7:55 blood pressure was 166/96; pulse, 62; respirations, 24. The pupils were dilated at 6 millimeters. There was no photosensitivity noted. The patient's color had improved to a pinkish color. He was up and moving around, although he appeared jittery and "wired." Pupils were noted to be 5 millimeters. At 8:06 blood pressure was 160/100; pulse was 60 and somewhat thready. At 8:14 an amyl nitrite vaporole was inhaled once again. A pulse rate of 140 was immediately noted, which dropped to 120; and by 8:16 the pulse had returned to 60. The euphoric effect as previously reported was again noted. The blood pressure at 8:16 was 160/90. At 8:18 P.M. 1 ml. of Inderal was given intravenously. The pulse rate was noted to be 58. At 8:19 an additional 1 ml. of Inderal was given intravenously; patient reported that his head was clearer. At 8:20 1 ml. of additional Inderal was given intravenously; the patient reported that he felt much more pleasant. The blood pressure was 156/88; the pulse was 44. Less headache was reported. The patient reported that he was "stoned," but without side effects. The pupils were widely

dilated at 6 millimeters. Patient reported that he was less nauseated. At 8:25 the blood pressure was 150/80; the pulse, 44. At 8:31 1 ml. of additional Inderal was given. The blood pressure was noted to be 150/80. The patient reported that he felt more coordinated and less jumpy. At 8:35 an additional 1 ml. of Inderal was given intravenously. The blood pressure was reported as 148/88; the respiration, 16; the pupils, 6 millimeters. At 8:40 an additional amyl nitrite vaporole was inhaled. The pulse was 52 at that time; it immediately became quite rapid, thready, and weak; and within two minutes it had returned to a strong, bounding 48 per minute. The patient reported that his mouth was much less dry. At 8:43 the blood pressure was 140/94; the pulse was 48; the respirations were 16. The patient reported that he felt much less irritable and, in general, much more comfortable.

OBSERVATIONS: This patient was noted to reflect the typical lytic effects of Inderal on blood pressure and pulse as noted with other case reports. The Inderal appeared to have little effect on pupil size or upon degree of subjective "wiredness." The patient remained quite active, although not unduly apprehensive, until about 1:30 A.M.—at which time he retired and experienced a good night's sleep.

* * * * *

We have found, in over 50 cases, that propranolol specifically and safely reverses the cardiovascular pressor effects of cocaine (i.e., amphetamine tachycardia) that place patients who are taking this drug at risk. Central cardiovascular hypermetabolism is the most serious consequence in a patient who has taken cocaine, either as a casually self-administered drug or as a topical anaesthetic before endoscopy. The classical cocaine reaction—with initial stimulatory effects followed, sometimes, by profound depressant action—can often confuse the physician. Once this potential crisis has passed and it is clear that one is indeed faced with a case of *chronic toxicity* (the "over-amped," "wired" individual with the cocaine "leaps"), then prompt intervention is indicated, for it is this patient at this time who is the prime candidate for cerebrovascular accident. A possible management problem sometimes being a danger to himself, imminent death from a CVA, cardiac arrhythmia possible but very infrequent in non-institutionalized cocaine "shooters", or high-output congestive heart failure.

In our experience, unique in its accessibility to an illicitly using cocaine population, we have found the following regimen to be effective and safe—namely, 1 mg. propranolol hydrochloride/min. intravenously (up to a maximum dose of 8 mg. in our series) with continuous cardiovascular monitoring. This immediately reverses the hypertension and tachycardia (and tachypnoea); one must be ever-mindful of the hyperthermia (hyperpyrexia) attendant on the use of all sympathomimetic agents.

EARTH SCIENCES

A LATE PLEISTOCENE-HOLOCENE VERTEBRATE FAUNA FROM RED WILLOW COUNTY, NEBRASKA

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Wet gravel pits in Red Willow County, Nebraska have yielded numerous fossil bones from sediments ranging in composition from black peat to coarse gravels. Glaciations to the north and northeast and in alpine situations in the Rocky Mountains may have caused a unique fauna to range into the High Plains in what is now southwestern Nebraska. The mammals recovered consist of twenty-four species. Of these twelve are extinct and six others no longer occur in the area. Geographic ranges are extended for *Sangamon*, *Rangifer tarandus*, *Symbos cavifrons*, *Ovibos moschatus*, and *Ovis catclawensis*. Techniques of gravel recovery resulted in mixing of the fauna, which ranges throughout the Latest Pleistocene (Rancholabrean) and into the Holocene. A temperate-to-cold climate is indicated for part of the Late Pleistocene (Post-Sangamon) in southwestern Nebraska.

† † †

INTRODUCTION

Vertebrate fossils of Late Pleistocene age occur in many commercial, wet gravel pits along the Republican River in southwestern Nebraska. Collections from two important localities in Red Willow County (Fig. 1) form the basis for this report.

The University of Nebraska State Museum first learned of vertebrate fossils from Red Willow County gravel pits in 1925 when Mr. John Cordeal sent in a bone which was "found in a sandpit about three miles and a half east of Red Willow station." Mr. W.B. Hall of Stratton donated numerous specimens in the 1930's from his gravel pits which were located near McCook, including a beautifully preserved *Symbos cavifrons* cranium with horn cores (Fig. 3-B).

U.N.S.M. Collecting Locality Rw-101 is located in N.½, Sec. 28, T. 3 N., R. 30 W., Red Willow County, Nebraska, 4.5 miles west of McCook. This locality consists of a series of wet-gravel pits currently operated by Frank and Clarence Gillen, both of McCook. U.N.S.M. Collecting Locality Rw-102 is in NE¼, Sec. 11, T. 3 N., R. 27 W., one mile west of Bartley, Nebraska. This site was identified in 1946 by Archie Davidson who contributed a partial bighorn sheep (*Ovis catclawensis*) cranium (Fig. 4-A) to the museum.

U.N.S.M. personnel have been making frequent stops at

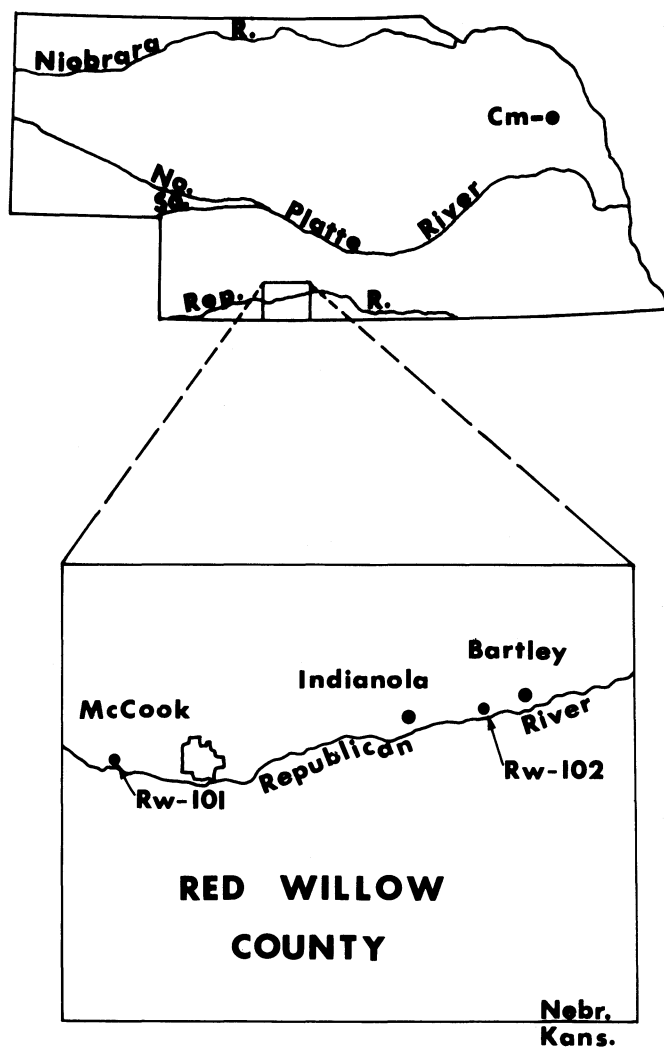


Figure 1. Index map for Red Willow County. Fossils utilized in this report are from U.N.S.M. Coll. Loc. Rw-101 and Rw-102. Cm- represents gravel pit localities in Cuming County, Nebraska, which produced a somewhat similar fauna (Frankforter, 1950).

the Red Willow pits since the 1930's-1950's when C.B. Schultz, T.M. Stout, Lloyd Tanner, and Cyril Harvey made the initial contacts with the commercial operators and collected some very important specimens. From 1968 to the present, the Highway Salvage Paleontologists for the state (King Richey, Ken Quinn, and the writer) have collected numerous fossils from these localities. Through the courtesy of Frank and Clarence Gillen and Lee Davidson, a large and important collection of fossil vertebrates has been amassed. The purpose of this paper is to describe this important and unique fauna and to discuss its ecological and temporal implications.

GEOLOGY

The general geology of Red Willow County has been discussed in several papers dealing with groundwater hydrology of the area (Condra, 1907; Waite *et al.*, 1946; Waite *et al.*, 1948; Bradley and Johnson, 1957; Johnson, 1960). The University of Nebraska's Conservation and Survey Division and the United States Geological Survey are currently involved in a joint mapping project of the bedrock of Red Willow County and adjoining areas (McCook Quadrangle), and these reports are forthcoming (Duane Eversoll, personal communication, 1976).

Both of the sites discussed in this paper are located on the floor of the Republican River valley. The valley floor is about two miles wide at both localities, and the stream gradient is about 7.5 feet to the mile. Bedrock of the area includes the Pierre shale and Niobrara chalk, both of Late Cretaceous age. Bradley and Johnson (1957, pl. 38) show the Pierre shale as underlying the valley in a cross section drawn from test holes and observation wells one mile west of McCook (just three miles east of Rw-101), and Waite *et al.*, (1946, Sec. L-M) show the same relationship one-half mile east of Bartley (one and one-half miles east of Rw-102). Most valley walls are composed of Late Tertiary (Ogallala) rocks and Pleistocene terrace deposits. The south wall, which is much steeper than the north, provides the best exposures of Ogallala rocks; this relationship persists throughout most of the course of the Republican River in Nebraska.

The sands and gravels beneath the valley floor do not occur in outcrop along the valley walls. Bradley and Johnson (1957:610) show these gravels as Late Wisconsin in age and up to fifty feet in thickness. At Rw-101 and Rw-102, sand and gravel are excavated commercially from depths of 0 to 35 feet or more. These deposits lie beneath the valley floor from wall to wall and are mantled with Recent floodplain deposits. The greatest thickness of the sand and gravel does not necessarily lie beneath the present-day stream channel (Waite *et al.*, 1948:10). Removal of the sand and gravel results in small lakes that mark the water table, which lies only a few feet below the surface at both localities.

Locally, at a depth of about 35 feet, a black peat bed is encountered which apparently produced some of the fossil

vertebrates. Some specimens, especially those from Rw-101, have a black peaty substance adhering to the bone; that may account for the gray color of many of the examples from Red Willow County. The association of the gravel and peat bed is similar to that in the Cuming County wet-gravel pits, reported by Frankforter (1950:38) which produced a somewhat similar fauna. The Early Wisconsin dissection in Red Willow County also resembles that suggested for Cuming County, extending from 40-to-60 feet below present river level. It is possible that the fossil-bearing sediments represent cores of older valley-fills, such as the T² of Schultz and Stout (1945, 1948). A detailed discussion of the development of the terraces along the Republican River and its tributaries is given in Schultz *et al.* (1948) and Schultz and Frankforter (1948).

PHYSIOGRAPHIC, CLIMATIC, AND FAUNAL SETTING

The two fossil localities described in this report are in the High Plains section of the Great Plains physiographic province of Fenneman (1931). The major stream of the area is the Republican River, which flows from west to east through Red Willow County and is margined by terraces. Major tributaries in the county enter the Republican from the northwest (Red Willow Creek) or from the southwest (Driftwood Creek).

The climate is variable. Annual precipitation for McCook (Fig. 1) from 1882 to 1950 averaged 19.85 inches. Most of the rainfall occurs in late spring and early summer as heavy local showers. Temperatures at McCook normally range from -20° to 110° F. The last killing frost usually occurs in early October (Bradley and Johnson, 1957).

There are three distinct vegetation zones in Red Willow County (Kaul, 1975). Along the floodplain of the Republican River is a zone of floodplain prairie and forest, which is typified by canary grass, cordgrass, cottonwood, willow, and elm. A mixed prairie zone, consisting of bluestem, grama, and buffalo grasses, occurs north of the river. South of the river, there is a zone of Kansas mixed-prairie, typified by bluestem and grama grasses, and locally yucca is common.

Jones (1964:47) places Red Willow County in his Southwestern District of the Central Grassland mammal distributional area, which has few mammals restricted to it, but serves to filter western species moving east and, in part, eastern species moving west.

VERTEBRATE PALEONTOLOGY

The vertebrate fauna consists of twenty-four forms (Table I), twelve of which are extinct. Nearly all of the fossils utilized here are in the University of Nebraska State Museum collections and assigned U.N.S.M. permanent numbers. All measurements are in millimeters; those in parentheses are approximate.

Table I:

Red Willow County Gravel Pit Fauna

TAXA		Gillen Pits Rw-101	Davidson Pits Rw-102
<i>Ondatra zibethicus</i>	Muskrat	X	
<i>Canis lupus</i> *	Gray Wolf	X	X
<i>Canis latrans</i>	Coyote	X	X
<i>Vulpes vulpes</i>	Red Fox		X
<i>Taxidea taxus</i>	Badger	X	
<i>Mustela nigripes</i>	Black-footed Ferret	X	
<i>Panthera atrox</i> **	North American Lion		X
<i>Mammuthus (Parelephas) sp.</i> **	Mammoth	X	X
<i>Equus conversidens</i> **	Small Horse	X	X
<i>Equus cf. niobrarensis</i> **	Medium-sized Horse	X	X
<i>Equus sp.</i> **	Slender-legged Horse		X
<i>Platygonus compressus</i> **	Extinct Peccary	X	X
<i>Camelops sp.</i> **	Camel	X	X
<i>Odocoileus sp.</i>	Deer	X	X
<i>Sangamona sp.</i> **	Extinct Deer	X	X
<i>Rangifer tarandus</i> *	Woodland Caribou	X	X
<i>Antilocapra americana</i>	Pronghorn	X	X
<i>Bison antiquus cf. barbouri</i> **	Barbour's Bison	X	
<i>Bison antiquus</i> **	Extinct Bison	X	X
<i>Bison bison</i>	Bison	X	X
<i>Symbos cavifrons</i> **	Woodland Muskox	X	X
<i>Ovibos moschatus</i> *	Muskox	X	
<i>Ovis catclawensis</i> **	Extinct Bighorn Sheep	X	X
<i>Homo sapiens</i>	Man	X	X

*Living but not found in Nebraska.

**Extinct.

The following additional abbreviations and designations are used: alv., alveolus; A.M.N.H., American Museum of Natural History, New York; A.N.S.P., Academy of Natural Sciences of Philadelphia; AP, anteroposterior length; C with slash, upper or lower canine; I with slash, upper or lower incisor; M, median; M with slash, upper or lower molar; max., maximum; min., minimum; N, number; O.R., observed range; P with slash, upper or lower premolar; prox., proximal; rt. or rts., root or roots; and TR, transverse length.

CLASS MAMMALIA
ORDER ROTENTIA
FAMILY CRICETIDAE

Ondatra zibethicus (Linnaeus)

Muskrat

Material.—Rw-101: Nearly complete skull with broken incisors, U.N.S.M. 48531.

Discussion.—This edentulous skull falls within the range of variation of modern *Ondatra zibethicus*. The species ranges in age from Late Illinoian (Nelson and Semken, 1970, Fig. 1) to Recent, and it is indicative of permanent water, preferring lakes and marshes. It still lives in the area.

ORDER CARNIVORA
FAMILY CANIDAE

Canis lupus Linnaeus

Gray Wolf

Material.—Rw-101: Posterior half of skull broken through the orbits, U.N.S.M. 46305; axis vertebra, U.N.S.M. 46306; right tibia, U.N.S.M. 46307; left tibia, U.N.S.M. 46308; right femur, U.N.S.M. 46309. Rw-102: Complete skull with all but left C/ and I 1/ and right I 1-2/, U.N.S.M. 46310; cranial fragment, U.N.S.M. 46311; left ramus with P/2—M/1, rts. I/2—/C, and alv. I/1 and M/2-3, U.N.S.M. 46312; and right humerus, U.N.S.M. 46313.

Discussion.—The above specimens show little variation in size from modern material in the U.N.S.M. zoological collections. The partial mandibular ramus (U.N.S.M. 46312) represents a somewhat larger individual than the skull (U.N.S.M. 46310), although tooth wear indicates individuals of approximately the same age. The late Pleistocene dire wolf (*Canis dirus*) is a much larger species. *Canis lupus* may be a member of either the Pleistocene or Holocene faunas at Red Willow, although it appears that the gray wolf is absent or rare in strata of Wisconsin age at most sites (Kurtén and Anderson, 1972:25). The gray wolf was abundant throughout Nebraska into Historic times, especially in association with the vast herds of *Bison*, and was extirpated from the state between 1915 and 1920 (Jones, 1964:249-250).

Measurements.—Skull (U.N.S.M. 46310): anterior edge premaxilla to condyle, 218; width across zygomatic arches, 135; I2/ AP X TR, 7.3 X 7.0; I3/ AP X TR, 9.3 X 7.6; C/AP X TR, 12.9 X 7.7; P1/ AP X TR, 7.9 X 5.3; P2/ AP X TR, 12.2 X 6.0; P3/ AP X TR, 13.8 X 8.3; P4/ AP X TR, 22.8 X 14.1; M1/ AP X TR, 16.7 X 20.3; M2/ AP X TR, 8.6 X 12.1. Mandibular ramus (U.N.S.M. 46312): Length from anterior end to condyle, 183; depth below hypocond M/1, 31.8; P/2 AP X TR, 12.3 X 5.9; P/3 AP X TR, 13.8 X 6.3; P/4 AP X TR, 14.6 X 7.3; M/1 AP X TR, 28.1 X 10.9.

Canis latrans Say

Coyote

Material.—Rw-101: Distal half of right humerus, U.N.S.M. 46314. Rw-102: Right scapula, U.N.S.M. 46315; and left humerus, U.N.S.M. 46316.

Discussion.—The above material falls well within the range of variation of size and morphology of the modern

coyote (*Canis latrans*), which is common in the area today. It may be a member of either the Pleistocene or Recent faunas at Red Willow. Most fossil occurrences of *Canis latrans* are Rancholabrean in age. The coyote prefers open country.

Vulpes vulpes Linnaeus

Red Fox

Material.—Rw-102: Left ramus with M/2 and alv. of all other teeth, U.N.S.M. 46317.

Discussion.—The partial lower jaw is best referred to the red fox rather than to the smaller kit fox (*Vulpes velox*). This is apparently one of the first fossil records of the red fox from the Late Pleistocene of the Great Plains. The species is known from Late Pleistocene cave deposits in the Southwest and also from Chimney Rock Animal Trap, Colorado (Hager, 1972), Little Box Elder Cave, Wyoming (Anderson, 1968), and Jaguar Cave, Idaho (Kurtén and Anderson, 1972). It is possible that the red fox may have been restricted to western and boreal woodlands during the Late Pleistocene and was forced onto the High Plains by alpine glaciation in the Rocky Mountains.

The red fox is probably more widely distributed throughout Nebraska today than at any time since the coming of the white man (Jones, 1964:254). Red Willow County lies at the western margin of red fox distribution in southwestern Nebraska, where it is still occasionally seen.

Measurements.—Ramus (U.N.S.M. 46317): Total length from alv. I/1 to angle, 94.6; P/1 alv. to posterior alv. M/3, 59.2; M/2 AP X TR, 12.2 X 4.8.

FAMILY MUSTELIDAE

Taxidea taxus (Schreber)

Badger

Material.—Rw-101: Anterior half of skull broken behind the orbits, in the private collection of Clarence Gillen, McCook, Nebraska.

Discussion.—This partial badger skull varies little from modern examples of *Taxidea taxus*. The species first occurs in the upper part of the Rexroad (Blancan) and ranges to the Recent. It lives in Red Willow County today and is generally considered to be an upland form.

Mustela nigripes (Audubon and Bachman)

Black-footed Ferret

Material.—Rw-101: Nearly complete skull, in the private collection of Clarence Gillen, McCook, Nebraska.

Discussion.—This is apparently the first fossil record

for this species in Nebraska. The first occurrence of *M. nigripes* is from the Cudahy Fauna (Medial Pleistocene). This form is about the size of the mink (*Mustela vison*), but it has all the characters of *M. nigripes* as outlined in Anderson (1968:32), especially the well-defined tube enclosing the *foramen ovale* that extends postero-laterally to the anterior margin of the auditory bulla.

The black-footed ferret is among the rarest of extant North American mammals. Its range in Nebraska corresponds very closely to that of the prairie dog upon which it preys (Jones, 1964:273). Due to the rarity of this little carnivore, its occurrence in Red Willow County today is questionable.

Measurements.—Skull: Max. length, 63.6; alv. C/ — alv. M1/, 20.0; P4/ AP X TR, 7.4 X 3.6.

FAMILY FELIDAE

Panthera atrox (Leidy)

North American Lion

Material.—Rw-102: Left facial fragment with alv. I1/ and I2/, I3/ — C/, alv. P2/, P3/ — P4/, and alv. M1/, U.N.S.M. 46450.

Discussion.—This is the first record of *Panthera atrox* from Nebraska, and it is probably the best example (Fig. 2) from the Great Plains. The size of the Red Willow specimen slightly exceeds the mean of the Rancho La Brea population (Merriam and Stock, 1932) and indicates a mature but not aged individual. The preserved teeth are in excellent condition, the canine being slightly broken at its tip. This facial fragment offers little in the way of additional information concerning the description of the species, and it is very similar to specimens figured by Merriam and Stock (1932) from Rancho La Brea.

Panthera atrox is widely distributed throughout much of North America and into South America (Harington, 1969:1971). *P. atrox* probably lived in open plains or open woodlands and may have had habits similar to the African lion (Kurtén and Anderson, 1972:22). The North American lion ranges from Sangamon to Late Wisconsinan (Harington, 1969:1285).

Measurements.—Facial fragment (U.N.S.M. 46450): Min. distance anterior of orbit to anterior tip of premaxilla, 165.7; width of palate between upper canines, (67); min. dorsoventral diameter of malar, 45; dorsoventral diameter of infraorbital foramen, 21; length anterior of C/ alv. to posterior of P4/ alv., 124; length anterior of P2/ alv. to P4/ alv., 84.8; I3/ TR, 11.7; C/ AP X TR, 31.1 X 22.6; P3/ AP X TR, 27.7 X 16.7; P4/ AP X TR, 41.8 X 21.0.

ORDER PROBOSCIDEA FAMILY ELEPHANTIDAE

Mammuthus (Parelephas) sp.

Mammoth

Material.—Rw-101: Thoracic vertebra, U.N.S.M. 48562. Rw-102: M/3, U.N.S.M. 2099, nine partial cheek teeth, U.N.S.M. 48546 through 48554; prox. third of ulna, U.N.S.M. 48556; seven isolated partial thoracic and lumbar vertebrae, U.N.S.M. 48555; patella, U.N.S.M. 48557; astragalus, U.N.S.M. 48558; one metapodial, U.N.S.M. 48559; and two phalanges, U.N.S.M. 48560, 48561.

Discussion.—The only apparent diagnostic tooth is U.N.S.M. 2099, which is a nearly complete M/3. All other teeth are first molars, deciduous teeth, or partials. The number of tooth plates and enamel thicknesses would indicate *M. (Parelephas) columbi* or *M. (Parelephas) jeffersonii* as opposed to the Imperial Mammoth, *M. (Archidiskodon)* sp., or the Woolly Mammoth, *M. primigenius*. There are, however, some differences in enamel thickness with the above specimens. U.N.S.M. 2099 averages about 3.0 in thickness; whereas, U.N.S.M. 48548 (only a partial tooth and probably an M3/) averages about 2.0 in thickness. This might indicate the presence of both *M. columbi* and *M. jeffersonii* in the Red Willow Fauna, although the latter is the typical elephant of the Sangamon and Wisconsin (Maglio, 1973:62).

The post-cranial skeletal elements are all referred here as there is no reason to suspect any other mammoth groups at these two localities. They do not compare with mastodont elements in the U.N.S.M. collections or with those described and figured in Olsen (1972). There are undoubtedly more proboscidean specimens (especially teeth) from both localities in private collections. Mammoth remains seem to be more common at Rw-102 than at Rw-101.

Measurements.—M/3 (U.N.S.M. 2099): All measurements were made as in Maglio (1973:11-13). Plate number, 20+; length, 331; width, 92; height, 161; lamellar frequency, 6.5; enamel thickness, 2.9; hypsodonty index, 175.

ORDER PERISSODACTYLA FAMILY EQUIDAE

Equus conversidens Owen

Small Horse

Material.—Rw-101: Two M3/'s, U.N.S.M. 48564, 48503; lower cheek tooth, U.N.S.M. 48505; three metatarsals, U.N.S.M. 48515, 48516, 48541; and rear phalanx, U.N.S.M. 48539. Rw-102: Two lower cheek teeth, U.N.S.M. 46441, 46446; two metacarpals, U.N.S.M. 46469-46470; three metatarsals, U.N.S.M. 46488, 46490, 46491; and three rear phalanges, U.N.S.M. 46476, 46477, 46480.

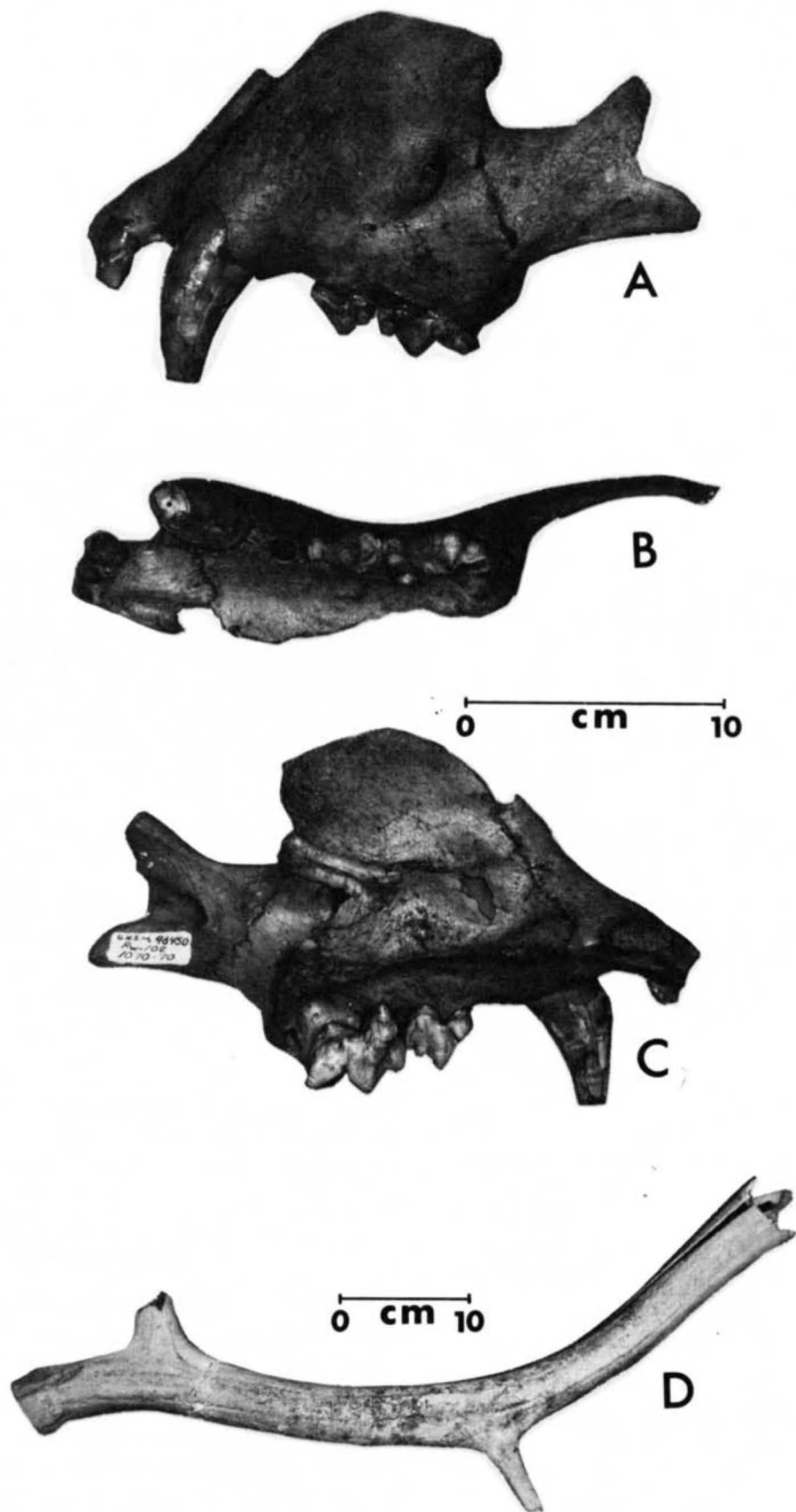


Figure 2. A–C, *Panthera atrox*, U.N.S.M. 46450, left facial fragment, labial, occlusal and lingual views. D, *Rangifer tarandus*, U.N.S.M. 46302, antler fragment.

Discussion.—The isolated cheek teeth are much smaller than those referred to *E. cf. niobrarensis*. An M3/ (U.N.S.M. 48503) is about the size of the same tooth in the holotype, which is extremely small (Hibbard, 1955:58), measuring only 21.0 X 17.2 (AP X TR). U.N.S.M. 48503 measures only 22.3 X 18.2. In the lower teeth, the notch between the metaconid and metastylid is deeper and not as broad as in the larger Red Willow species. The groove between the lingual styles which make up the metaconid and metastylid is narrow and shallow in this form, but broad and deep in *E. cf. niobrarensis*.

Measurements of the limb elements (Table II) are similar in size to those referred to *E. conversidens* from other localities (Dalquest and Hughes, 1965; Dalquest, 1967; Churcher, 1968 and 1975). There are numerous phalanges from the Red Willow pits, some of which can probably be referred to the small form and some to the large form. However, some fall directly between the two groups, perhaps indicating an overlap in the size of the post-cranial skeleton of *E. conversidens* and *E. cf. niobrarensis*; thus, most phalanges remain unassigned. The hind proximal phalanges of *E. conversidens*, however, seem to have been much more slender than the front (Dalquest and Hughes, 1965:415). Most other species do not show this extreme size differential in the front and rear proximal phalanges.

E. conversidens is a common component of Late Pleistocene faunas but ranges from Yarmouthian to Late Wisconsinan (Dalquest and Hughes, 1965:417). The geographic range includes much of North America from Alaska to Mexico.

Table II:

Measurements of Limb Bones of *Equus conversidens*

		Greatest length	Greatest proximal width	Least medial width	Greatest distal width
Metacarpals					
	U.N.S.M. 46469	222	—	38.8	48.3
	46470	220	—	34.5	44.5
Metatarsals					
	N	6	5	6	5
	O.R.	246-272	46.3-50.8	33.3-35.3	42.0-47.5
	M	259	48.0	34.1	44.5
Rear Phalanges I					
	N	3	3	4	4
	O.R.	72.5-80.5	42.1-44.0	28.7-29.1	35.8-38.3
	M	77.8	42.9	28.7	36.6

Equus cf. niobrarensis Hay

Medium-sized Horse

Material.—Rw-101: Partial cranium, U.N.S.M. 46498; portion of muzzle, U.N.S.M. 48543; five upper cheek teeth, U.N.S.M. 46499, 48500-48502, 48538; five lower cheek teeth, 48504, 48506-48509; and one metatarsal, U.N.S.M. 48536. Rw-102: Nine upper cheek teeth, U.N.S.M. 46443, 46447, 46448, 46451-46455, 48544; six lower cheek teeth, U.N.S.M. 46444, 46445, 46449, 46456, 46457, 48545; three humeri, 46460-46462; three complete and three partial radii, U.N.S.M. 46463-46465, 46467, 46468, 48512; and two partial tibiae, 46482, 46483.

Discussion.—The size of the teeth and skeletal elements (Table III) compares best with those referred to *E. niobrarensis* by Dalquest (1967). The referral of the above material to *E. cf. niobrarensis* is basically for convenience. There are no other medium-sized Pleistocene horses for which the post-cranial skeleton is known.

Equus sp.

Slender-legged Horse

Material.—Rw-102: Right metatarsal, U.N.S.M. 46492; and right radius, U.N.S.M. 46466.

Discussion.—These limb elements are extremely narrow and do not fit within the range of *E. cf. niobrarensis* or *E. conversidens* at Red Willow. The metatarsal compares best with the holotype of *E. ?quinni* from the Late Pleistocene of Texas (Slaughter *et al.*, 1962:33), but it has broader proximal and distal articular surfaces and is slightly shorter.

Table III:

Measurements of Limb Bones of *Equus cf. niobrarensis*

		Greatest length	Greatest proximal width	Least medial width	Greatest distal width
Radii					
	N	3	5	3	4
	O.R.	329-349	81.1-89.1	40.8-46.0	68.0-78.3
	M	336.7	84.8	43.3	72.8
Humeri					
	N	3	2	3	3
	O.R.	291-302	88.8-92.0	33.5-40.8	80.1-84.3
	M	298	90.4	37.5	82.1
Metatarsal					
	U.N.S.M. 48536	272	49.0	33.7	44.3

Measurements.—Metatarsal (U.N.S.M. 46492): Greatest length, 271; greatest proximal width, 41.2; least medial width, 26.2; least medial width, 26.2; greatest distal width, 40.0. Radius (U.N.S.M. 46466): Greatest length, 305; least medial width, 36.7; greatest distal width, 60.3.

ORDER ARTIODACTYLA
FAMILY TAYASSUIDAE

Platygonus compressus LeConte

Extinct Peccary

Material.—Rw-101: Partial left maxillary with alv. P2/ and P3/ — M3/, U.N.S.M. 48528. Rw-102: Partial palate with left alv. P2/, P3/ — P4/, alv. M1/, M2/ — M3/ and right alv. P2/, P3/ — P4/, alv. M1/, M2/ (br.) and M3/, U.N.S.M. 48529.

Discussion.—The last two upper premolars (P3/ and P4/) are non-molariform. The Red Willow specimens (Table IV) are within the observed-size ranges of *Platygonus compressus* from Cherokee Cave in St. Louis (Simpson, 1949), and from the Wisconsinan of Washtenaw County, Michigan (Eshelman *et al.*, 1972).

The Red Willow peccaries also compare with *P. leptorhinus* from near Goodland, Kansas (Williston, 1894), which is only about 80 miles southwest of the Red Willow localities. Simpson (1949), after comparing the Cherokee Cave material with one of Williston's syntypes, concluded that the Goodland, Kansas population was but a local population of *P. compressus*.

Apparently *P. compressus* had wide-ranging climatic tolerance, varying from temperate to periglacial regions (Ray *et al.*, 1970; Eshelman *et al.*, 1972) and, thus, cannot be considered an important climatic indicator.

Table IV

Measurements of Upper Dentition
of *Platygonus compressus*

	U.N.S.M. 48528	U.N.S.M. 48529
P3/ AP X TR	9.6 x 11.0	10.9 x 11.8
P4/ AP X TR	9.8 x 12.8	10.6 x 12.7
M1/ AP X TR	13.9 x 13.6	-----
M2/ AP X TR	16.9 x 16.0	16.6 x 15.3
M3/ AP X TR	20.0 x 16.9	18.3 x 15.3

FAMILY CAMELIDAE

Camelops sp.

Extinct Camel

Material.—Rw-101 and Rw-102: Some complete limb bones, broken ends of long bones, vertebrae, calcanea, astragali, phalanges, and isolated teeth (U.N.S.M. 46349-46440).

Discussion.—Camel material is relatively abundant in the Red Willow pits. Selected measurements (see below) of the metapodials and the calcanea show the Red Willow *Camelops* to be somewhat smaller than *Camelops hesternus* from Rancho La Brea (Webb, 1965) or *Camelops* cf. *hesternus* from the Gordon, Rushville, and Hay Springs localities (Breyer, 1974), but larger than *Camelops* sp. of the Ingleside Fauna of Texas (Lundelius, 1972). The measurements are still apparently within the size range of the large group of *Camelops* species (Savage, 1951), consisting of *C. kansanus*, *C. hesternus*, and *C. huerfanensis*. Due to a lack of skull material, no attempt is made here to speciate the Red Willow *Camelops*.

Camelops is known throughout the Pleistocene, and large herds roamed throughout what is now Nebraska. This camel was primarily adapted as a grazer, but its long neck and limbs allowed it to be an occasional browser as well (Webb, 1965).

Measurements.—Metatarsals: Total length — N=3, O.R.=343-368, M=355.3; Max. width prox. end — N=3, O.R.=68-79, M=72.6; Max. width distal end — N=3, O.R.=82-93, M=86.3. Calcanea: Max. length — N=3, O.R.=154-159, M=155.0.

FAMILY CERVIDAE

Odocoileus sp.

Deer

Material.—Rw-101: Left maxillary fragment with P2/ — M3/, U.N.S.M. 46323; partial right ramus with P2/ — M3/, U.N.S.M. 46324; distal end of left metacarpal, U.N.S.M. 46325; distal two-thirds of left humerus, U.N.S.M. 46329. Rw-102: Right maxillary fragment with M1/ — M3/, U.N.S.M. 46327; partial right ramus with P2/ — M3/, U.N.S.M. 46328.

Discussion.—The above material represents a small deer. These specimens are not diagnostic as to species, but they are within the size range of the modern white-tailed deer (*O. virginianus*) and the mule deer (*O. hemionus*).

Measurements.—Occlusal length: P2/ — M3/, U.N.S.M. 46323, 78.2; M1/ — M3/, U.N.S.M. 46327, 45.7; P2/ — M3/, U.N.S.M. 46324, 87.9; P2/ — M3/, U.N.S.M. 46328, 94.9.

Sangamona sp.

Extinct Deer

Material.—Rw-101: Left antler fragment with pedicel and fragment of frontal, U.N.S.M. 46326; and distal halves of two right humeri, U.N.S.M. 48534, 48535. Rw-102: Left metacarpal, U.N.S.M. 48526; and distal half of right humerus, U.N.S.M. 46304.

Discussion.—The metacarpal is referred to *Sangamona* mainly on the basis of size, being intermediate between the mule deer and the wapiti (Kurtén, 1974:508). *Sangamona* differs from *Navahoceros* in having longer, more slender limbs. The metacarpal is structurally similar to that of the wapiti (*Cervus canadensis*), except the posterior vascular groove is not as deep.

The partial humeri were compared with a humerus (A.N.S.P. 13930) from Burnet Cave (Schultz and Howard, 1935:287), considered to be *Navahoceros fricki* by Kurtén (1974:507), and were found to be similar in size and structure. They are referred to *Sangamona* and not *Navahoceros* because there is no evidence to suggest that both forms are present at Red Willow, and the complete metacarpal can be referred to *Sangamona* with some confidence. The two genera are not known at present to occur together (Kurtén, 1974:508), but the best place for such a mutual occurrence might be at Red Willow. These fossil humeri differ from *Rangifer* in that the olecranon fossa is not as high proximally as in *Rangifer*, and the lateral condyloid crest is much better developed in the caribou.

The antler fragment is much larger than one would expect for the small *Odocoileus*, and it is also assigned to *Sangamona*. This is the westernmost occurrence of the genus. Schultz *et al.* (1951) list *Sangamona* from the Sangamon Soil of Nebraska, with most other references to *Sangamona* as Wisconsinan.

Measurements.—Metacarpal (U.N.S.M. 48526): Articular length, 270; width proximal end, 45.2; width distal end, 44.4. Humeri: Width of distal articular surface — N=3, O.R.=48.3-54.7, M=50.8.

Rangifer tarandus (Linnaeus)

Woodland Caribou

Material.—Rw-101: Posterior third of skull with two-thirds of left antler attached, U.N.S.M. 46300; and antler fragment, U.N.S.M. 46301. Rw-102: Right basal antler fragment, U.N.S.M. 46302; basal antler fragment with frontal fragment attached, U.N.S.M. 48527; and prox. half of metacarpal, U.N.S.M. 46303.

Discussion.—The antler fragments (Fig. 2-D) are large and palmate and resemble the woodland caribou rather than

the barren-ground caribou, which are longer, more slender, and not so palmated (Hibbard, 1952:236). U.N.S.M. 46300 and 46302 are nearly identical in size and structure to a recent specimen (A.M.N.H. 121819) originally referred to *R. osborni* (Allen, 1902), but this species has since been synonymized with *R. tarandus*. No well-developed burrs are present on any of the basal antler fragments, nor is there evidence of a circumferential groove on any of the specimens, which would indicate that the animals died during mid-winter (Ray *et al.*, 1967). A broken stub is all that remains of the brow tine in U.N.S.M. 48527, which measures 19.9 at its base. The brow tine has been broken off in the other specimens. U.N.S.M. 48527 is smaller than the other two antler specimens and may represent a female. In both U.N.S.M. 46300 and 46302 the posterior tine is in the same position as in *R. osborni*, but the base of the bez tine is located much higher on the beam than in *R. osborni*. A portion of the terminal tine is preserved in U.N.S.M. 46302, and it is flattened and palmate.

The partial skull (U.N.S.M. 46300) is not as large as that of *R. osborni*, although the antler compares favorably. Most distinctive of the fossil specimen is the broad and flattened occiput which is typical of the *Compressicornis* Group of Banfield (1961:70). This is apparently the first fossil skull known of *Rangifer* south of Canada. The limb elements all compare well with modern *Rangifer*.

I am following Banfield (1961:40), who referred all the fossil *Rangifer* to *R. tarandus*. Schultz and Frankforter (1951, Table I) list *Rangifer* from the Wisconsinan of Nebraska, but they do not discuss it. The genus is apparently known from Illinoian deposits of Alaska (Banfield, 1961:35), but I have found no definite Illinoian record south of Canada.

Banfield (1961:70) states that the habitat of the modern woodland caribou is in bogs, swales, and alpine tundra, and in boreal coniferous-forested regions. Late Wisconsinan alpine glaciation in the Rockies may have driven the caribou out of its normal alpine habitat to the High Plains.

Measurements.—Skull (U.N.S.M. 46300): Length from apex of occipital crest to base of *foramen magnum*, 83.0; max. width of occiput, 116.0.

FAMILY ANTILOCAPRIDAE

Antilocapra americana (Ord)

Pronghorn

Material.—Rw-101: Distal half of right humerus, U.N.S.M. 46332. Rw-102: Fragment of left ramus with P/4 and alv. /C — P/3, U.N.S.M. 46321; right metatarsal, U.N.S.M. 46318; right tibia, U.N.S.M. 46319; and distal end of right metacarpal, U.N.S.M. 46320.

Discussion.—This material is best referred to the extant species, although some differences are noted. The lower jaw

fragment (U.N.S.M. 46321) is more like *Antilocapra* than *Stockoceros*, in that the double roots of P/4 are almost absent (Skinner, 1942:204). The above specimen differs from the jaws of the modern *Antilocapra*, which were available for study, in that the distance from the mandibular foramen to the alveolus of the canine is extremely short. Judging from the size of the canine alveolus, this tooth was much larger in the Red Willow specimen than in modern *Antilocapra*.

The post-cranial elements all appear to fall within the range of variation of modern *Antilocapra americana*. There is no evidence at this time to indicate the presence of extinct antilocaprids in the Red Willow Fauna.

The pronghorn was present in Red Willow County into historic times, but it is seldom seen in the area today.

Measurements.—Metatarsal (U.N.S.M. 46318): Length, 208; width prox. articular surface, 21.4; width distal articular surface, 23.4.

FAMILY BOVIDAE

Bison antiquus cf. *barboursi* Schultz and Frankforter

Material.—Rw-101: Horn core, U.N.S.M. 30950.

Discussion.—The large horn core (Fig. 3-A) is close to the size of the holotype of *B. antiquus barboursi* (Schultz and Frankforter, 1946), which is from the Gilman Canyon Formation of Early Wisconsinan (Schultz, Tanner and Martin, 1972) or/and Sangamon age. U.N.S.M. 30950 differs from the holotype in being round in cross section at the burr, instead of being dorso-ventrally flattened at the base of the horn core. The Red Willow specimen is larger (especially in total length) than the holotypes of *B. antiquus*, *B. taylori*, and *B. occidentalis*, and it is larger than large specimens of *B. antiquus taylori* from the Folsom Quarry and the Scottsbluff Bison Quarry (Barbour and Schultz, 1936). The horn core (U.N.S.M. 30950) is of the morphology and size which one would find in the Sangamon (C.B. Schultz, personal communication, 1976).

Measurements.—Horn core (U.N.S.M. 30950): Vertical diameter at base of horn core, 102; transverse diameter of same, 108; circumference of same, 345; length of horn core along upper curve, 350; and length of horn core along lower curve, 410.

Bison antiquus Leidy

There are hundreds of *Bison* specimens from the Red Willow pits, comprising at least 80% of all the materials collected there. The study of this enormous amount of material lies outside the scope of this report. There are many specimens which probably are best referred to the various subspecies of *B. antiquus*, which ranges throughout the Wisconsinan and into the Early Holocene.

Bison bison (Linnaeus)

The presence of the extant species of *Bison* is indicated by numerous specimens of partial skulls, horn cores, and post-cranial elements from both Red Willow localities. The mixing of this material is best illustrated by the occurrence of the extinct species with *Bison bison*, which is restricted to the Holocene.

Symbos cavifrons (Leidy)

Woodland Muskox

Material.—“From gravel pit near McCook”: Posterior half of skull with complete horn cores and dorsal portion of orbits, U.N.S.M. 1112. Rw-101: two axis vertebrae, U.N.S.M. 31504 and 46348. Rw-102: Occipital region of skull, U.N.S.M. 9306.

Discussion.—The well-preserved fossil skull (Fig. 3-B) can be confidently referred to *S. cavifrons*, having cranial characters which easily separate it from *Ovibos* (Semken *et al.*, 1964:827). The skull is apparently of average size (see below).

The axis vertebrae compare very well with those of *Symbos cavifrons* from Michigan, illustrated by Hibbard and Hinds (1964:111), except for U.N.S.M. 31054, which is somewhat larger (Table V). No doubt there are other post-cranial elements of *Symbos* in the Red Willow collections that have not yet been separated.

Symbos was apparently a woodland form (Hibbard, 1951: Semken *et al.*, 1964), and it is well distributed throughout much of the eastern half of the United States (Kitts, 1953; Harington, 1968). Barbour (1931) listed six records of *Symbos* from Nebraska, and specimens from several other localities have been found since. The Red Willow *Symbos* represents the westernmost report for the genus in Nebraska.

Most of the occurrences of *Symbos cavifrons* have been from the Wisconsinan, although Harington (1968:1164) lists some *Symbos* material from Saskatchewan that appears to be

Table V:

Measurements of Axis Vertebrae of *Symbos cavifrons*

	U.N.S.M. 31054	U.N.S.M. 46348
Greatest width across anterior face	137	121
Greatest height across anterior face	195	-----
Anterior width of neural canal	32	30
Anterior height of neural canal	37	31
Greatest width across posterior articular processes	113	-----



Figure 3. A, *Bison antiquus* cf. *barbouri*, U.N.S.M. 30950, horn core. B, *Symbos cavifrons*, U.N.S.M. 1112, partial skull, dorsal view. C, *Ovibos moschatus*, U.N.S.M. 9307, partial skull, dorsal view.

from the Sangamon. The earliest record apparently is that from Illinoian-age deposits near Mullen, Nebraska (Jakway, 1961), although there may be some mixing of material at this site (Schultz and Martin, 1970:348).

Measurements.—Skull (U.N.S.M. 1112): Length from condyle to fronto-nasal suture, 341; height from bottom of condyles to top of exostosis, 263; AP diameter of horn core base, 102; vertical diameter of horn core base, 84; distance between tips of horn cores, 563; width across condyles, 135; width across orbits, 236; exostosis length, 248; exostosis width anterior to horn core, 128; and width at constriction at rear of orbits, 151.

Ovibos moschatus (Zimmerman)

Muskox

Material.—Rw-101: Posterior portion of cranium with horn cores broken at base, U.N.S.M. 9307.

Discussion.—The partial cranium (Fig. 3-C) is somewhat waterworn, but the left horn core was probably broken during recovery. The Red Willow *Ovibos* cranial fragment was compared directly with a specimen of *Ovibos moschatus* which Harington (1970a) described from Illinoian deposits near Nome, Alaska, and it was found to be very similar. The only difference was in the shallower depth of the median groove on the dorsal surface in U.N.S.M. 9307, although this could be accounted for in the more-waterworn condition of the Red Willow specimen.

The median groove on the dorsal surface of the skull (Harington, 1970a:1326) indicates that the Red Willow specimen was an adult male. The specimen is within the size range of living *Ovibos moschatus* (Harington, 1970a-b; Kitts, 1953).

This is apparently the southwesternmost occurrence of the species. *Ovibos moschatus* is usually associated with tundra. However, some fossil *Ovibos* localities indicate that the muskox lived on loess steppes or on cool, dry, grasslands (Harington, 1970a:1329). This may be the case with the Red Willow *Ovibos*, as it is apparently farther away from the margin of the Wisconsin ice sheets than any other specimen. It is possible that the Red Willow skull fragment is pre-Wisconsinan in age as were the Morrill, Nebraska, and Jinks Hollow, Illinois, specimens (Harington, 1970a:1329). However, the evidence of the entire fauna discounts this. Most fossil *Ovibos* are of Wisconsinan age, although pre-Wisconsinan occurrences are being documented. The earliest occurrence is from Yarmouthian deposits of Nebraska (Schultz *et al.*, 1951, Table I).

Measurements.—Skull (U.N.S.M. 9307): Basioccipital width, 57.5; height of *foramen magnum*, 30; width of *foramen magnum*, 32.5; occipital height (dorsal margin of *foramen*

magnum to base of median groove on dorsal surface), 121; length of hornbase, 172; min. width of skull just above nuchal crest, 137.

Ovis catclawensis Hibbard and Wright

Extinct Bighorn Sheep

Material.—Rw-101: Posterior portion of skull with bases of both horn cores, U.N.S.M. 46330; posterior portion of female skull with horn cores, U.N.S.M. 46331; portion of female skull with horn cores, U.N.S.M. 46332; immature left ramus with DP/3 – DP/4 and M/1 emerging, U.N.S.M. 46333; atlas vertebra, U.N.S.M. 46334; distal two-thirds of metacarpal, U.N.S.M. 46335; and distal end of metacarpal, U.N.S.M. 46336. Rw-102: Complete posterior portion of skull with left horn core and base of right, U.N.S.M. 46337; posterior portion of skull with left horn core, U.N.S.M. 46338; and posterior portion of skull with right horn core and fragment of left, U.N.S.M. 46339.

Discussion.—This fossil bighorn sheep is known in the U.N.S.M. collections from eight localities in the Frenchman and Republican River valleys. A partial lower jaw (U.N.S.M. 48536) from a gravel pit of similar age at Palisade (28 miles northwest of McCook on the Frenchman River) is almost identical to the holotype of *O. catclawensis* from Catclaw Cave, Arizona (Hibbard and Wright, 1956).

At least seven individuals are represented in the Red Willow Fauna: four adult rams, two adult ewes, and one lamb. The female skull (Fig. 4 B–D) differs from that of the male (Fig. 4A) in being decidedly smaller (Table VI) and in having short, straight, pointed, laterally-compressed horn cores. Stokes and Condie (1961:606) point out that cranial sutures of the bighorn begin to fuse at about five years of age. The suture between the frontals on the female specimens is not discernible between the horn cores, but all other sutures are distinctly visible. This indicates that U.N.S.M. 46331 and 46332 represent mature females, probably about five years of age, instead of immature males, which in *O. canadensis* are similar in size at the age of one year to full-grown females (Hansen, 1965). The ram skulls all have sutures which are for the most part indiscernible and probably represent individuals ten years old or more. The lamb is represented by a lower jaw in which M/1 is just about to erupt and DP/2 – DP/4 are in full use. These are the first evidences of the female and lamb of this extinct species.

The Red Willow bighorn sheep sample was compared with an extremely large sample of unpublished material from Natural Trap Cave, Wyoming, which is currently being studied by Larry D. Martin and others at the University of Kansas Museum of Natural History. The Natural Trap material is not only much larger in skull measurements than *O. canadensis*, but the post-cranial limb elements indicate extremely long-legged animals much different from the modern form

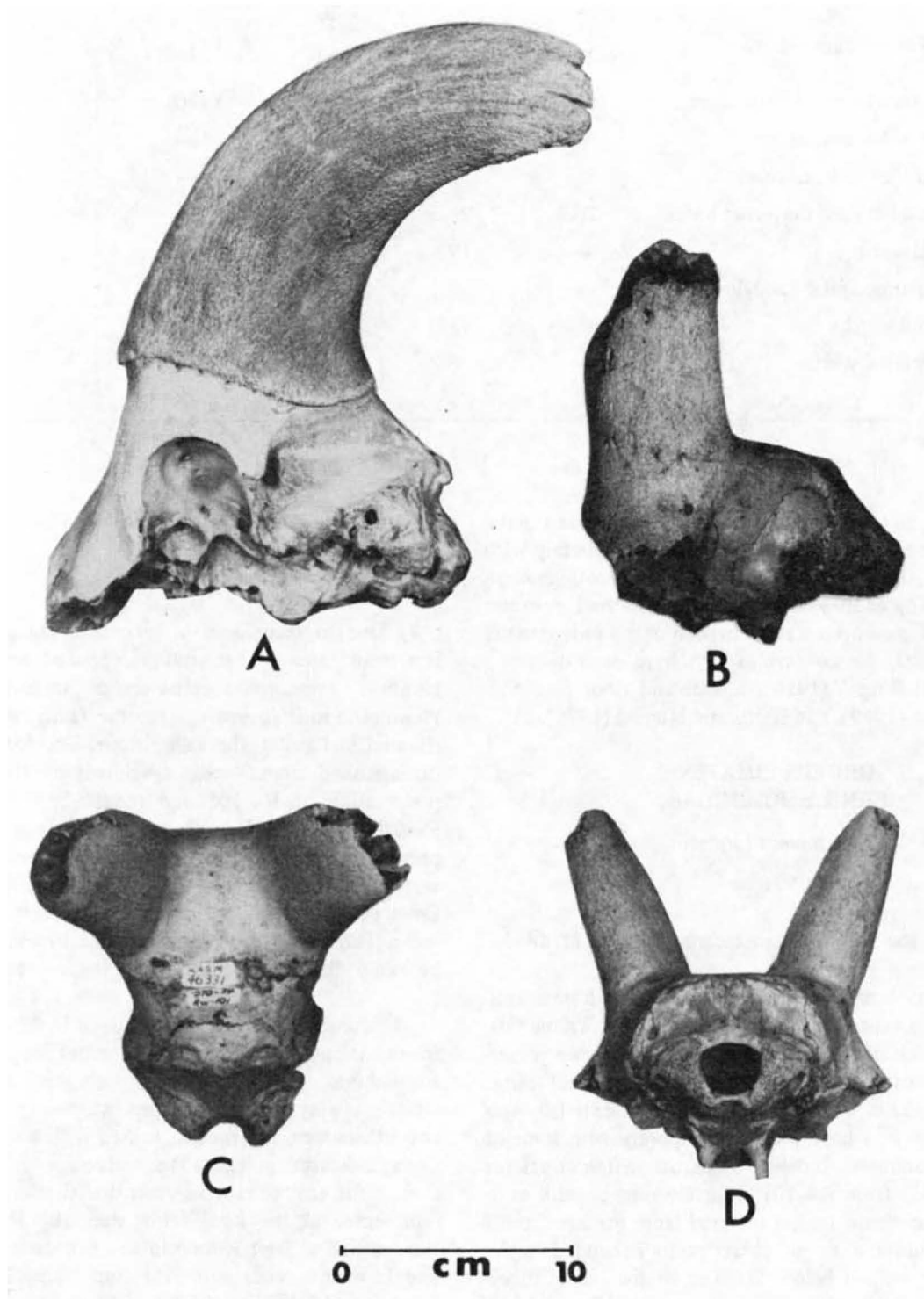


Figure 4. A–D, *Ovis catclawensis*: A, male, U.N.S.M. 46337, lateral view; C–D, female, U.N.S.M. 46331, lateral, dorsal and occipital views.

Table VI:

Measurements of Skulls of *Ovis catclawensis*

(U.N.S.M. specimens)	Males				Females	
	46330	46337	46338	46339	46331	46332
Maximum diameter at base of horn cores	120	128	(127)	(120)	60	62.7
Minimum length of horn cores	-----	335	-----	-----	-----	135
Circumference at base of horn cores	351	385	362	-----	175	175
Minimum distance between horn core bases	20.9	21.5	19.8	18.4	46.5	52.0
Maximum orbital width	-----	192	-----	-----	-----	-----
Maximum diameter occipital condyles	-----	77.4	-----	69.1	63.4	-----
Maximum mastoid width	-----	117	-----	-----	80.5	-----
Minimum basioccipital width	-----	38.7	-----	39.2	30.3	-----

(Larry Martin, personal communication, 1976). Broken metapodials from Red Willow compare much more favorably with the long-legged form from Natural Trap than with modern *O. canadensis*. The additional material from Natural Trap and Red Willow will necessitate a re-evaluation of the phylogenetic relationships of *O. catclawensis*, which have been discussed by Hibbard and Wright (1956), Stokes and Condie (1961), Stock and Stokes (1969), and Harris and Mundel (1974).

ORDER PRIMATES
FAMILY HOMINIDAE

Homo sapiens Linnaeus

Man

Material.—Rw-102: Right metacarpal I, U.N.S.M. 48532.

Discussion.—Both osteological remains and human artifacts (Myers, this volume) were found in the Red Willow pits. The only bony element recovered has the gray-brown preservation characteristic of many of the bones of the fossil forms. The possibility exists that the individual represented by this single metacarpal may have been contemporary with some of these extinct animals. Indeed, a partial *Bison* humerus (U.N.S.M. 48533) from Rw-101, which compares with average-sized *Bison antiquus taylori* material from the Scottsbluff Bison Quarry, has the tip of a dart point imbedded in the proximal epiphysis, just below the base of the lateral tuberosity. However, it should not be construed that man was contemporaneous with all of the extinct species. This again points to the mixed nature of the material from the Red Willow pits.

DISCUSSION

Age of the Fauna

Due to techniques of recovering the gravel, the fauna is a mixed one so that stratigraphic data are of limited use. However, geomorphic consideration indicates a very Late Pleistocene-to-Holocene age for the fauna, since the sites are situated just below the valley floor. The fossil bones can be distinguished from Recent specimens by their black-to-gray preservation at Rw-101 and reddish-brown preservation at Rw-102; whereas, Recent specimens are white and poorly preserved. There are also some obviously reworked mosasaur vertebrae from the Pierre Shale or Niobrara Chalk (Late Cretaceous) and rhinoceros and horse bones from Ogallala rocks (Pliocene). These fossils are heavily mineralized and can be easily distinguished from the Pleistocene-Holocene fossils.

Faunal mixing is best shown by the association of *Bison antiquus* cf. *barboursi*, an apparent Sangamon form, with *Bison bison*, which is seemingly restricted to the Holocene. Of the twenty-four species present, twelve are extinct and two others were not present in Red Willow County in historic times, indicating at least a Pleistocene age for most. Consideration of the entire fauna suggests that the depositional interval represented at the Red Willow sites may include Sangamon time as well as later Wisconsin and Holocene. Both Sangamon and Loveland occur along the Republican River valley, and Bradley and Johnson (1957, pl. 38) show a thin layer of sand assigned to the Grand Island Formation resting on the Pierre Shale about fifty feet below the present valley floor. However, there is no clear faunal evidence of pre-Sangamon forms, and

only *Bison antiquus* cf. *barboursi* might be indicative of the Sangamon, but reworking is possible. A Rancholabrean age for the bulk of the fauna is indicated.

Due to methods of obtaining the gravels only intermediate- to large-sized fossils were recovered. No micromammals were collected, so faunal comparisons must be made on the large mammals, especially ungulates. It cannot be shown that all Rancholabrean forms at Red Willow were contemporaneous, but it is probable that several faunas representing distinct depositional cycles throughout the Late Pleistocene and Recent are present. Some described faunas which share taxa with Red Willow include Burnet Cave, New Mexico (Schultz and Howard, 1935), Jaguar Cave, Idaho (Kurtén and Anderson, 1972), Little Box Elder Cave, Wyoming (Anderson, 1968), and Chimney Rock Animal Trap, Colorado (Hager, 1972).

The Late Pleistocene fauna of Nebraska has been listed several times (Schultz, 1934; Schultz and Stout, 1948; Schultz *et al.*, 1951) but not described. Frankforter (1950) listed the Cuming County gravel-pit material, but also left it undescribed. The Cuming County collection shows an even greater mixing with *Bison alleni* and *Bison bison* present, as well as ground sloths (*Paramylodon* sp. and *Megalonyx jeffersonii*) and the muskox, *Symbos*. It is likely that the Red Willow and Cuming County faunas were at least in part contemporaneous, but differing ecologies may be sampled.

Paleoecology

It has been suggested above that the Red Willow gravel pit collections are primarily of Rancholabrean age. They might, therefore, be expected to reflect the rapidly changing environmental conditions associated with the advance and retreat of alpine glaciers to the west and of continental glaciers to the north and northeast. Both open-plains and river-margin environments probably are sampled here. Grazing forms such as *Mammuthus*, *Equus*, *Bison*, and *Antilocapra* are far more abundant than *Odocoileus* and *Sangamona*, which are usually considered browsers requiring wooded areas near streams. Of the other species, *Ovibos moschatus* is usually associated with tundra, the woodland caribou (*Rangifer tarandus*) with alpine tundra or coniferous forests, and the extinct bighorn sheep (*Ovis catclawensis*) less certainly with alpine conditions. It seems probable that *Ovibos*, *Rangifer*, and *Ovis* were driven onto the Great Plains from their normal ranges by cold associated with advancing alpine and continental glaciations. However, cold winters could produce a similar result in a climate like that presently characteristic of the region.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to all those who aided in the preparation of this report. I would especially like to thank the commercial gravel pit operators, Frank and Clarence Gillen of McCook and Lee Davidson of Indianola, Nebraska,

without whose assistance and donation of numerous specimens this study would have been impossible. C. Bertrand Schultz, Lloyd G. Tanner, and T.M. Stout gave aid in many ways. Michael R. Voorhies and Larry D. Martin also gave help and encouragement and critically read the manuscript. Karen and Charles Messenger did the preparatory and photographic work. Martha Haack assisted with the figures, and Rebecca Monke and Gail Littrell typed the manuscript.

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CARNIVORES FROM THE JAMBER LOCAL FAUNA (PLIOCENE, VALENTINIAN), BOYD COUNTY, NEBRASKA

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Five types of carnivores have so far been recognized in the preliminary study of the Jamber Local Fauna (University of Nebraska State Museum Collecting Locality Boyd County no. 6), northern Nebraska. These include *Tomarctus* cf. *brevirostris*, *Aelurodon haydeni*, *Aelurodon* sp., *Leptocyon* cf. *vafer*, and *Pseudaelurus* cf. *marshi*. The Jamber Quarry carnivores and associated fauna appear to be Early Valentinian in age.

† † †

INTRODUCTION

Abbreviations used in the text are as follows: A.M.N.H. (American Museum of Natural History); F.S.G.S. (Florida State Geological Survey); U.N.S.M. (University of Nebraska State Museum); U.N.S.M. Coll. Loc. Bd-6 or Cr-12 (University of Nebraska State Museum Collecting Locality Boyd County no. 6 or Cherry County no. 12); U.S.N.M. (United States National Museum); and Y.P.M. (Yale-Peabody Museum). The specimens from the University of Nebraska State Museum Collections are the only ones studied first-hand.

An interesting and varied fauna has been recovered from the Jamber Quarry, Boyd County, northern Nebraska (U.N.S.M. Bd-6). One carnivore (Messenger and Messenger, 1976) and a rhinoceros (Tanner, 1976, and this volume) from this fauna have been published on to date. The rest of the carnivore specimens recovered from Jamber Quarry are described in this paper, with the remainder of the fauna and the stratigraphy to be published in the future.

Sediments in the quarry consist of cross-bedded, limonitic sands which contain lenses of green clay balls. The bones appear to be concentrated near the clay ball zones. Preliminary work on the biostratigraphic evidence from Jamber Quarry indicates a Lower Valentinian Provincial Age (Lower Pliocene) (Schultz and Stout, 1961; Schultz, Schultz, and Martin, 1970; Schultz, Martin, and Corner, 1975) for this fauna.

Individual variation has been taken into account in assigning specific identifications to the carnivores from the Jamber Local Fauna. For example, the *Aelurodon haydeni* jaw, U.N.S.M. 9401, is approximately one-third smaller than the published type. All the tooth measurements of this

specimen correspond with the type measurements in length-to-width ratio and fall within the range of observed variation of the *A. saevus* group of McGrew (1944) except for the P/3. This difference is attributed by the authors to individual variation within the *Aelurodon* group. Perhaps a comparison may be made to the degrees of variation documented in the modern-day wolf population. Young and Goldman (1944: 407) state:

"Irregular individual variation in relative size of the large cheek teeth are not infrequent." They further contend: "One or both of the small anterior premolars or posterior molars in either jaw may be absent, and in a few skulls supernumerary teeth were noted."

SYSTEMATICS

CLASS MAMMALIA ORDER CARNIVORA FAMILY CANIDAE

Tomarctus Cope 1873

Tomarctus cf. *brevirostris*, Cope, 1873

Holotype.—A lower jaw fragment A.M.N.H. 8302 from the Upper Miocene Pawnee Creek beds of northwestern Colorado (Matthew, 1924:88-96; Galbreath, 1953:34-35, 100).

Referred Specimens.—Anterior portion of a right ramus including /C-P/4: U.N.S.M. 9403 (Fig. 1, a-c). Posterior portion of a right ramus with M/1, M/2, and alveolus of M/3: U.N.S.M. 9404 (Fig. 1, d-f).

Discussion.—U.N.S.M. 9403 represents the anterior portion from the right ramus of a young adult. Its premolars show very little evidence of wear. The teeth are crowded but the tooth row remains straight, which White (1942:8) mentions as a characteristic of *Tomarctus brevirostris*. P/4 shows none of the backward tilt which is regarded as characteristic of *Aelurodon* (Matthew and Cook, 1909:373). Both the anterior and posterior borders of all the premolars are stepped. U.N.S.M. 9404 is the posterior portion, right

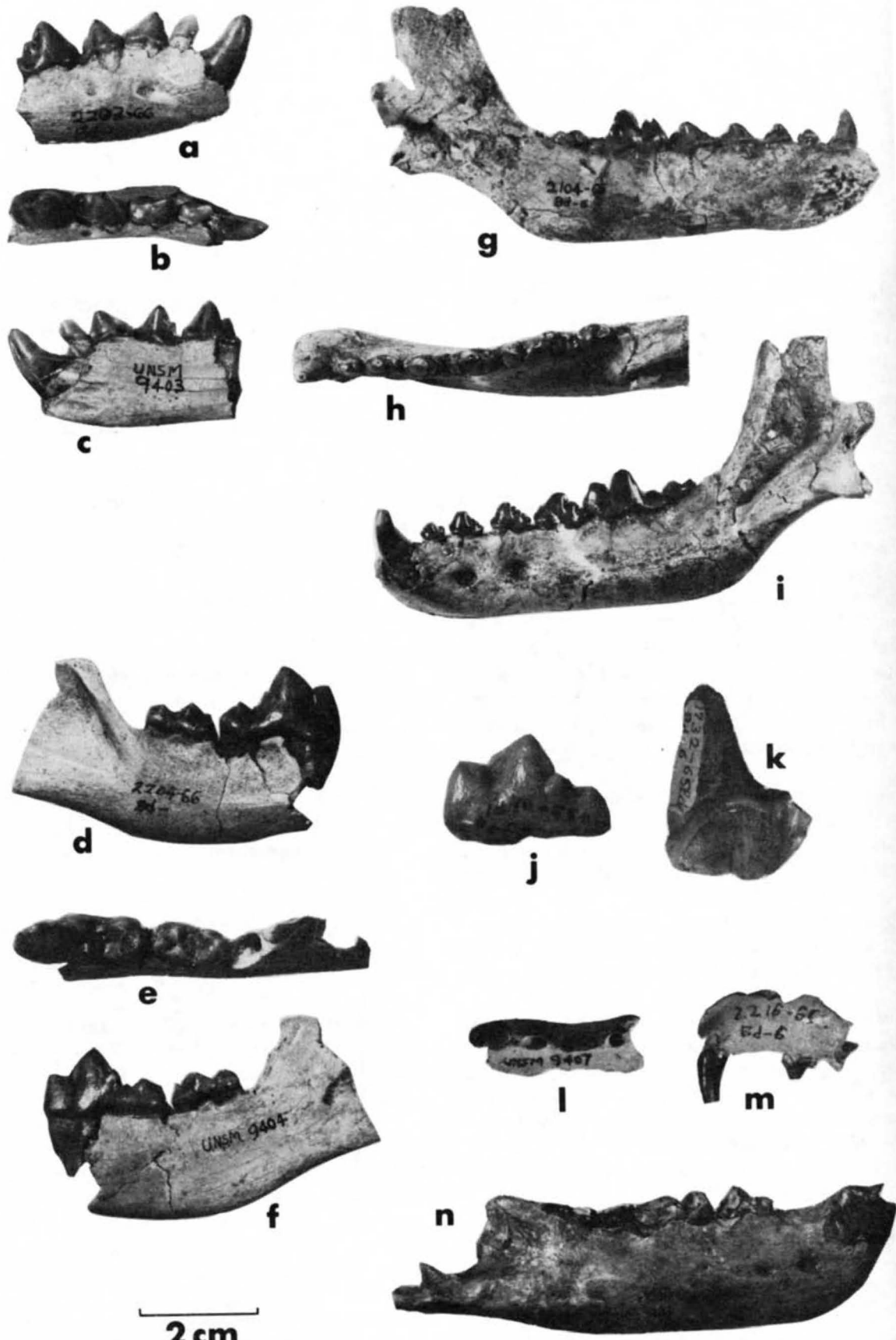


Table I:

Comparison of Measurements (in millimeters) of *Tomarctus* cf. *brevirostris*
 (U.N.S.M. 9403-9404) from the Jamber Quarry with A.M.N.H. 13836
 (After Matthew and Cook, 1909, Holotype of *Tephrocyon hippophagus*,
 Later Referred to *Tomarctus brevirostris*)
 and with F.S.G.S. V-5260 (After Olson, 1956, Holotype of *Tomarctus canavus*).
 (), Approximate or Alveolar
 A-P, Anteroposterior Length
 T, Transverse

	F.S.G.S. V-5260	A.M.N.H. 13836	U.N.S.M. 9403	U.N.S.M. 9404
A-P, /C			9.4	
T, /C			5.6	
A-P, P/1			4.7	
T, P/1			3.3	
A-P, P/2	7.0	8.5	7.7	
T, P/2	3.5	5.0	4.4	
A-P, P/3		9.4	9.0	
T, P/3		6.0	4.9	
A-P, P/4	10.0	12.0	10.5	
T, P/4	5.0	6.8	6.3	
A-P, M/1	16.0	19.7		21.0
T, M/1	7.0	9.0		8.4
A-P, M/2	9.0	10.3		12.2
T, M/2	6.0	7.2		6.8
A-P, M/3				(6.0)
T, M/3				(4.5)
Length, M/1-M/2				(33.1)
Length, M/2-M3				17.4
Length, premolars		33.0	29.3	
Length, molars		35.8		48.8
Depth jaw, below P/1*			13.9	
Depth jaw, below P/2*		21.3	15.1	
Depth jaw, below P/3*			13.8	
Depth jaw, anterior P/4			14.1	
Depth jaw, middle M/1				17.6
Depth jaw, middle M/2		25.0		19.2
Thickness, below P/2			9.0	
Thickness, below P/4			8.6	
Thickness, below M/1				11.0

*Internal measurement.

←

- Figure 1. a-c *Tomarctus* cf. *brevirostris*, U.N.S.M. 9403, partial right ramus (lingual, occlusal, and buccal views). X 1.
 d-f *Tomarctus* cf. *brevirostris*, U.N.S.M. 9404, partial right ramus (buccal, occlusal, and lingual views). X 1.
 g-i *Aelurodon haydeni*, U.N.S.M. 9401, left ramus (lingual, occlusal, and buccal views). X 1/2.
 j *Aelurodon haydeni*, U.N.S.M. 9402, partial right M/1 (lingual view). X 1.
 k *Aelurodon haydeni*, U.N.S.M. 9405, partial left P4/ (lingual view). X 1.
 l-m *Leptocyon* cf. *vafer*, U.N.S.M. 9407, partial left maxillary (occlusal and buccal views). X 1.
 n *Pseudaelurus* cf. *marshi*, U.N.S.M. 9408, partial right ramus (buccal view). X 1.

ramus, of a young adult with all molars fully erupted and showing little wear. The talonid of the M/1 shows the hypoconid-entoconid ridge that is typical of *Tomarctus* (Olsen, 1956:2).

Only *Tomarctus brevirostris* and *T. canavus* are noted as having "two subsidiary cusps anterior to the hypoconid and entoconid respectively" (Olsen, 1956:2). U.N.S.M. 9404 has only one well developed subsidiary cusp located anterior to the hypoconid.

Tephrocyon hippophagus (Matthew and Cook, 1909:373) has been synonymized with *Tomarctus brevirostris* (VanderHoof and Gregory, 1940:159). The type measurements of *Tephrocyon hippophagus* and *Tomarctus canavus* (= *Cynodesmus canavus*, according to Olsen, 1956) were used for comparison of the Jamber Quarry specimens. In size, the U.N.S.M. specimens correspond more closely with *Tomarctus brevirostris* than with *T. canavus*. The slightly smaller size of U.N.S.M. 9403 and 9404 as compared to the type specimen of *T. hippophagus* (Matthew and Cook, 1909:375) and the presence of only one subsidiary cusp instead of two is attributed to individual variation.

Measurements.—See Table I.

Aelurodon Leidy, 1858

Aelurodon haydeni (Leidy) 1858

Holotype.—Fragment of a lower jaw with P/3–M/1, and alveoli for the posterior molars. U.S.N.M. Type no. 124 from the Pliocene of northern Nebraska (Leidy, 1858; 1869, pl. 1, Fig. 10).

Referred Specimens.—Nearly complete left ramus of a young adult with the incisors and M/3 missing: U.N.S.M. 9401 (Fig. 1, g-i) (see Messenger and Messenger, 1976). Partial right M/1 lacking roots: U.N.S.M. 9402 (Fig. 1, j). Posterior half of a left P4/ with metacone and base of protocone: U.N.S.M. 9405 (Fig. 1, k).

Discussion.—In U.N.S.M. 9401 all premolars are stepped, increase gradually in size from P/1–P/4, and tilt slightly backward in the jaw. P/4 is relatively enlarged (see also McGrew, 1935:311), with the length of P/3 more than 70% of P/4 as in *A. haydeni*. M/1 of U.N.S.M. 9401 has a long talonid, large in relation to the length of the tooth, with the hypoconid and entoconid opposite and subequal. There is no evidence of any hypoconid-entoconid ridge or accessory cusps. A broad talonid and strong anterolabial cingulum are present on the M/2. The protoconid and metaconid are subequal, and with the smaller paraconid, form a trigonid. In this specimen the teeth are not crowded and are set straight in the jaw. The jaw is not massive or shortened as is typical of the *A. taxoides* group (see Gregory, 1942, Fig. 9, and VanderHoof and Gregory, 1940, for illustration and comparisons of the *A. taxoides* group).

Cook's type specimen of *Tephrocyon mortifer* (Cook, 1914) which has been referred to *Aelurodon haydeni* by VanderHoof and Gregory (1940:147), is somewhat larger than U.N.S.M. 9401, and has a double-rooted M/3. The M/3 on the Jamber Quarry specimen is missing, but appears to have had a single root. Other specific characteristics seem to correspond. U.N.S.M. 9401 is assigned to *Aelurodon haydeni* even though in some measurements it is up to one-third smaller than the type. In general the measurements of this specimen fall within the observed range of variation of the "*A. saevus* group" of McGrew (1944) which includes *Aelurodon haydeni* as its largest member.

U.N.S.M. 9402 is a partial right M/1 lacking roots. The tooth appears to be unworn and is slightly smaller than U.N.S.M. 9401, but possesses the same characteristics. The lack of wear might indicate that this tooth was unerupted at the time of the animal's demise.

U.N.S.M. 9405, the posterior half of a left P4/, is broken in such a way that the metacone and the base of the protocone are all that remain (Fig. 1, k). A strong lingual cingulum is present and the metacone is unworn. The posterior root of the tooth appears to extend from mid-way above the protocone almost to the posterior edge of the tooth.

Measurements.—See Table II.

Aelurodon sp.

Referred Specimen.—Partial left lower canine: U.N.S.M. 9406.

Discussion.—This tooth is a little smaller but compares favorably in form with the canine in U.N.S.M. 9401.

Leptocyon Matthew, 1918

Leptocyon cf. *vafer* (Leidy), 1858

Holotype.—Greater portion of a right ramus of a lower jaw, containing all the teeth except the incisors (Leidy, 1858: 21; 1869, pl. 1, Fig. 11).

Referred Specimen.—Left maxillary fragment with C/ (lacking tip) and P2/. The alveolus for P1/ and the anterior alveolus for P3/ are also present: U.N.S.M. 9407 (Fig. 1, l, m).

Discussion.—The canine is slender, oval shaped, and set at almost a right angle to the tooth row. P2/ has two roots, is slightly stepped on the anterior border and distinctly stepped on the posterior. A small cingulum is present and better developed lingually than buccally. The whole tooth is slender, delicate and little-worn. This specimen compares well with referred specimens in the U.N.S.M. Collections from the basal part of the type section of the Valentine Formation at

Table II

Comparison of Measurements (in millimeters) of *Aelurodon haydeni*
(U.N.S.M. 9401-9402) from the Jamber Quarry with U.S.N.M. 124
(After Matthew and Cook, 1909, Holotype of *Aelurodon haydeni*).

(), Alveolar

A-P, Anteroposterior Length

T, Transverse

	U.S.N.M. 124	U.N.S.M. 9401	U.N.S.M. 9402
A-P, /C			
T, /C		10.8	
A-P, P/1		9.7	
T, P/1		8.5	
T, P/1		6.0	
A-P, P/2		12.0	
T, P/2		7.4	
A-P, P/3		14.1	
T, P/3		8.3	
A-P, P/4	20.1	18.6	
T, P/4	10.0	9.8	
A-P, M/1	36.0	29.2	26.2
T, M/1	16.0	12.2	10.8
A-P, M/2	18.0	12.5	
T, M/2		8.2	
A-P, M/3		(5.5)	
T, M/3		(3.3)	
Length, /C-M/3		117.8	
Length, P/1-M/3		102.6	
Length, P/2-M/3		93.5	
Length, P/3-M/3	97.0	79.2	
Length, P/4-M/3		65.0	
Length, P/1-M/2		96.4	
Length, P/2-M/2		87.4	
Length, P/3-M/2		73.5	
Length, P/4-M/2		59.1	
Length, M/1-M/2		40.6	
Length, M/2-M/3		18.3	
Length, premolars		55.3	
Length, molars		47.3	
Depth jaw, posterior /C		27.8	
Depth jaw, posterior M/2		38.5	
Depth jaw, below P/1 *		29.0	
Depth jaw, below P/2 *		30.1	
Depth jaw, below P/3 *		30.1	
Depth jaw, anterior P/4 *		30.9	
Depth jaw, middle M/1 *	44.3	34.0	
Depth jaw, middle M/2 *		37.6	
Thickness, below P/2		15.7	
Thickness, below P/4		16.8	
Thickness, below M/1	20.0	16.5	

*Internal measurement.

the Railroad Quarry (U.N.S.M. Coll. Loc. Cr-12) near Valentine, Cherry County, Nebraska.

Measurements of the specimen are given below.

	C/	P1/ (alveolar measurement)	P2/	P3/ (anterior alveolus)
A-P	6.6	3.8	6.2	2.5
T	3.6	2.2	2.3	1.9

FAMILY FELIDAE

Pseudaehurus Gervais, 1848-1852

Pseudaehurus cf. *marshi* Thorpe, 1922

Holotype.—Both lower jaws, partially restored. Y.P.M. 12865 from the Upper Miocene (Valentine) Beds of the Niobrara River near the mouth of Minnechaduza Creek, Cherry County, Nebraska (Thorpe, 1922: 446-447, Fig. 12).

Referred Specimen.—Partial right ramus, with /C-M/1: U.N.S.M. 9408 (Fig. 1, n).

Discussion.—The teeth, with the exception of the P/3, are broken off at the jaw line. Only the lingual half of the P/3 and a piece of the anterior lingual quarter of the P/4

remain. Alveolar measurements of the teeth fall in the range between *P. marshi* and *P. intrepidus* as given by Thorpe (1922:447), but seem to correspond more closely to *P. marshi*, especially in the diastema measurement. This jaw is shorter than the type of *P. intrepidus*.

Measurements.—See Table III.

SUMMARY

The carnivore assemblage from the Jamber Quarry (Bd-6) appears to be composed of *Pseudaehurus*, one species of *Tomarctus* (2 specimens), at least one species of *Aelurodon* (4 specimens), and a *Leptocyon*. Most of the specimens represent young adults, with the exceptions being the possibly unerupted *Aelurodon* M/1, and the *Pseudaehurus* specimen. Although all of the teeth in the *Pseudaehurus* jaw were fully erupted, they are too badly broken to determine the age of the individual. The carnivores represented in this fauna and the sediments from which the fauna was recovered appear to be Lower Valentinian in age.

ACKNOWLEDGMENTS

The discovery of this important fossil quarry (Bd-6) was a direct result of the Visiting Scientist Program of the Nebraska Academy of Sciences in that Ronald Gustafson, County Extension Agent for Boyd County, requested that a speaker be sent to School District No. 1 in Boyd County, Nebraska. The Evan Lewis family had located some large

Table III:

Comparison of Measurements (in millimeters) of *Pseudaehurus* cf. *marshi*
From the Jamber Quarry with Y.P.M. 12865
(After Thorpe, 1922, Holotype of *Pseudaehurus marshi*)
and with the Holotype of *Pseudaehurus intrepidus*
(Also After Thorpe, 1922, Depository Not Given).
A-P, Anteroposterior Length

	Y.P.M. 12865	<i>Pseudaehurus</i> <i>intrepidus</i>	U.N.S.M. 9408
Length of tooth series (P/3-M/1)	36.0	44.5	40.1
Diastema between /C and P/3	8.6	14.8	8.9
A-P, P/3	9.5	11.6	11.2
A-P, P/4	12.5	14.8	13.3
A-P, M/1	16.0	19.6	16.9
Width of jaw at sectorial	9.0	-----	11.4
Depth of jaw at P/4	17.0	23.2	20.0

"elephant bones" on the Joseph Jamber farm and wished to have the specimens identified. Professor Lloyd Tanner made the Academy visit to the school in 1961 and identified the fossils. A field trip to the Joseph Jamber farm resulted in the discovery of this very important fossil locality.

We would like to thank our staunch supporters and colleagues in the Division of Vertebrate Paleontology at the University of Nebraska State Museum; namely, R. George Corner, King Richey, Dr. C.B. Schultz, Professor T.M. Stout, Professor Lloyd Tanner, and Dr. Michael Voorhies, for their counsel. Dr. Larry Martin, now of the University of Kansas, Tod Ashmun, David Nixon, Ron Marquart, and Joan Tomlinson helped us collect the specimens from the Jamber farm. Typing was done by Mrs. Rebecca Monke and Gail Littrell. We especially wish to thank Mr. and Mrs. Joseph Jamber for letting us excavate fossils on their land, and Ronald Gustafson, the Floyd McNares, and the Evan Lewis family for their aid during the period of excavation.

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THE ANTIQUITY OF *BISON LATIFRONS* (HARLAN) IN THE GREAT PLAINS OF NORTH AMERICA

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There is abundant evidence available which strongly supports the Middle Pleistocene (Sheridanian) stratigraphic position of the fossilized remains of *Bison latifrons* (Harlan) in the Great Plains of North America. This would place the geologic age of this giant beast as post-Kansas to Early Illinoian. Fourteen localities, where the bones of *B. latifrons* have been found in the central part of North America, have been examined for stratigraphic and geomorphologic evidence.

† † †

INTRODUCTION

The antiquity of the remains of *Bison latifrons* in the Quaternary deposits of North America has long been controversial. During the early part of the century, Henry Fairfield Osborn (1910) and O.P. Hay (1913, 1914, 1930) considered many of the Medial and Late Pleistocene faunas to be Aftonian in age, basing their beliefs on the research of Samuel Calvin (1909, 1911) and Buhumil Shimek (1908, 1909) in Iowa. Thus *B. latifrons* became known as "the Aftonian bison" (Hay, 1914:327). Various other workers, including W.D. Matthew (1918), also accepted this "Aftonian" age determination for faunas of various Quaternary ages, and this concept was not challenged for many years. As a result, many workers considered that there was little, if any, evidence of evolution during the Pleistocene. The remains of *Bison bison*, *B. antiquus*, and *B. latifrons* were commonly thought to be associated together at Big Bone Lick, Kentucky (Lucas, 1899; Osborn, 1910; Jillson, 1936), and, to date, there is no evidence in favor of this assumption but there is considerable evidence against it.

Most of the "Aftonian" vertebrate fossils of Calvin and Shimek from Iowa actually are Medial to Late Pleistocene in age. This was pointed out by Lugn and Schultz (1934), Lugn

(1935), and by Barbour and Schultz (1937), and a preliminary stratigraphic sequence of fossil mammals based on geologic evidence, was presented for the first time in 1934. Reed *et al.* (1965) summarized continuing efforts to refine the stratigraphic sequence of the Quaternary initiated by Lugn (1935) and his colleagues. Later, Frankforter (1971) furnished additional information on the age of the "Aftonian" vertebrates in Iowa. There has been an increasing effort to establish a more precise stratigraphic sequence of the fossil mammals as new geologic and geomorphologic data become available.

During the past forty years, it has become evident that the remains of *Bison bison*, *B. antiquus*, and *B. latifrons* do not occur in sediments of the same geologic age. Although the osteological and historical information on bison published by Skinner and Kaisen (1947) has provided an excellent foundation for further revision, these researchers, unfortunately, did not have adequate stratigraphic and geomorphological data available at the time they revised the bison nomenclature. Flerov and Zablotski (1961) pointed out that the classification of the bison by Skinner and Kaisen "does not, in our opinion, correspond to reality." Thus, there is a definite need for a revision of the classification of the bison, and it can now be attempted, based on more refined stratigraphic and geomorphologic evidence. In addition, knowledge of the stratigraphic distribution of bison remains is necessary for an understanding and proper interpretation of the morphological differences among the specimens attributed to the various genera, subgenera, species, and subspecies now used in the literature.

Precise geologic data associated with fossil mammal specimens provided Schultz and Falkenbach (1968) with

scientific information necessary for the revision of the oreodonts (another group of artiodactyls which also had long needed to be reclassified). The extensive work with the oreodonts (1934-1968) has provided an insight into the problems of bison taxonomy. The same approach has been used in determining phylogenies of the beavers and the mylagaulids (Stout, unpublished), and for other groups as well.

Such a study has also been done on the general stratigraphic distribution of bison remains (*Bison latifrons*, *B. alleni*, *B. antiquus*, and *B. bison*) and is elsewhere presented by the authors (Schultz and Hillerud, 1977a, 1977b). We now are in the process of publishing a series of eight papers under one cover on the bison of the Great Plains. These manuscripts have been in preparation for the past eight years and include computer analyses and statistical parameters which describe quantitatively a number of Pleistocene and Holocene fossil-bison samples.

Recently, there has been an increasing number of workers who have suggested that bison (including *Bison latifrons*) did not reach North America until as late as the Sangamon interglacial or even during Early Wisconsinan glacial times. For example, Robertson (1974) reported that "it is generally agreed that *Bison* probably reached North America in Early Rancholabrean times," i.e. Sangamon (last interglacial) or Early Wisconsinan (last glacial). He quoted Hibbard, *et al.* (1965), Guthrie (1970), and Sher (1971) for documentation, but he did not provide geologic evidence, and also overlooked published data from the Central Great Plains (Schultz and Frankforter, 1946; Schultz and Stout, 1948; Schultz, Tanner, and Martin, 1972). Miller (1968) presented measurements on postcranial bison elements which he identified as *B. latifrons* from Rancho La Brea. Recent studies, however, suggest that his "*latifrons*" material is only slightly larger than *B. antiquus* and is probably referable to a larger subspecies similar to *B. antiquus barbouri* (Schultz, Tanner and Martin, 1972).

Conversely, Flerov (1971) noted that he believed the bison, the mammoth, and other large mammals dispersed from Asia into America "before the maximum glaciation (Illinoian)." Our evidence certainly confirms this. P  w   (1975) reports that he has collected Alaskan specimens of mammoth and *Bison* (*Superbison*) from gravels that underlie Illinoian and Yarmouth (?) beds. Mammoth remains are plentiful in Nebraska in deposits of post-Kansan to Early Illinoian age. Other bovids also are known from these same sediments, but *B. latifrons* remains are rare. These giant forms apparently did not come to North America in as large numbers as the mammoths.

PRE-SANGAMON BISON

There are two well-known localities (Fig. 2, sites B and X on map) which should be listed to demonstrate the occurrence of pre-Sangamon bison in Nebraska. Both of these

localities contain fossil bison bones which are Illinoian in age, but are post-*Bison latifrons*. The two localities are as follows:

- (B) The presence of pre-Sangamon bison remains is well known from the Terrace-4 fill complex at the Bartek Brothers farm (University of Nebraska State Museum [U.N.S.M.] Coll. Loc. Sd-15), 26 miles N. of Lincoln, center of NE¼, sec. 12, T.14N., R.5E., Saunders County, Nebraska (Schultz and Frankforter, 1946; Lueninghoener, 1947; Schultz and Tanner, 1957; Kreycik, 1969). At this locality (see Fig. 2,B) two partial skulls (U.N.S.M. 30356 and 30358) of *Bison alleni* have been recorded from the sands (Crete Formation) below the Loveland Loess (Schultz and Frankforter, 1946). Various skeletal elements of *Bison* sp. also have been recorded from pre-Sangamon sediments at this faunal locality (Kreycik, 1969; Schultz, Tanner, and Martin, 1972). These fossils are all considered to be of Illinoian age. No *B. latifrons* remains, however, have been recorded from this locality, despite thirty years of continuing extensive study.
- (X) The occurrence of pre-Sangamon bison remains has been recorded also in the Terrace-4 complex at Buzzard's Roost (U.N.S.M. Coll. Loc. Ln-103) south and east of Brady, in W¼, SE¼, sec. 7, T.10N., R.26W., Lincoln County, Nebraska (see Fig. 2,X). A large bison radius-ulna (U.N.S.M. 45639) was found *in situ* in the Ingham Paleosol (Schultz and Martin, 1970) approximately fifty feet below the base of the Sangamon Paleosol complex and some forty-five feet above a layer of Pearllette Ash (Frankel, 1956; Schultz and Tanner, 1957, Fig. 7; see also Fig. 3, present paper). The specimen was found on August 23 at Stop 10-5 of the 1965 INQUA (International Union for Quaternary Research) Field Conference D, "Central Great Plains" (Stout, Dreeszen, and Caldwell, 1965), when the participants of the conference were visiting the Buzzard's Roost section (also known as Gilman Canyon). There can not be any question concerning the association of the radius-ulna with the Ingham Paleosol. This paleosol is in the lower portion of the Loveland (Illinoian) loess. The size of the bones would indicate the animal was within the size range of *Bison antiquus*, but larger than average. The bones instead may represent a small *B. alleni*, but a radius-ulna of the latter species was not available to us for comparison. This Loveland Loess section is one of the best known in Nebraska, and, indeed, in the Great Plains (Reed and Dreeszen, 1965; Dreeszen, 1970; Stout, *et al.*, 1971).

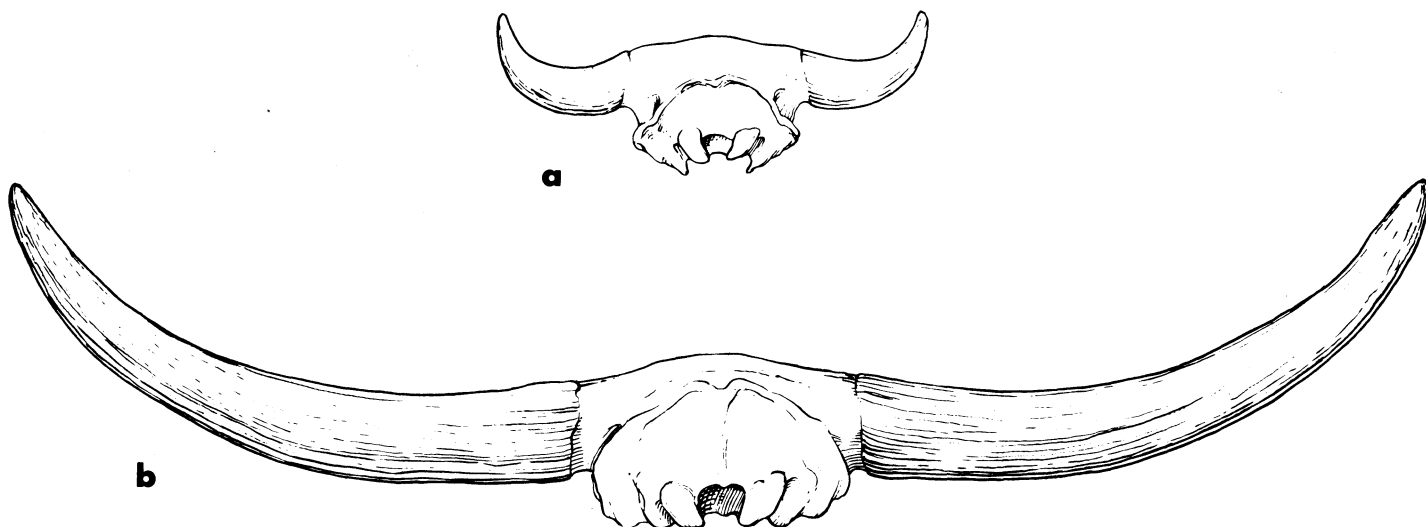


Figure 1. Comparative sizes of *Bison bison* Linnaeus (above) from the Late Holocene and *B. latifrons* (Harlan) (below) from the Medial Pleistocene of the Central Great Plains and adjacent areas.

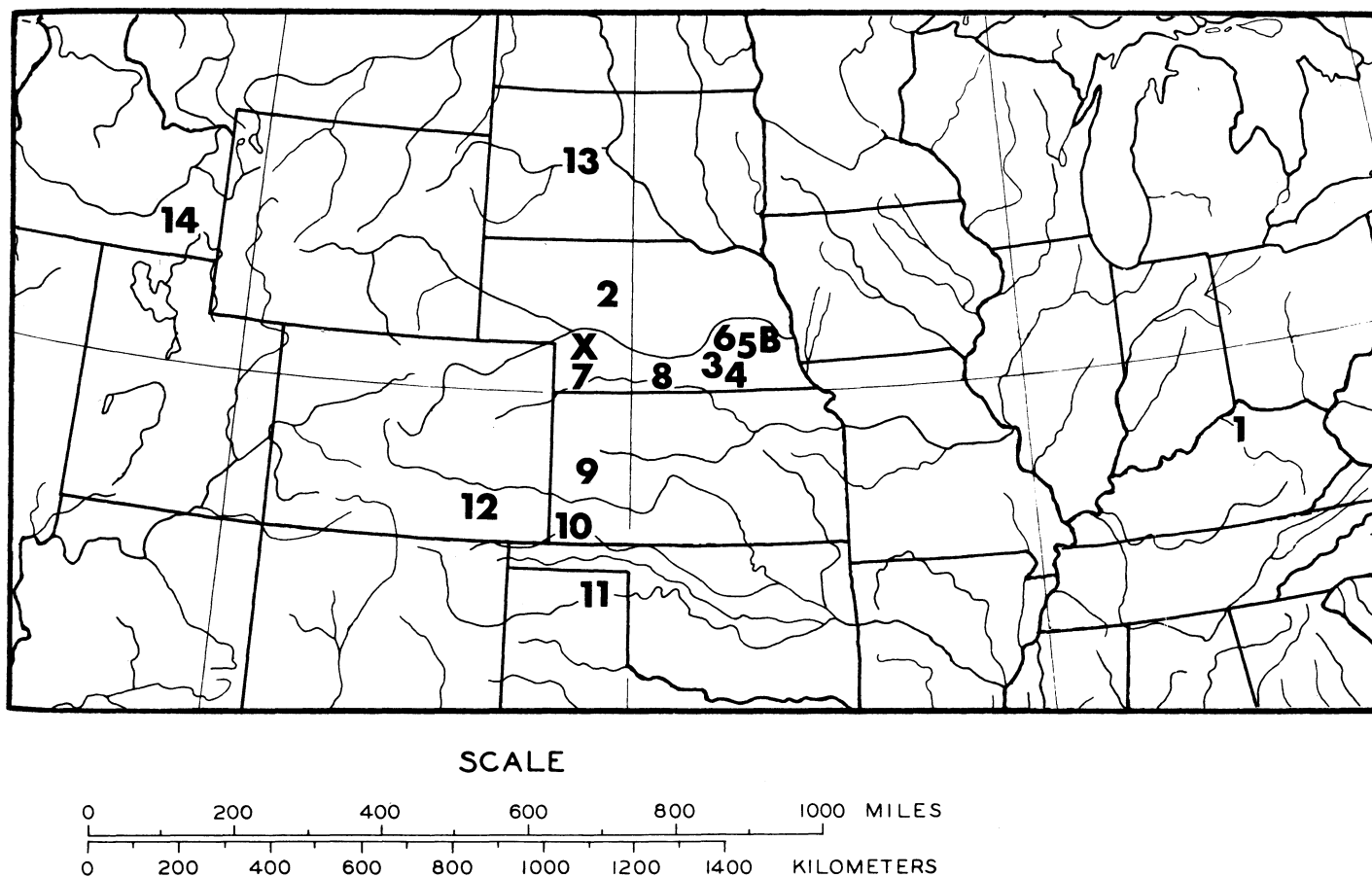


Figure 2. Map of the central portion of North America, showing approximate locations of *Bison latifrons* sites (1 through 14) which are cited in the text. Locality B: Bartek Brothers farm, Saunders County, Nebraska, where bison bones of Illinoian age have been found below the Sangamon Paleosol complex. Locality X: Buzzard's Roost (Gilman Canyon), Lincoln County, Nebraska, where bison remains have been found in the Ingham Paleosol (Illinoian, interstadial).

Figure 3. Diagrammatic interpretation of the sequence of post-Kimballian terrace-fills as developed in the Central Great Plains (from Schultz and Hillerud, 1977b; modified from Schultz and Stout, 1945, 1948, 1961; Schultz, Lueninghoener, and Frankforter, 1951; Schultz and Tanner, 1957; Schultz, 1968, 1976, 1977; Schultz and Martin, 1970, 1976; Schultz, Schultz, and Martin, 1970; Schultz, Tanner, and Martin, 1969, 1972). The placement of the complex Terrace-4 (Sheridan) fill is shown in relation to the other terrace-fills (5, 3, 2B, 2A, 1, and 0). No *Bison latifrons* remains are known from any of the post-Illinoian deposits in the areas thus far studied. Radiogenic dates from Boellstorff (1973), Izett *et al.* (1970), Izett *et al.* (1971), Izett *et al.* (1972). The geologic studies of Frye *et al.* (1968), Frye (1969), Wilman and Frye (1970), and Kukla (1970) have emphasized the importance of paleosols, loesses, tills and stratigraphic sequences in terrace fills in the correlation of Quaternary sediments.

CRITICAL LOCALITIES OF *BISON LATIFRONS* (HARLAN)

There are fourteen localities (Fig. 2) in the Central Great Plains and other areas which are critical to the understanding of the antiquity of *Bison latifrons*. These localities are in Kentucky (type locality of *B. latifrons*), Nebraska, Kansas, Texas, Colorado, South Dakota and Idaho. Locational and stratigraphic data for each specimen involved are summarized below:

(1) Boone County, Kentucky

Holotype of *Bison latifrons* (Harlan, 1825), partial cranium with occiput and base of left horncore, Academy of Natural Sciences of Philadelphia, 12993 (cast, U.N.S.M. 2496C).

Location.—Apparently from Woolper Creek ("in the bed of a creek falling into the Ohio River, a dozen or more miles north of Big-bone-lick, Kentucky," Leidy, 1869:372).

Stratigraphy.—Probably from the blue lacustrine clay under the Split Rock Conglomerate. Ray (1974:48), who studied the geology of the lower Ohio River valley from 1956 to 1967, stated, "... the Split Rock Conglomerate is here interpreted to be a kame terrace ... below the mouth of a short, now-abandoned valley that once served as a marginal sluiceway for melt-water torrents and debris from the Illinoian ice."

Discussion.—The holotype of *Bison latifrons* is not from Big Bone Lick, although many workers (Leidy, 1869:372; Lucas, 1899:769; Osborn, 1910; Hay, 1913, 1914:327; Frick, 1937:578; and others) have inferred that it was. Hay (1923:265), however, recognized the locality to be "Woolper Creek?, Boone County," which is some 12 to 14 miles north of Big Bone Lick. He also stated (p. 265) that "the presence of the species with the widely-spread horns at Big Bone Lick is doubtful." Jillson (1936:116), who did considerable research on Big Bone Lick, followed Hay and recorded only *Bison bison* and *B. antiquus* from this historic fossil locality. He did quote from other authors who had listed *B. latifrons*, but apparently assumed that the identifications were incorrect. Alfred Romer (in Jillson, p. 68) listed eight molars of *B. latifrons* from Big Bone Lick in the collections of the Museum of Comparative Zoology at Harvard College. These specimens, however, are considered by us to be referable to large individuals of *B. bison*, or possibly to small examples of *B. antiquus*. Although Romer listed fifteen separate species from Big Bone Lick based on the Harvard collection, he did not list *B. antiquus*. The holotype and other examples of *B. antiquus* Leidy are from the Big Bone Lick locality, but they are not associated with the remains of *B. bison*, except in reworked deposits (Schultz, Tanner, Whitmore, Ray, and Crawford, 1963, 1967). The bison jaws and teeth from Big Bone Lick in the British Museum (Natural History) in London,

which have been catalogued as *B. latifrons*, were examined, measured, and photographed by Schultz in 1964 and 1969. The measurements of these specimens proved to be within the range of those of *B. bison*.

Schultz, Tanner, Whitmore, Ray, and Crawford (1963: 1167; 1967:5) spent five field seasons (1962-1966) in the Big Bone Lick area deciphering the paleontology and stratigraphy of the fossil locality. Prior to this, very little attention had been given to the stratigraphic association of specimens obtained there. No examples of *Bison latifrons* were found in the extensive excavations at Big Bone Lick, and it was the consensus of the workers that the Woolper Creek area was the most probable locality for the holotype of this species. Bone fragments were found in the blue clay under the Split Rock Conglomerate exposed near the mouth of Woolper Creek; these show the same kind of preservation as the holotype of *B. latifrons*. This type of fossilization is not seen in specimens from the Wisconsinan and Holocene deposits at Big Bone Lick. Ray's extensive studies (1974:48) of the Woolper Creek area indicate that the Split Rock Conglomerate is of Illinoian age.

The widely-known fossils and deposits from Big Bone Lick have contributed much to the myth of bison variation and lack of evolution. Many earlier workers did not recognize that a number of strata of varying ages were present and, therefore, assumed that all the fossils obtained from an excavation were of the same age. This fact has colored the conclusions of many commentators on bison phylogeny. We consider that the holotype of *B. latifrons* came from deposits which are of post-Kansas to Early Illinoian age.

(2) Hooker and Cherry Counties Area, Nebraska

Bison latifrons, referred (holotype of *B. ferox* Marsh, 1877), partial horncore, Yale Peabody Museum 10910 (cast, U.N.S.M. 55164C).

Location.—Recorded in the Yale Peabody Museum catalogue as having been found along the Niobrara River of Nebraska in 1870 (see Schultz and Frankforter, 1946:5, for discussion of location). The Yale Expedition of 1870, which obtained the specimen, did not reach the Niobrara River, but did go to the "Loup Fork of the Platte," which is the area of the fossiliferous Middle Loup River valley in Hooker and Cherry counties. Marsh's expedition appears to have been seeking the fossiliferous locality discovered by the F.V. Hayden - G.K. Warren exploration party of 1857 (Hayden, 1858; Leidy, 1869). The color and preservation of Marsh's example of *B. latifrons* compare favorably with those of some of the fossilized remains from the U.N.S.M. collecting localities along the Middle Loup River and the North Prong of the Middle Loup.

Stratigraphy.—We consider that the holotype of Marsh's *B. "ferox"* came from the post-Kansas to Early Illinoian

fossiliferous deposits which are well developed along the Middle Loup River, but definitely not associated with the Blancan faunas (Broadwater) which are derived from underlying sediments.

Discussion.—A distal portion of a radius-ulna (U.N.S.M. 30360) was found by a U.N.S.M. field party in 1930 north of Mullen, Hooker County, on the north side of the Middle Loup River. This specimen was derived from sediments which are of post-Kansan to Illinoian age. The preservation of the Yale specimen (Y.P.M. 10910) would suggest that it was obtained from the same sediments. Smith (1965, 1968) and Lugen (1968) considered the sand dunes of Nebraska to have originated during Illinoian and Wisconsin time. It should be noted that no *B. latifrons* remains have ever been recovered from the aeolian sands or their associated paleosols in the Sandhills region.

(3) Clay County, Nebraska

Bison latifrons, referred (holotype of *B. "angularis"* Figgins, 1933), partial skull with horncores, Hastings Museum 4710 (cast, U.N.S.M. 30326C).

Location.—1½ miles east and 3½ miles north of Sutton, Clay County, on north side of School Creek drainage, near center of N½, SE½, sec. 13, T.3N., R.5W.

Stratigraphy.—From gravels below Loveland Loess (Illinoian) in the Terrace-4 (Sheridan) fill. The skull was found in a dry-gravel pit, in strata well exposed at the time of the discovery. Lugen and Schultz (1934:390) considered the gravels to be "Grand Island (Kansan)," but these deposits are now considered to be of post-Kansan to Illinoian age (Schultz and Stout, 1948).

Discussion.—This example of *B. latifrons* is smaller than the holotype and other examples of the classical phase. Perhaps it could be considered a geologic variety.

(4) Saline County, Nebraska

Bison latifrons, referred (holotype of *B. "rotundus"* Figgins, 1933), partial skull with horncores, Colorado Museum of Natural History 1187, and associated radius-ulna, U.N.S.M. 5476 (both specimens associated with the holotype, left ramus, of *Castoroides ohioensis nebraskensis* Barbour, 1931, U.N.S.M. 2538).

Location.—U.N.S.M. Coll. Loc. Sa-102, 2 miles south and 4+ miles west of Dorchester, Saline County, in a dry-gravel pit on north side of Turkey Creek near center of E½, NW¼, sec. 33, T.8N., R.2E.

Stratigraphy.—All specimens mentioned above were collected by Otto Chubb, and the locality was investigated by Lugen and Schultz (1934:390-391) when the gravel pit was

being worked. They concluded that the gravels were "Grand Island (Kansan)." These fossil-bearing sediments underlie the Sangamon Paleosol and Loveland Loess (Illinoian). The site has been studied many times since then, and the conclusions remain the same, but these sediments now are considered to be post-Kansan to Early Illinoian age rather than Kansan.

Discussion.—Thompson M. Stout (oral communication) states that the holotype of *Castoroides ohioensis nebraskensis* Barbour (1931), which was associated with the holotype of *Bison "angularis"* (= *B. latifrons*), is in the same stage of evolution as shown in examples of "*Castoroides*" from the well-known Sheridanian fossil quarries south of Hay Springs and Rushville in Sheridan County, Nebraska. Stout reports that the Saline County fossil locality is "definitely pre-Sangamon and pre-Loveland, and surely equivalent to the Grand Island and Crete deposits (post-Kansan to Illinoian) or Terrace-4 (Sheridan) valley-fill of the Central Great Plains."

(5) Lancaster County, Nebraska

Bison latifrons, referred, two partial horncores belonging to the same individual, U.N.S.M. 30956.

Location.—U.N.S.M. Coll. Loc. Lc-101, 3 1/8 miles west and 3/4 miles south of Emerald, Lancaster County, in a dry-gravel pit in the center of SE¼, sec. 30, T.10N., R.5E.; collected by Lloyd G. Tanner, Marian Schultz, and Bertrand Schultz (1954).

Stratigraphy.—From sands and gravels below fine sands of Illinoian age.

Discussion.—The specimen was obtained from the U.S. Army Engineers Borrow Pit, which also was known as the Pickle Farm Pit. This gravel and said pit was extensively used by the U.S. Army Engineers for borrow material for construction at the Lincoln Air Force Base during the Korean War. As a result, some splendid geologic exposures were made available. Eugene Reed, State Geologist, and Thompson M. Stout, Lloyd G. Tanner, and C. Bertrand Schultz of the University of Nebraska State Museum and Department of Geology staffs spent considerable time studying the stratigraphy of the area. The sediments appear to be part of the Terrace-4 (Sheridan) fill, which is well developed in the area. The operators of the pit had been instructed to watch out for fossils, and the discovery of a skull of *Bison latifrons* resulted. Unfortunately, the bulldozers destroyed much of the skull, but portions of both horncores were salvaged.

(6) Hamilton County, Nebraska

Bison latifrons, referred, portion of horncore, U.N.S.M. 30324.

Location.—Near Giltner in SW. Hamilton County, Nebraska.

Stratigraphy.—Lugn and Schultz (1934:391) considered the dry-gravel pits in the vicinity of Giltner to be “Grand Island (Kansan),” but we now consider them to be of post-Kansas to Early Illinoian age.

Discussion.—The horncore, U.N.S.M. 30324, was collected in 1928 by C.E. Dawson, and the gravels from which the specimen was derived were well exposed when Lugn and Schultz visited the locality. The gravels definitely underlie Loveland Loess.

(7) Hitchcock County, Nebraska

Bison latifrons, referred, partial right horncore, U.N.S.M. 30359.

Location.—Near Trenton in Hitchcock County, Nebraska.

Stratigraphy.—Lugn and Schultz (1934:391) had difficulty in establishing the exact site where the specimen had been collected. The horncore had been found in a dry-gravel pit north of the Republican River, according to the meager records available. Gravels in the area which produced fossils of the same type of mineralization as the horncore were considered by Lugn and Schultz (1934:391) to be “probably Early Pleistocene,” but these deposits are now thought to be post-Kansan to Early Illinoian since they are mantled with Loveland (Illinoian) Loess in the Terrace-4 (Sheridan) fill.

Discussion.—The horncore, U.N.S.M. 30359, was discovered by former Governor R.W. Furnas in 1892 in a dry-gravel pit. The late Paul Edwards, a native of Benkelman, a former graduate student in the Department of Geology, University of Nebraska-Lincoln and a graduate assistant in the University of Nebraska State Museum, spent considerable time from 1970 to 1975 trying to find more evidence of *B. latifrons* in the Trenton and Benkelman areas. However, no further examples of the giant bison were uncovered, but additional stratigraphic evidence was obtained (personal communication with C. Bertrand Schultz).

George Corner (1977) has undertaken the salvage of a considerable number of vertebrate fossils from various sand-and-gravel borrow pits in both Red Willow and Hitchcock counties. These borrow pits are of the wet-gravel type along the Republican River, and the fossils are pumped out along with the sand and gravel. The fossils are primarily Rancholabrean and Holocene (Sangamonian, Wisconsinan, and Recent) in age, and the preservation of the bones from these sands and gravels is distinctly different from the mineralization of the horncore of *B. latifrons* from Hitchcock County (U.N.S.M. 30359).

(8) Franklin County, Nebraska

Bison latifrons, referred, partial horncore, U.N.S.M. 55181.

Location.—2½ miles west and 2½ miles south of Napoleon, Franklin County, on west side of Rebecca Creek in SE¼, NW¼, sec. 23, T.1N., R.16W.; collected by King A. Richey, 1971.

Stratigraphy.—Specimen found in the basal sediments of a Pleistocene fill overlying clay and Niobrara (Cretaceous) chalk.

Discussion.—The lithology and geomorphology of the locality indicate that the horncore was buried in a meandercore of a Terrace-4 (Sheridan) fill. Terrace-4 is well developed in this area. The specimen is considered to be of post-Kansan to Early Illinoian age.

(9) Scott County, Kansas

Bison latifrons, referred, partial skull with horncores, U.N.S.M. 30361.

Location.—5 miles north and 3½ miles west of Scott City, Scott County, from Geist (Christy) Gravel Pit in NE¼, SW¼, sec. 21, T.17S., R.33W. (Waite, 1947, p. 128).

Stratigraphy.—From terrace deposits of Beaver (Ladder) Creek Valley in gravels intermixed with sand, silt, and clay (Waite, 1947). Waite reported that the terraces are of cut-and-fill origin, and the trough was cut to its maximum depth early in the Pleistocene, after which several successive periods of channel-filling resulted in great thickness of undifferentiated Pleistocene deposits in the buried trough.

Discussion.—Schultz, who obtained the partial skull from Scott City for the University of Nebraska State Museum, has visited the fossil locality several times and has studied the terrace fills in the area. On one occasion he accompanied M.K. Elias, John C. Frye, Claude W. Hibbard, and Eugene C. Reed on a field trip (Elias, *et al.*, 1945) and a stop was made at the Scott City bison site. Reed and Schultz concluded that the stratigraphic and geomorphologic evidence at the Geist (Christy) Gravel Pit indicated that the gravels were a part of the Terrace-4 fill, which is well exposed in the area. Thompson M. Stout (oral communication), who also has examined the site, agrees with this conclusion. Two mammoth teeth (Waite, 1947, Pl. 15, B-C, D-E) were found at the Geist (Christy) Gravel Pit and were identified as “*Parelephas columbi*,” but we question this identification. The enamel is much too heavy for this Late Pleistocene species, and the teeth compare favorably with these from the Medial Pleistocene examples from the Sheridan County, Nebraska fossil mammal localities at Hay Springs and Rushville (see Schultz, Tanner, and Martin, 1972, on the evolutionary importance of enamel thickness). Hence, this is additional evidence for the antiquity of *Bison latifrons* at this locality.

(10) Meade County, Kansas

Bison latifrons, referred, partial skull, University of

Location.—“Along the banks and bed of Shorts Creek (locally known as Lone Tree Arroyo) in SW¼, sec. 32, T.33S., R.29W.” (Hibbard, 1955, p. 194), on “the Jinglebob pasture of XI Ranch,” Meade County, Kansas.

Stratigraphy.—The stratigraphy of this site has been controversial, but with the evidence at hand we regard the Jinglebob Local Fauna to be of post-Kansan to Early Illinoian age.

Discussion.—Hibbard (1955) regarded the Jinglebob Local Fauna as “inter-glacial (Sangamon?)” but used paleoclimatic and invertebrate faunal evidence to reach this assumption. We feel that this is excellent supportive evidence but it can be questioned if used as primary documentation. Hibbard and Taylor (1960:62) stated that “the Jinglebob sediments were deposited . . . after dissection of the High Plains surface . . . this dissection can be dated no older than late Yarmouth. The oldest fossils found in sediments younger than this dissection are Illinoian.” The High Plains surface, however, had been dissected during the post-Kimblian and pre-Blancan, and again during the post-Kansan and pre-Illinoian times (Schultz and Stout, 1945, 1948; Schultz, Lueninghoener, and Frankforter, 1951). Thompson M. Stout (Stout, *et al.*, 1965, p. 69) in correlating this Meade County locality with Nebraska localities states, “It is to be noted that the Jinglebob Site is not Sangamon, as claimed, but pre-Loveland, in the lower part of a Terrace-4 valley fill.” Stout had studied the stratigraphy of the site on various occasions and arrived at his conclusions on geomorphologic, stratigraphic, and lithologic, as well as faunal evidence. Schultz also has visited the Jinglebob Locality with Hibbard and others, and independently arrived at the same conclusions as Stout. We therefore consider the example of *Bison latifrons* from this locality to be of post-Kansan to Early Illinoian age.

(11) Lipscomb County, Texas

Bison latifrons, referred, skull, Panhandle-Plains Historical Museum, 2315-1 (G.E. Schultz and C.H. Lansdown, 1972).

Location.—“Along the north bank of Sand Creek, one quarter mile east of Farm-to-Market Road 1920 in the SW¼, SE¼, NW¼, sec. 421, Blk. 43, H. and T T.C. Ry. Co. Survey, Lipscomb County, Texas” (Schultz and Lansdown, 1972), on the ranch of Sam Waters.

Stratigraphy.—From medium to coarse-grained, gray to brown sand in the base of a “Late Pleistocene terrace” (Schultz and Lansdown, 1972). Evidence, however, obtained by University of Nebraska State Museum field parties in 1939, 1946, 1955, and 1956 on Sand Creek at the Sam Waters ranch and adjacent areas indicates that sands are at the base of a Terrace-4 (Sheridan) fill, and thus the age would be post-

Kansan to Illinoian.

Discussion.—Members of the University of Nebraska State Museum field parties studied the stratigraphy and geomorphology of the Sam Waters ranch area in conjunction with the excavation of the *Lipscomb Bison Quarry* in 1939, 1946, 1954, and 1955. The bison quarry (U.N.S.M. Coll. Loc. TEX-1) is located near the head of Sand Creek, a branch of Wolf Creek, on the Sam Waters ranch to the west of the *Bison latifrons* site. The *Lipscomb Bison Quarry* site was reported to the University of Nebraska by Charles H. Falkenbach in 1938, and excavating privileges were obtained in 1939 from the Frick Laboratory, American Museum of Natural History in exchange for similar rights at certain Nebraska fossil quarries. The ranch was owned by Commodore Hopper, who later sold it to Sam Waters. The quarry was first worked from June 10 to August 26, 1939 (Schultz, 1943), and thirty-eight boxes and crates of *B. antiquus taylori* remains, associated with twenty-nine Folsom artifacts (projectile points, knives, scrapers, etc.) were recovered. The quarry was worked again by a U.N.S.M. field party in the summer of 1946, and it was also visited in 1954 and 1955 in order to obtain additional geologic evidence. In 1939 a topographic map showing the relation of the quarry site to the region along Sand Creek was made by members of the field party. Several Holocene and Pleistocene terraces, including Terrace-4, are well developed along the creek. The 1939 field party included the following: John Adams, James Crosby, William Hendy, and Marian Schultz, and the excavation was accomplished under the direction of Bertrand Schultz. Robert Kubicek and Harry Tourtelot joined the field party for the month of August.

Weldon Frankforter and Bertrand Schultz supervised the 1946 excavations and studied the stratigraphy and geomorphology of the Sand Creek and Canadian River areas. During the summers of 1954 and 1955, Lloyd Tanner and Bertrand Schultz continued the study of the terrace fills at the Waters Ranch and adjacent areas. The locality where the *B. latifrons* skull was found also was studied, and it was the consensus of Frankforter, Tanner, and Schultz that the sands at the base of the high terrace were associated with the Terrace-4 (Sheridan) fill.

(12) Fremont County, Colorado

Bison latifrons, referred, partial horncore, U.S. Geology Survey Denver-720 (U.S. National Museum 25912; cast, U.N.S.M. 55168C. The U.N.S.M. cast was obtained by courtesy of Dr. G. Edward Lewis, U.S.G.S., Denver).

Location.—Fremont County Highway Department gravel pit in SW¼, NE¼, sec. 26, T.18S., R.70W., Fremont County, Colorado (Lewis, 1970; Scott and Lindvall, 1970).

Stratigraphy.—From Slocum Alluvium, Canon City section. Specimen was found “in a sand lense 5 ft. above the base” of the section (Scott and Lindvall, 1970).

Discussion.—Scott and Lindvall have suggested that the sediments of the Slocum Alluvium, “which contained the *B. latifrons*, probably are Sangamon in age.” We must question this dating on the basis of the interpretation of the geomorphic evidence. In this area the geomorphology and stratigraphy are extremely complex, and have been studied intensively by many workers. Schultz has visited the section on several occasions and also has discussed these problems with Scott and others. A case for an earlier date can be defended and further study may resolve the question of the dating of *B. latifrons* at this locality.

Scott and Lindvall do quote B.J. Szabo (personal communication, 1968) as obtaining a date of 160,000 years B.P. on a sample of bone from the bison horncore. However, they question the validity of this date because a new radiogenic method (using protactinium) was used. Such a date would indicate a pre-Sangamon origin of the Canon City specimen.

(13) Haakon County, South Dakota

Bison latifrons, referred, skull with left P^4-M^3 , right P^3-M^3 , left horncore complete, and right horncore tip abraded, South Dakota School of Mines 5889 (Green and Martin, 1960).

Location.—From the Ralph Jones quarry, 1.2 miles north of Midland, South Dakota, in SW $\frac{1}{4}$, SW $\frac{1}{4}$, sec. 31, T.2N., R.25E., Midland Quadrangle, Haakon County.

Stratigraphy.—From a cross-bedded sand and gravel deposit.

Discussion.—Green and Martin define the specimen as Late Pleistocene in age: “The SDSM specimen comes from the highest of several terraces in the area and the oldest possible dating is Iowan.” The authors cite Flint (1955) and interpret Crandell’s 1954 geological map (1:62500) of the area to determine the age of the Pleistocene terraces along the Bad River.

We disagree with the conclusions of these writers that “*B. latifrons* is found only in deposits of Late Pleistocene Age.” Data presented earlier in this paper have totally refuted this sweeping generalization. Field studies of terrace stratigraphy, which culminated in a paper by Schultz, Lueninghoener, and Frankforter (1951), included extended visits to the terrace deposits along the White, Bad, and Missouri Rivers, during the field seasons from 1946 through 1949. Much of the work was accomplished in company with R.F. Flint, D.R. Crandell, H.E. Simpson, and C.R. Warren. Frankforter and Schultz identified the majority of the vertebrate fossils recovered by the field parties from the various terrace fills (Flint, 1955). Contrary to the conclusion of Green and Martin mentioned above, Flint has stated (p. 161) that sediments older than “Late Pleistocene” are present. The highest terrace, Terrace-4 (Sheridan) is well developed along the White River,

only 20 miles south of the Haakon County *B. latifrons* site. These high terrace fills and others near Chamberlain, South Dakota, have yielded local vertebrate faunas of undoubted Sheridanian age. Therefore, we can assume that the Haakon County sand and gravel deposits which produced the *B. latifrons* specimen may be of Illinoian or earlier age, and need not be younger than Iowan, and “Late Pleistocene,” as Green and Martin concluded.

(14) Bingham County, Idaho

Bison latifrons, referred, five cranial specimens and associated postcranial material, reported by Hopkins (1951) and Hopkins, Bonnicksen and Fortsch (1969): the “Whitlow specimen,” found in 1933 by Wayne B. Whitlow, now apparently displayed at Pocatello High School; the “Hopkins specimen” (“*B. latifrons* I”); “*B. latifrons* II”; “*B. latifrons* III”; Idaho State University Museum 2252, with which is associated a partial tibia (I.S.U.M. 2633) and other skeletal elements. A number of other cranial specimens have been recovered since 1969 (George E. Jakway, personal communication, 1976).

Location.—The “Whitlow specimen”: from the east beach of American Falls Reservoir, SE $\frac{1}{4}$, SE $\frac{1}{4}$, sec. 9, T.6S., R.32E. (Hopkins, 1951); the specimens “*B. latifrons* I” and “II,” apparently from the same site, “. . . toward the north-east end of the fairly large bay in the SE $\frac{1}{4}$, sec. 3, T.6S, R.32E . . . from the lower beach . . .”; “*B. latifrons* III” and I.S.U.M. 2252 from “. . . a short distance up reservoir from, but within sight of, this same bay. . . from the upper beach. . .” (Hopkins, Bonnicksen and Fortsch, 1969).

Stratigraphy.—From *Bed E* (cobble gravel with layers of sand). “The known stratigraphic range of *Bison latifrons* is restricted to *Bed E*.” (Hopkins, Bonnicksen and Fortsch, 1969). These writers note that a 30-foot difference in elevation exists between the “lower beach” and the “upper beach” sites. *Bed E* is overlain by “alternating beds of silt and sand” capped by a possible fossil soil and more beds of “diatomaceous blocky clay” (*Beds D* and *C*). These three strata are assigned by Carr and Trimble (1963:G34) to the “American Falls Lake Beds.” They correlate *Bed E* with the basal gravel, “probably Illinoian in age,” which is exposed in a section in the Snake River Bluffs near Neeley, Idaho.

Discussion.—Hopkins, Bonnicksen and Fortsch (1969) quote Trimble’s conclusion (personal communication) that the *Bed B*, overlying the “American Falls Lake Beds” is a part of the fill of the “Aberdeen Terrace.” These writers accept with reluctance the Illinoian age of the lowest *Bed E*, apparently influenced by the affinities of their associated faunas with the Jinglebob Local Fauna, which Hibbard (1955) had tentatively considered to be “interglacial (Sangamon?)” in age.

We suggest that the beds containing the *B. latifrons*

specimens at American Falls Reservoir may be of Early Illinoian, or even pre-Illinoian, age. We attach great significance to the presence of a prominent paleosol complex capping the *Bed D* (see "Fossil soil?," Fig. 1, Hopkins *et al.*, 1969). It is very apparent that the sedimentary mechanism in this area is not a simple lacustrine basin infilling. Numerous rodent burrows associated with the paleosol, and containing fossil remains of *Spermophilus* (= *Citellus*) and other microvertebrates, clearly indicate a terrestrial environment for at least a portion of the time of deposition.

A radiogenic date (W-358, Rubin and Alexander, 1958: 10) from a sample of charcoal taken from beneath the facial portion of a *B. latifrons* skull by Marie Hopkins prior to November, 1956 indicates an age of "greater than 32,000" years B.P. We would suggest "much greater than . . .", perhaps by a factor of ten or more.

Various members of the University of Nebraska State Museum paleontological and geological field staff have independently visited the Idaho *B. latifrons* locality in company with Marie Hopkins. On one occasion (1958), Schultz spent ten field days at the American Falls reservoir sites (including both the *B. latifrons* and *B. alleni* localities) in company with G. Edward Lewis, Marie Hopkins, Dwight Taylor, Claude Hibbard, Harold E. Malde and other workers, and made extensive field sections, measurements, and observations on the geomorphology of the region. The Nebraska workers (T.M. Stout, W.D. Frankforter, G.C. Lueninghoener, L.G. Tanner, and C.B. Schultz) have all been strongly impressed by the striking similarities of the section at the American Falls Reservoir with Terrace-4 (Sheridan) fill complexes in the Great Plains. The Terrace-4 fill, as well as the fills of Terraces -5, -3, -2, and -1, have been found to be of regional extent in the Interior Plains (Schultz and Stout, 1948; Schultz, Lueninghoener, and Frankforter, 1951; and subsequent publications), and it is not unlikely that similar terrace fill complexes would occur to the west of the Rocky Mountains, since the sedimentary mechanism was primarily climatically controlled.

We think that it is significant that the remains of *Bison latifrons* (Hopkins, 1951) and *B. alleni* (Gazin, 1935; Hopkins, 1951), although found in the same vicinity east of the American Falls Reservoir, do not occur in the same stratum. The *B. alleni* remains are from higher sands and gravels in the terrace fill complex, and Hopkins (1951) concludes that "*B. (Gigantobison) latifrons* seemingly occurs at a lower stratigraphic level in Southern Idaho than does *B. alleni*." This datum confirms evidence previously reported from Great Plains sites.

CONCLUSIONS

Evidence at hand indicates that *Bison latifrons* remains are derived from deposits of post-Kansan to Early Illinoian age. We are aware of at least 13 other sites from which this

species has been reported, but we have not considered them in this paper because there have been no precise stratigraphic data associated with the specimen(s).

Although we have suggested that there was a sequential evolution of bison forms from the largest (*B. latifrons*) through *B. alleni* and *B. antiquus* to the present plains bison (*B. bison*) we cannot accept the concept of a monophyletic lineage of bison in North America. We believe that after *B. latifrons* became established in North America there evolved a number of different contemporary "paleospecies" which inhabited areas with different ecological conditions. Some of these "paleospecies" may have been ancestral to several phylogenetic lineages which continued throughout portions of Late Quaternary time.

The general tendency toward smaller size was a gradual one requiring considerable time (probably at least one-half million years), and was not saltatorial. Possibly the evolution was influenced by periodic invasions of small numbers of bison from Asia, but there can be no acceptance of the extinction-and-invasion mechanism suggested by Skinner and Kaisen (1947) as a possible explanation for the apparent "macro-evolution" which they hypothesized.

We present the data in this paper to aid in the documentation of the early history of the bison in North America. Misidentification of numerous specimens and misinterpretation of stratigraphy has clouded the general understanding of the bison phylogeny. The hypothesis here presented regarding the post-Kansan to Early Illinoian age of *B. latifrons* is properly subject to continued testing. We plan to do this and hope that other workers will extend their research into the stratigraphic documentation of *B. latifrons* specimens.

ACKNOWLEDGMENTS

We wish to express our sincere thanks to the following for assistance in the preparation of this manuscript: John Boellstorff, George Corner, James Gunnerson, Larry Martin, Marian Schultz, Lloyd Tanner, and Michael Voorhies for counsel and encouragement; Karen and Charles Messenger for curatorial help and preparation; Valerie Blake, Mary Halsey, Gail Littrell, and Rebecca Monke for typing; Mary Tanner for preparing Figure 1 and Martha Haack for Figures 2 and 3; the staff of the University of Nebraska State Museum for sharing research space; and the officers of the Nebraska Academy of Sciences for encouraging Quaternary research.

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FRONTIERS OF NEBRASKA GEOLOGY

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At this bicentennial time, it is appropriate to reflect not only upon geological progress, but also to consider the future.

Historically, many themes could be developed, such as has been done recently by Challinor (1971). British geology also was just beginning in 1796 when James Mackay, a Scot in the employ of the Spanish, made perhaps the earliest geological observation in what is now Nebraska. Soon after, by 1812, the Yellowstone Expedition line of forts was planned for the western frontier of the United States, along the Missouri River border; only two forts were established. One of these was Fort Atkinson (1820), the largest and farthest outpost. Geological descriptions multiplied thereafter. By 1863, the period of initial geological exploration ended with the work of Jules Marcou along the Missouri River. He was the last of the French explorers, bringing to an end three centuries of effort (beginning with Coronado, for the Spanish, in 1541).

Looking ahead, we should take pride in the richness of the geologic record for this region, especially with regard to the Quaternary, Tertiary, Cretaceous, and Late Paleozoic. Refined global correlations and stage-reclassification should be primary objectives. Buried soils and unconformities punctuate the record, suggesting that "event stratigraphy" rather than Ager's "golden spike" should be given emphasis. Climatic fluctuations probably have been with us always, to be linked with advances and retreats of the sea here or elsewhere.

† † †

INTRODUCTION

The earliest frontier in Nebraska geology was intimately associated with the discovery and exploration of a new land, but the later frontiers have been of a wholly different character. They have consisted of progressive reassessments, in entirely new ways, of accumulated information, so that now we must attempt to place Nebraska geology in a global perspective. The approach to problems at any given time is dependent to a considerable extent upon the way the *tradition* has developed and how our experience has prepared us. To look at them differently requires much effort and the application of the method of multiple working hypotheses. Or, like putting on a variety of colored spectacles (Rudwick, 1975), we must try to observe through each other's eyes. However, we must all confess to experiencing periods of "blindness" as we attempt to solve certain problems, by not observing carefully enough what we later consider to have been obvious.

Historically, we can trace numerous *themes* that have dominated the development of Nebraska geology, as with any

region (see Challinor, 1971, and his method of treating British geology; also Porter and Poulton, 1977), but we should pay particular attention to the chronologic development of ideas. I am reminded of the often-quoted aphorism of George Santayana that seems to me to be appropriate here: "Those who cannot remember the past are condemned to repeat it." (1914, *The Life of Reason*, Vol. 1).

EXPLORING THE MISSOURI

In the early days of last century, the Missouri River was the western boundary of the United States; there keen competition existed among the American, Spanish, French, and British furtrappers. These were the "beaver men" (Sandoz, 1964; Nasatir, 1952) who, both before and after the Lewis and Clark Expedition of 1804-1806, found their way up the Missouri and even farther west. Among the most interesting of the later group were Jim Bridger and James Clyman (Camp, 1928), but of the pre-Lewis and Clark men, two require special mention.

James Mackay (Diller, 1955; Nasatir, 1952) was a Scot employed by the British and then by the Spanish, and John Evans had come up the Missouri in search of a tribe of supposed "Welsh Indians." The explorations of these two frontiersmen are difficult to differentiate, but Mackay reported in 1796 finding a thigh-bone, seemingly of a mastodont or mammoth, along what is now the Keyapaha River of north-eastern Nebraska (Diller, 1955:127). The history of the maps of Mackay and Evans, some copies of which were carried by Lewis and Clark, has been brought up-to-date by Wheat (1957, 1:161-164, 245-246). So much has been written concerning the latter expedition that reference need only be given here to two recent summaries (Jackson, 1962; Osgood, 1964). Several fossils were collected and a few geological observations were made by them along the upper Missouri in 1804.

By 1812, the Yellowstone Expedition line of forts was planned for this western frontier, but only two forts were established. One of these was Fort Atkinson, the largest and farthest outpost, established in 1820 at the Council Bluffs, just north of what is now Omaha. It was built on higher ground, only a short distance from the Engineer Cantonment which had been constructed a year earlier.

The first steamboat to ascend the upper Missouri was the *Western Engineer* in the late summer of 1819 (Dillon, 1967:96). On board were Stephen H. Long and his men, who wintered at the Council Bluffs (Engineer Cantonment). The following spring, they were joined by Edwin James, who succeeded Thomas Say as the geologist, zoologist, and botanist of the Long Expedition. His report of the journey up the Platte to the Rocky Mountains (James, 1822-1823) is chiefly a descriptive narrative, best known for the notion of a Great American Desert (Dillon, 1967:100-104).

Geological observations increased rapidly after 1819 along the rivers of what is now Nebraska, and, after the 1830's, overland. European visitors included three that are of considerable interest.

In 1823, Paul Wilhelm, Duke of Württemberg (nephew of King Friedrich of Württemberg), traveled up the Missouri beyond the mouth of the White River, a journey that he repeated from December, 1829 to February, 1830 (Lottinville, 1973). Inquiry in Stuttgart some years ago (personal communication from Karl Adam) revealed that his journals and other records have survived and are preserved in the archives there.

In 1833-1834, Prince Maximilian zu Wied-Neuwied journeyed up the Missouri, accompanied by his talented artist, Karl Bodmer, and they left a precious record of their travels that has been in the custody of the Joslyn Art Museum in Omaha since 1962 (Goosman in Thomas and Ronnefeldt, 1976). The vivid watercolors of Bodmer, together with the work of other early painters such as Alfred Jacob Miller and George Catlin, allow us to see through their eyes what this region and its Indian inhabitants were like nearly a century and a half ago.

The 1863 visit by the geologist Jules Marcou (1864) to Nebraska City and Omaha, as well as to other sites along the Missouri River, may be taken as the end of the long period of French exploration of this region, a period that had begun with De Bourgmond in about 1724 (Folmer, 1937; 1939). The centennial observance of this event was on the occasion of the 1963 "mission" to Nebraska by René Lavocat of the Paris Museum (Muséum d'Histoire naturelle de Paris). He accepted my invitation, on behalf of colleagues at the University of Nebraska State Museum, to join us in obtaining a comparative collection of fossil mammals from the "Badlands" of northwestern Nebraska, and to celebrate officially the renewed interest of French scientists in this region after a century. It turned out that Marcou had once been a curator at the Paris Museum and a professor at the Sorbonne, and that he had been born at Salins (Jura) not far from where Lavocat's family also had been established.

BADLANDS' EXPLORATIONS

Although the French expeditions which were led by the

la Vérendrye's (1738-1739, 1742-1743) may possibly have reached the Badlands areas of South Dakota and northwestern Nebraska, other early French and Spanish explorers probably did not. Despite some claims to the contrary, the Spanish group under Coronado (1541) seems not to have entered Nebraska. The Mallet Brothers (French, 1739) probably explored only the upper Missouri and Republican rivers, and the Villasur (Spanish) expedition was massacred along the Platte in 1720.

Aside from occasional penetrations by Spanish or French voyageurs, the Badlands remained virtually unknown to Americans until the 1840's. Thaddeus Culbertson's diary, as republished (Culbertson, 1952), fully and vividly records his steamboat trip in 1850 up the Missouri to Fort Pierre and from there into the Badlands. He brought back fossils that were deposited with the Smithsonian Institution and described in 1854 by Joseph Leidy as a contribution to "The Ancient Fauna of Nebraska." In 1869, after studying additional fossils collected by Hayden and Warren, Leidy was able to prepare a more extended treatment of "The Extinct Mammalian Fauna of Dakota and Nebraska." This made the Badlands a classical area for the collecting and study of fossil mammals, as it is even today (Schultz and Stout, 1955).

MODERN GEOLOGY AND PALEONTOLOGY

Since the early 1850's, there has been a gradual development of rather extensive knowledge concerning Nebraska's geology and its fossils. The official expedition of 1857—which was led by G.K. Warren and F.V. Hayden, but which was based on earlier individual efforts by them, F.B. Meek, and a few others—resulted in a general understanding of the rock succession in Nebraska. This was expanded, especially by Hayden and Meek, during and immediately after the period of the Territorial Surveys.

Nebraska was quickly settled after it became a Territory (May 30, 1854), and especially after it was declared a State (March 1, 1867). However, the truly immense region once embraced by the territorial boundaries was greatly reduced with its establishment as a State. The University of Nebraska was founded on February 15, 1869, with the first classes beginning about two years later. Samuel Aughey, a scientific promoter (Manley, 1967), developed the first State geological efforts and founded the Museum Cabinets (Nicholson, 1971; Schultz, 1957). Erwin H. Barbour, George E. Condra, and Eck F. Schramm were dominant figures at the University in the development of the Geology Department, the Geological Survey, and the State Museum (Schultz, 1948; Schramm, 1933; Nicholson, 1971).

GLOBAL CORRELATIONS

New frontiers of essentially global character now have emerged, so that Nebraska geology and paleontology must be viewed in this world perspective. Stratigraphic re-classifica-

tion, probably best considered on a stage/group basis, is indicated as part of the "International Geological Correlation Programme."

The Nebraska rock column is punctuated by unconformities and also, in most of the exposed sections, by buried soils. These surely document episodes of some significance locally and regionally ("event stratigraphy") as well, so that Ager's (1973) concept of a "golden spike" as necessary for correlation purposes seems to be here of little value. Climatic fluctuations probably have been with us always, as recorded particularly in the Carboniferous-"Early Permian" and all younger sediments of the State. These I believe can be tied in with transgressive and regressive stands of the sea, both here and in other parts of the world.

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A NEW SPECIES OF *DICERATHERIUM* FROM THE LOWER PLIOCENE (VALENTINIAN) OF BOYD COUNTY, NEBRASKA

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The presence or absence of rugose areas and convex bosses on the skull are characters useful in the identification of most genera and species of fossil rhinoceros. A rhinoceros skull, collected more than a decade ago from Pliocene sediments in Boyd County, Nebraska (University of Nebraska Collecting Locality Bd-6, the Joseph Jamber farm), is like *Diceratherium armatum* in these respects, but it differs in others. It resembles *Diceratherium* in the presence of very small, elongate, roughened areas on the nasals, but the occipital region of the skull is wide, as in *Peraceras*. In skull outline, the resemblance is to *Diceratherium*, but the teeth are like those of *Peraceras*.

Indeed, this skull for some years was tentatively considered to represent a new species of *Peraceras*, but it is now assigned to *Diceratherium* as the latest species of this genus in the Tertiary of the High Plains.

† † †

INTRODUCTION

In 1965 the Pliocene deposits in Boyd County, Nebraska (University of Nebraska State Museum Locality Bd-6, the Joseph Jamber farm) yielded a nearly complete, well-preserved rhinoceros skull. Initially assigned to *Peraceras* (Tanner, 1976), this skull is here considered instead to represent a new species of *Diceratherium*.

The site, discovered and first worked by the author, has now become a quarry that has produced a large collection of fossil vertebrates—the Jamber local fauna—preserved in the University of Nebraska State Museum (U.N.S.M.).*

The fossils other than the rhinoceros are to be reported upon chiefly by Karen and Charles Messenger, but they include the following: fish; anurans; turtle; snakes; the beaver, *Anchitheriomys*; other beavers, undetermined; a fox-like carnivore, *Leptocyon*; a wolf-like carnivore, *Aelurodon*; a mastodont, *Gomphotherium*; a browsing horse, *Hypohippus*; a

larger browsing horse, *Megahippus*; a grazing horse, *Hipparion*; a camel, *Procamelus*; another camel, undetermined; and a prong-horn, probably *Merycodus*. The assemblage and the stratigraphy indicate a Valentinian age (Schultz and Stout, 1961; Schultz, Martin, and Corner, 1975), considered as Pliocene.

SYSTEMATICS

ORDER PERISSODACTYLA OWEN, 1848

Suborder Hippomorpha Wood, 1937

FAMILY RHINOCEROTIDAE OWEN, 1845

Subfamily Caenopinae Brunning, 1923

Diceratherium Marsh, 1875

Diceratherium jamberi, new species**

Holotype.—U.N.S.M. 62048, a nearly complete skull, including nasals.

Type Locality.—Boyd County, Nebraska, 3.0 miles east and 4.5 miles south of Butte, in Sec. 7, T. 33 N., R. 21 W., in a quarry on the farm of Joseph Jamber (U.N.S.M. Collecting Locality Bd-6).

Geologic Occurrence.—Valentine Formation, probably upper part, possibly from an equivalent of the Burge Member: Valentinian (Pliocene).

Diagnosis.—The skull is relatively elongate, not saddle-shaped, but some measurements are about the same as for *Aphelops megalodus*. However, the occipital region is narrower and less elevated than for *Aphelops megalodus* (Table I), and the occipital crest is situated vertically with respect to the occipital condyles. The frontal region is only slightly lower than the anterior portion of the sagittal crest, and it is smooth, not convex. The brow areas are heavy and only slightly roughened. The nasals are not completely co-ossified, and they show small, elongate, elliptical ridges on each side, which are probably the bases for small horns. The ridges are posterior

*Other abbreviations for institutions cited are: A.M.N.H., American Museum of Natural History (and F:AM, the Frick Collection), New York City; C.M., Carnegie Museum, Pittsburgh; U.S.N.M., United States National Museum, Washington, D.C.; and Y.P.M., Yale Peabody Museum, New Haven, Connecticut. Thanks are expressed to the officers of each of these collections for allowing me to study specimens in their charge.

**Named for Joseph Jamber, to whom we are indebted for many courtesies.

to the tip of the nasals and similar to those on the holotype skull of *Diceratherium armatum* (Y.P.M. 10003).

The premaxillae are retracted and lack the alveoli for I 2/. The anterior openings of the infraorbital foramina are large and situated outside the narial opening, with only slight facial depressions below the foramina. The zygomata are deepest anterior to the mid-point of the arches. The post-glenoid processes are relatively small and curved forward at the tips.

Dentition.—The teeth exhibit the following characters:

- P 1/, tooth relatively small, with well-developed parastyle; lacks both pre-fossette and post-fossette; protoloph swings posterad to join the lingual margin of the metaloph, which is short and wider than the protoloph; there is no buccal cingulum and only a trace of a lingual cingulum.
- P 2/, tooth larger than the P 1/; both pre-fossette and post-fossette are present; the protoloph and metaloph are nearly confluent; the lingual cingulum is strong, with a weak crochet, but there is only a trace of a buccal cingulum.
- P 3/, tooth larger than the P 2/, and nearly the same length as the P 4/; there is a post-fossette, a shallow, median valley, and both ante-crochet and crochet; the lingual cingulum has a slight crenulation at the opening of the median valley, and there is only a trace of the buccal cingulum, but it is situated posterad.
- P 4/, tooth nearly the same size as the M 1/ and M 2/; there is a post-fossette, the median valley is open, and the parastylar fold is weak; the lingual cingulum is strong, but the buccal cingulum is weak.
- M 1/, tooth nearly the same size as the M 2/ and P 4/; there is a post-fossette, the median valley is open, and both an ante-crochet and crochet are present; the lingual cingulum is interrupted by a median valley, and the buccal cingulum is weak.
- M 2/, tooth nearly the same size as the two preceding teeth; a post-fossette is present, the median valley is open and deep, and both the ante-crochet and crochet are weak, with the latter situated near the metaloph-ectoloph junction; the lingual cingulum is at the anterior side of the protoloph.
- M 3/, tooth smaller than the M 2/ and triangular; the median valley is open, and the crista is strong;

the parastylar fold is strongest on this tooth, but this is progressive from the P 4/; the lingual cingulum is at the anterior portion of the protoloph, but it is weak at the base of the metaloph.

Selected Measurements (see also Table I).—The distance from the anterior margin of the orbit to the posterior edge of the narial notch is 75 mm. for *Diceratherium jamberi*, compared to 62.5 mm. for *Aphelops megalodus* (A.M.N.H. 8292), 74 mm. for *Peraceras superciliosus* (A.M.N.H. 8380), and 88 mm. for *Peraceras troxelli* (A.M.N.H. 14434).

This measurement is usually greater than these values for both *Diceratherium* and *Menoceras*. It is 110 mm. for the holotype of *Metacaenopus egrigius* (A.M.N.H. 82591), probably best considered as a female *Menoceras*, and as much as 150 mm. for some of the very large skulls (F:AM) of *Diceratherium* from eastern Wyoming. However, the skull of *Menoceras marslandensis* (U.N.S.M. 62004) measures 90 mm. in this regard.

Taking a different measurement—the length of the free portion of the nasal from the narial notch to the tip of the nasal—we obtain a value of 107 mm. for *Diceratherium jamberi*, 116 mm. for *Diceratherium armatum* (U.S.N.M. 11682), and 178 mm. for *Aphelops montanus* (C.M. 1569). One, however, must establish a lineage-progression with a considerable number of specimens, so that age and sex factors, as well as individual variation, are reasonably well known.

DISCUSSION

This skull was first considered by the author (Tanner, 1976) to represent a new species of *Peraceras*, but the assignment to *Diceratherium* is now preferred for the following reasons.

(1) *Peraceras* has a relatively brachycephalic, saddle-shaped skull, with the occipital region well-elevated above the frontal region and with both the occiput and the occipital crest inclined far forward with respect to a vertical plane rising from the occipital condyles. The skull of *Diceratherium* is more elongate, and the occiput as well as the occipital crests rise nearly vertically from the occipital condyles.

(2) *Diceratherium*, as its name indicates, had two, paired horns located toward the anterior end of the nasals. It is differentiated from its contemporary, *Menoceras* in several ways: by being slightly concave, not saddle-shaped in side-profile; with the narial notch above the P 1/ and not retracted; with nasal bosses that are elongate, elliptical ridges with a broad and relatively shallow palate; and with the length of the M 1/—M 3/ series approximately 250 mm. (Tanner 1969).

(3) The dental pattern of *Diceratherium* is relatively simple in the early forms of the lineage, but it seems

Table I:

Measurements in Millimeters of Three Rhinoceros Skulls:
Diceratherium jamberi, New Species (U.N.S.M. 62048),
Aphelops megalodus (A.M.N.H. 8292),
and *Diceratherium armatum* (Y.P.M. 10003)

	U.N.S.M. 62048	A.M.N.H. 8292	Y.P.M. 10003
Occipital condyles to tip of premaxillary	-----	-----	-----
Occipital condyles to tips of nasals	470	495	(512)
Midpoint occipital crest to tips of nasals	453	451	(503)
Anterior margin of P ¹ to occipital condyles	440	445	452
Narial notch to occipital crest	354	332	453
Palatal notch to foramen magnum	237	258	272
Palatal notch to palatal foramina	-----	-----	170
Narial notch to tips of nasals	107	163	-----
Zygomatic breadth (maximum)	277	-----	278
Width across palate to buccal sides M ²	170	168	174
Orbital breadth (between notches)	152	145	210
Occipital height, base condyles to crest	162	181	159
Occipital width (maximum)	165	188	150
Condylar width (outer margins occ. condyles)	104	-----	107
Tooth row, P ¹ —M ³ (midline, to rear of M ³)	236	-----	254
Tooth row, P ² —M ³ (midline, to rear of M ³)	97	-----	-----
Premolars (midline)	120	-----	123
Length P ² —P ⁴ (midline, to rear of P ⁴)	-----	-----	95
Molars (midline, to rear of M ³)	123	-----	133
Length P ¹ (maximum)	23	22	27
Width P ¹ (maximum)	20	18	23
Length P ² (maximum)	29	28	27
Width P ² (maximum)	39	36	37
Length P ³ (maximum)	32	31	33
Width P ³ (maximum)	48	48	43
Length P ⁴ (maximum)	33	34	31
Width P ⁴ (maximum)	57	53	47
Length M ¹ (maximum)	40	41	47
Width M ¹ (maximum)	55	55	52
Length M ² (maximum)	45	40	50
Width M ² (maximum)	53	52	56
Length M ³ (maximum)	35	47	37
Width M ³ (maximum)	49	52	47

() = estimated dimension

to become progressively more complicated. The teeth of *Diceratherium jamberi* are more complicated than for the holotype of *Diceratherium armatum*, especially in the presence of a well-developed crista on the upper third molar, lacking in *Diceratherium armatum*. However, a complicated tooth-pattern similar to that found in both *Peraceras* and *Aphelops* is seen in *Diceratherium jamberi*.

(4) There seem to be few affinities of *Diceratherium jamberi* with the *Teleoceras* lineage, for *Teleoceras major* has more hypsodont teeth and the third upper molar is much longer.

These considerations are suggestive of a close relationship, possibly an ancestral-descendant one, between the *Diceratherium* and *Peraceras* lineages, but at present this can be only an hypothesis.

ACKNOWLEDGMENTS

Thanks are extended to Joseph Jamber and his family of Boyd County, Nebraska, for permission to excavate the fossil quarry on their farm, and for other help. Examination of comparative rhinoceros material, particularly of *Diceratherium*, was facilitated due to the cooperation of Richard Tedford, Malcolm McKenna, Earl Manning, and Morris Skinner at the American Museum of Natural History. C. Bertrand Schultz, T.M. Stout, and Michael Voorhies gave helpful suggestions. Other much-appreciated assistance was given by George Corner, Karen and Charles Messenger, Martha Haack, Rebecca Monke, and especially by my wife, Mary.

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Figure 1. Lateral view of holotype skull (U.N.S.M. 62048) *Diceratherium jambori* n. sp. X 2/5.

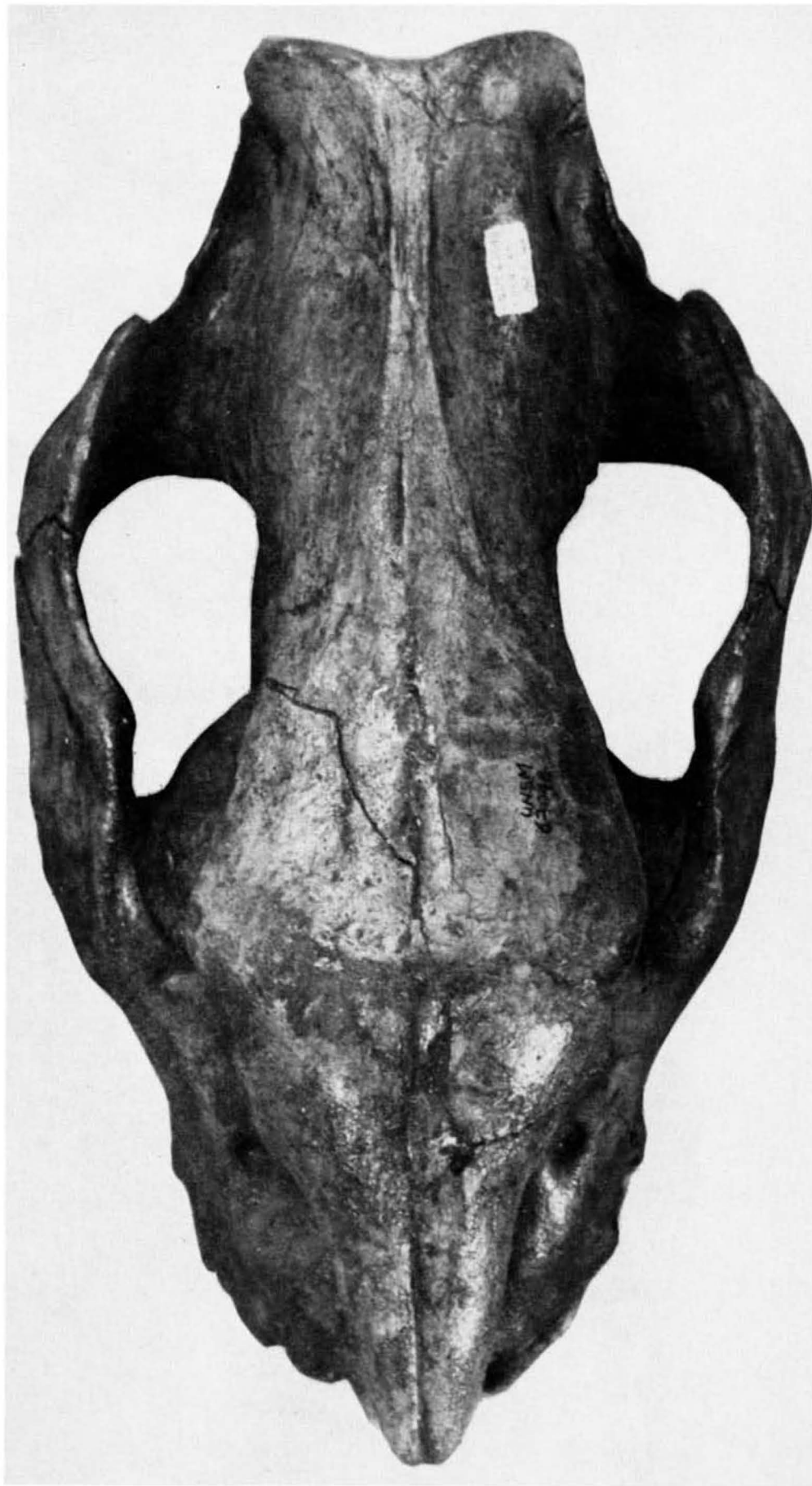


Figure 2. Dorsal view of same skull as shown in Fig. 1. X 2/5.

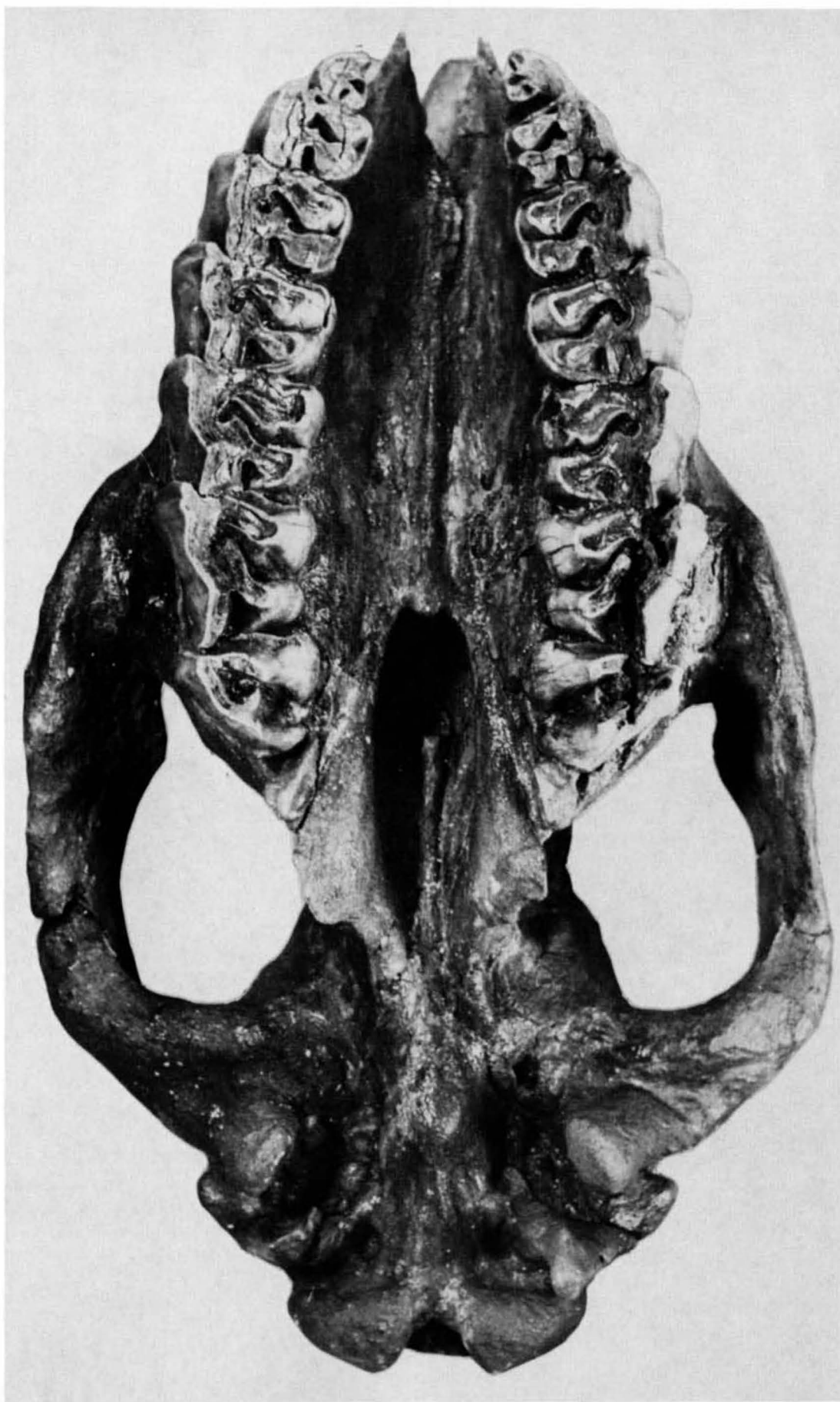


Figure 3. Palatal view of same skull as shown in Fig. 1. X 2/5.

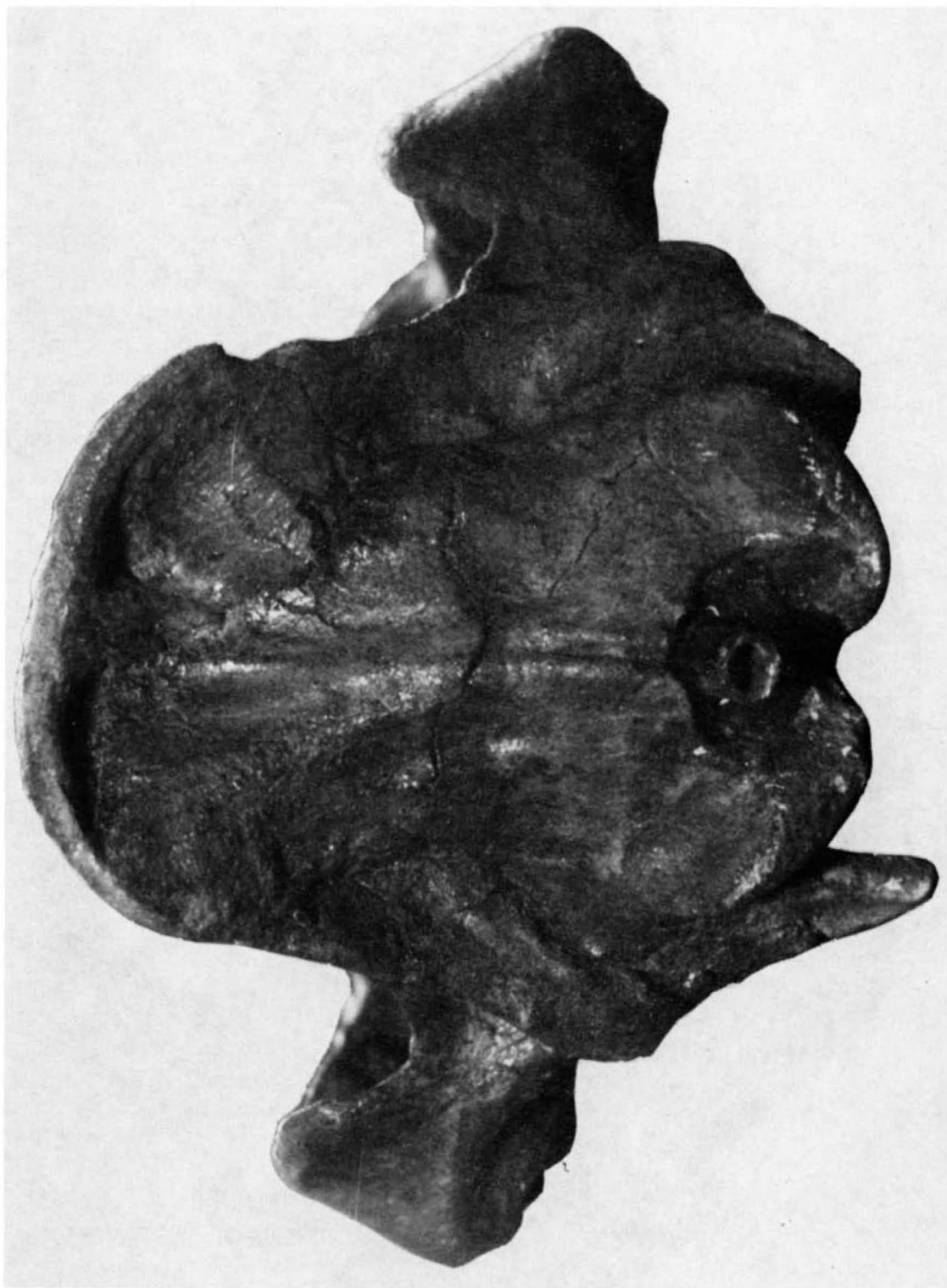


Figure 4. Occipital view of same skull as shown in Fig. 1. X $3/4$.

FOSSIL MOLES OF LATE HEMPHILLIAN AGE FROM NORTHEASTERN NEBRASKA

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Disarticulated remains of more than thirty fossil moles (Insectivora: Talpidae) have been recovered by washing alluvial sediments of late Hemphillian age near Santee in northern Knox County, Nebraska. A fission-track age (on glass) of 5.0 ± 0.2 million years before present has been determined for an ash lying stratigraphically above the fossiliferous stratum (Boellstorff, 1976).

Four distinct talpid taxa are represented in the sample (based on differences in humeri), but over 98% of the material pertains to a single species of highly specialized burrowing mole allied to *Scalopus* (*Hesperoscalops*) *sewardensis* K.M. Reed. A new species of *Hesperoscalops*, differing from the two previously known species by its larger size and heavier development of cingular cusps, is named on the basis of the new material. Examples of all upper and lower cheek teeth and most major limb bones are described. A digging ability equalling or exceeding that of Recent *Scalopus* (*Scalopus*) *aquaticus* is suggested for the new species on the basis of its brachial morphology. The new material supports Hutchison's (1968) view that *Hesperoscalops* is best considered a subgenus of *Scalopus*. The remaining taxa, represented by humeri only, consist of the following:

- (1) a very small, highly specialized fossorial mole of *Scalopus*-grade;
- (2) a large mole with a humerus approaching that of *Parascalops* but larger than the living species; and
- (3) a small, moderately fossorial mole resembling *Scalopoides* in humeral morphology.

† † †

INTRODUCTION

Remains of moles are not uncommon in vertebrate fossil assemblages of Arikarean through Barstovian age in the Great Plains, but they have been noted infrequently in later Tertiary deposits of the area (see historical review in Hutchison, 1968). My purpose here is to describe a more adequate sample of Great Plains Hemphillian talpids than has previously been available. The specimens, although fragmentary, provide evidence for the existence of a relatively diverse mole fauna (four species) on the plains, approximately 5 million years ago. Remains of one of the species are sufficiently distinct and complete to warrant recognition as a new species of the extinct subgenus of highly fossorial talpid, *Hesperoscalops*. A minimum of 30 individuals is represented in the sample which includes well preserved examples of the lower jaw, maxilla, humerus, ulna, and radius as well as all upper and lower molars. Hutchison's (1968) suggestion that *Hesperoscalops* should be regarded as a subgenus of *Scalopus* is

reinforced by the present study as is Hibbard's (1964) view (*contra* K.M. Reed, 1962) that *Scalopus* (*Hesperoscalops*) *sewardensis* may be ancestral to *S. (H.) rexroadi*. A review of the evidence now available suggests that the *Scalopus* lineage was well established on the Great Plains by Hemphillian time and that populations of these highly fossorial moles have evolved *in situ* since then. Trends toward 1) decrease in size and 2) reduction in cingular cusps on the molars are evident in the following progression from oldest to youngest: *Scalopus* (*Hesperoscalops*) n. sp. (this paper)—late Hemphillian; *S. (H.) sewardensis* (K.M. Reed, 1962)—latest Hemphillian/earliest Blancan; *S. (H.) rexroadi* (Hibbard, 1941)—early Blancan; *S. (S.) aquaticus*—Pleistocene and Recent.

The present paper also calls attention to the existence of alluvial sediments of Hemphillian age within the glaciated region of northeastern Nebraska. These deposits have only recently received attention from geologists and paleontologists. Rather extensive collections of mammalian and other vertebrate fossils from these strata are being assembled by field parties from the Nebraska State Museum and taxonomic studies of several groups by the writer and others are underway. The presence of radiometrically datable volcanic ash beds interlayered with the fossiliferous alluvial sediments is particularly fortunate.

GEOGRAPHIC AND GEOLOGIC SETTING

A succession of stream channel deposits confined to three or more paleovalley systems of Hemphillian age occur in Knox, Antelope, and Holt counties in northeastern Nebraska. Detailed mapping of these paleovalley systems will require subsurface studies far beyond the scope of the present paper. A brief description of a cross section of one of these channel fills will suffice for present purposes. This channel-fill is exposed in a series of roadcuts between 1.9 miles and 3.5 miles south of the village of Santee in northern Knox County, just south of the Missouri River. Unfortunately, detailed topographic maps are not yet available for the area, so only an approximate location may be given. As determined from the 1955 USGS Sioux City (Iowa, Nebr., S. Dakota) Transverse-Mercator-Projection Map, the principal roadcut lies in the NE¼, NW¼, sec. 25, T33N, R5W at an elevation between 1500 and 1600 feet.

The stratigraphic relationships at the Santee roadcut (University of Nebraska State Museum [U.N.S.M.] locality Kx-111) are shown in Figure 1. A black (weathering to orange-brown) marine shale of Cretaceous age—the Pierre Shale—locally makes up the pre-Tertiary bedrock as it does throughout most of northeastern and north-central Nebraska. It is disconformably overlain by unconsolidated sand with lenses of lithic gravel and clay. The erosional surface at the top of the Pierre Shale descends abruptly toward the south, suggesting that the outcrop lies at the northern edge of a paleovalley which was filled with alluvial sediment. Bedding within the channel-fill is steeply inclined, mostly toward the south, with successively younger sets of inclined beds overlapping each other toward the south. Locally at least, a southward-migrating stream system was responsible for depositing the channel-fill.

Farther south, particularly at a roadcut 3.5 miles south of Santee near the center of sec. 35, T33N, R5W, the upper portion of the channel-fill is exposed. Here the sand and gravel occurring at the lower contact of the channel-fill at Kx-111 may be seen passing gradationally upward into horizontally bedded silt and very fine sand. A distinctive white volcanic ash lying within this finer-textured upper portion of the sequence has been dated at 5.0 ± 0.2 million years before present by the fission track method (Boellstorff, 1976). Although less common than in the lower, coarser part of the channel-fill, Hemphillian vertebrate fossils taxonomically identical to those at Kx-111 have been found in the roadcut from which the dated ash sample was taken.

The relationship between the channel-fill and earlier Tertiary rocks cannot be directly observed in the Santee area because the unit rests directly on Cretaceous bedrock. Two lines of evidence, however, show that post-Clarendonian and pre-late Hemphillian erosion removed the Valentine Formation and Caprock Member of the Ash Hollow Formation (Skinner, Skinner, and Gooris, 1968) which were probably continuous over the area originally. 1) Outcrops of the Valentine Formation and overlying Caprock have been recognized both east and west of the Santee area in Knox County (Voorhies, 1971, 1973). 2) Fragments of rock types distinctive of the Valentine and Caprock occur as clasts in the gravelly sand lenses at Kx-111, especially near the base of the channel (Fig. 1). Most notable of these clasts are fragments of green orthoquartzite, which are found abundantly in the Valentine, and calcite-cemented sandstone with abundant siliceous tubules, which is characteristic of the Caprock (Skinner, Skinner, and Gooris, 1968, Figs. 2-4). A particularly distinctive feature of the channel-fill at Santee, and also of other late-Hemphillian channels in northeastern Nebraska, is the great abundance of silicified rootlets and horsetail rush (*Equisetum*) stem fragments in the gravel lenses. This fossil plant debris is usually much abraded and is certainly reworked from pre-existing sediments, probably largely from the Caprock in which similar root and stem material is locally abundant *in situ*. A further characteristic of the pebble- and cobble-sized clasts in the

exposure at Kx-111 and other Hemphillian channels in northeastern Nebraska is the absence of crystalline igneous and metamorphic rock types. In sharp contrast, the gravel fraction of Blacan and Pleistocene deposits in this area is predominantly crystalline (Stanley and Wayne, 1972).

The alluvial channel-fill sediments at Kx-111 cannot be assigned to any formally named lithologic unit known to me. Perhaps eventually they will be referred to as a new formation but such a step would require areal and subsurface mapping far beyond the scope of the present study. The deposits are clearly not referable to the Ash Hollow or Kimball formations which have yielded fossils of Hemphillian age in southwestern Nebraska. Crystalline gravel makes up a significant proportion of these units (Stout *et al.*, 1971; Breyer, 1975). For the present, therefore, the beds yielding the Santee local fauna are best left unnamed.

NATURE OF THE SAMPLE

The fossils studied were recovered by washing approximately two tons of unconsolidated gravelly sand through boxes of 16-mesh screen and carefully picking all fossils from the resulting residue. The sediment was obtained from a 2-foot-thick, cross-stratified unit identified by the informal term "squirrel lens" in Figure 1. Most of the fossils are somewhat broken and abraded, but, in general, preservation is good, the bone being extensively permineralized and of a mottled grey or brown color. As might be expected in a channel deposit, fossils reworked from older beds are not uncommon at the Santee exposure. In the coarse rubble at the base of the channel occur shark teeth and mosasaur vertebrae, probably derived from the underlying Pierre Shale. Some partial horse teeth and merycodont horn fragments resemble specimens indigenous to the Valentine Formation. These probably were derived from the Valentine along with the pebbles and cobbles of green orthoquartzite reworked from this unit, as discussed above.

Sampling at 3-foot intervals up the exposure showed that the abundance of reworked fossils decreased markedly above the channel base. No obviously reworked specimens were detected in the two-ton sample from "squirrel lens." The fossil insectivore and rodent material from this sample so far studied by the writer show no more intraspecific variability than that encountered within a similarly sized collection of Recent small mammals from a single locality. The conclusion seems warranted, therefore, that the fossils constitute a "local fauna" as the term is usually understood by vertebrate paleontologists (see discussion in Tedford, 1970).

AGE OF THE SANTEE LOCAL FAUNA

The fission-track date of 5.0 ± 0.2 m.y. on an ash overlying the beds that yield the Santee local fauna accords well with a date of 5.3 ± 0.4 on an ash overlying the "type

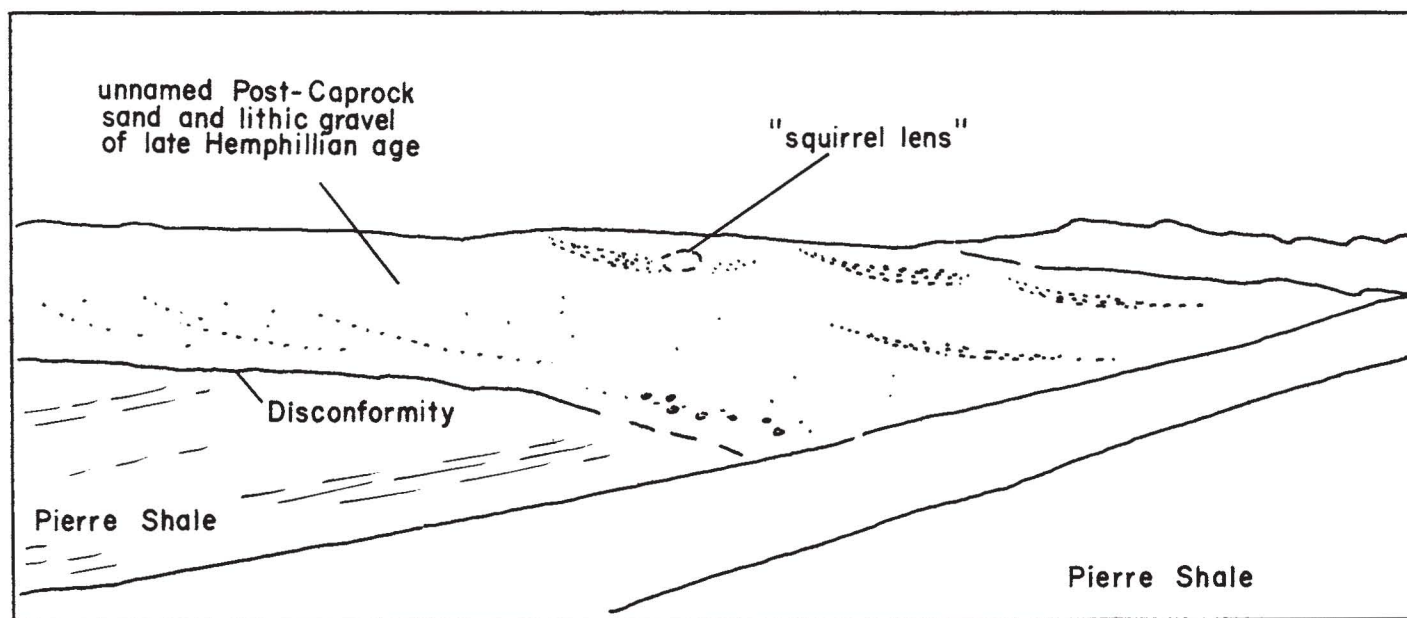
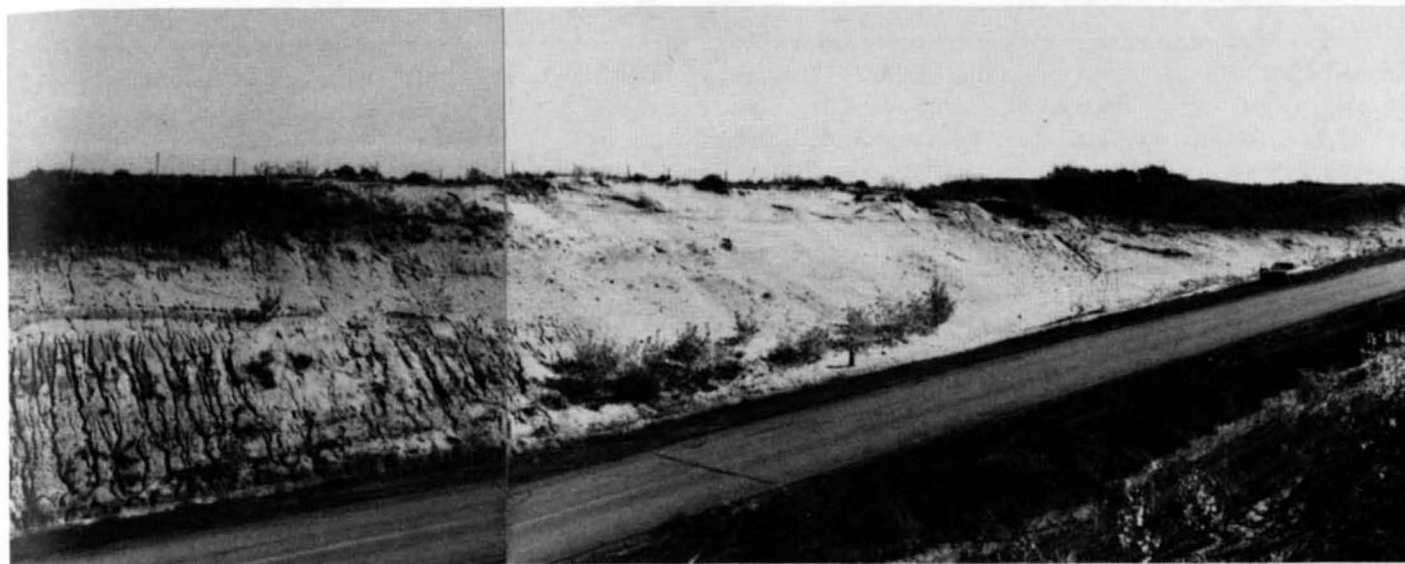


Figure 1. Looking southeastward at U.N.S.M. locality Kx-111 in northern Knox County, Nebraska. Fossils comprising the Santee local fauna were collected from the unnamed post-Caprock channel-fill well exposed in the roadcut. A scour surface of considerable relief has developed on the Pierre Shale; note that it deepens progressively toward the South (right). The channel fill consists of unconsolidated fine to medium sand with interbedded lenses of gravel consisting of sedimentary rock fragments and silicified root casts. The holotype and all referred specimens of *Scalopus* (*Hesperoscalops*) *mcgrewi* n. sp. were obtained by washing approximately two tons of gravelly sand from the depositional unit informally termed "squirrel lens" at the place indicated.

fauna" of the Hemphillian at Coffee Ranch, Texas (Boellstorff, 1976) and with similar dates on correlative faunas obtained by Evernden *et al.* (1964) using the potassium-argon method.

The joint occurrence of mylagaulid rodents, *Dipoides*, rhinoceroses and megalonychid sloths at Kx-111 firmly establishes its age as Hemphillian, as discussed by Wood *et al.* (1941). Only one fossil specimen has previously been described from the Santee exposure, a referred specimen of *Propiophenacomys parkeri*, a primitive arvicoline (Martin, 1975:106). As pointed out by Martin, *P. parkeri* is similar to, but more primitive than, the early Blancan genera *Pliophenocomys* and *Pliolemmus*. On the basis of the fossil mole material described below, I believe the Santee local fauna is slightly older than the Saw Rock Canyon local fauna which "probably is late Hemphillian" (Schultz, Tanner, and Martin, 1972:184).

SYSTEMATIC PALEONTOLOGY

ORDER INSECTIVORA

FAMILY TALPIDAE

Subfamily Talpinae

TRIBE SCALOPINI

Subtribe Scalopina

genus *Scalopus* E. Geoffroy Saint Hilaire 1803

subgenus *Hesperoscalops* Hibbard 1941

Scalopus (Hesperoscalops) mcgrewi n. sp. (Fig. 2)

Type.—U.N.S.M. 51700, right mandibular ramus with P/4—M/3.

Hypodigm.—U.N.S.M. 51701–51705, U.N.S.M. 51707, U.N.S.M. 51710, U.N.S.M. 51713, U.N.S.M. 51714, U.N.S.M. 51699, lower teeth and partial mandibles including five M/1's, four M/1's and two M/3's; U.N.S.M. 51706, U.N.S.M. 51720, U.N.S.M. 51688, U.N.S.M. 51692, U.N.S.M. 51693, upper teeth and partial maxillae including five M1's, six M2's, and two M3's; U.N.S.M. 51747–51766, U.N.S.M. 51786–51795, U.N.S.M. 51800, 31 right humeri; U.N.S.M. 51767–51785, 19 left humeri; U.N.S.M. 51723, U.N.S.M. 51726–51729, five complete radii, U.N.S.M. 51734–51746, three complete and eleven partial ulnae; U.N.S.M. 51733, distal end of tibia; U.N.S.M. 51724, right metacarpal III; U.N.S.M. 51732, right metacarpal II; U.N.S.M. 51731, left proximal phalanx II. All from type locality.

Type Locality and Lithic Unit.—University of Nebraska State Museum locality Kx-111, Santee locality, 1.9 miles south of Santee in NE¼, NW¼, sec. 25, T33N, R5W, Knox County, Nebraska. Type and hypodigm collected from lens of lithic gravel approximately 30 feet above base of unnamed post-Caprock channel-fill.

Age.—Late Hemphillian, approximately 5 million years before present.

Etymology.—For Dr. Paul O. McGrew, in gratitude and admiration.

Diagnosis.—Large scalopine mole with dental formula:

$$\frac{? \cdot 1 \cdot 3 \cdot 3}{2(3) \cdot 1 \cdot 3 \cdot 3}$$

Larger than *Scalopus (Hesperoscalops) sewardensis* and *S. (H.) rexroadii* (molars at least 20% longer) and cingular cusps much more prominent, that on M/3 forming a distinct shelf approximately as long as the trigonid.

Description.—A right maxillary fragment, U.N.S.M. 51720, including M2/ and the alveoli of M1/, C, and P2/—P4/, differs little from the equivalent region in Recent *Scalopus (Scalopus) aquaticus* except for the considerably smaller size of the latter. The fossil shows a well-defined ridge for the insertion of m. masseter running from the ventral root of the zygoma to a point above the anterior extremity of M1/ much as in *S. (S.) aquaticus*. The excavation of the face anterior to the infraorbital foramen, however, is less pronounced in the fossil than in any of the 25 skulls of *S. (S.) aquaticus* examined by the writer.

No upper antemolars are present in the sample, but relative alveolar sizes show that the premolars were graded in size from P4/ (largest) to P2/ (smallest) with a larger tooth anterior to P2/ as in *S. (S.) aquaticus*. I follow Ziegler (1971) in regarding this tooth as the canine, P1/ having been lost. As noted by Hibbard (1953) in a maxilla of *S. (H.) rexroadii*, the upper cheek teeth in U.N.S.M. 51720 are very closely spaced in contrast to the wide spacing of these teeth which is a consistent feature of *S. (S.) aquaticus*.

Both the upper and lower molars are fully hypsodont (crown height/length > 1.0; enamel concealed beneath alveolar rim in early wear stages; os cementum extensively developed).

There are five M1/'s in the sample. They are fundamentally similar to homologous teeth in *S. (S.) aquaticus* but all possess a distinct parastyle which is lacking in the Recent species. In the fossil, mesostyle I (in Hibbard's, 1953, terminology) arises gradually from the crista, extending posterolabially from the paracone, and is not separated from the latter by a distinct notch as it is in the Recent species. In this, the M1/ of the new species resembles that of *H. rexroadii* as described and figured by Hibbard (1941, 1953). Likewise, the notch separating mesostyles I and II is much shallower in the fossil than in the Recent *Scalopus*. The valley separating mesostyle II from the metastyle is broad and deep in *S. (H.) mcgrewi* as in *S. (H.) rexroadii* (Hibbard, 1953:23) rather than narrow and restricted as in *S. (S.) aquaticus*. Upper molars of *S. (H.) sewardensis* are not known. Small but distinct posterolabial cingular cusps occur in all *S. (H.) mcgrewi*

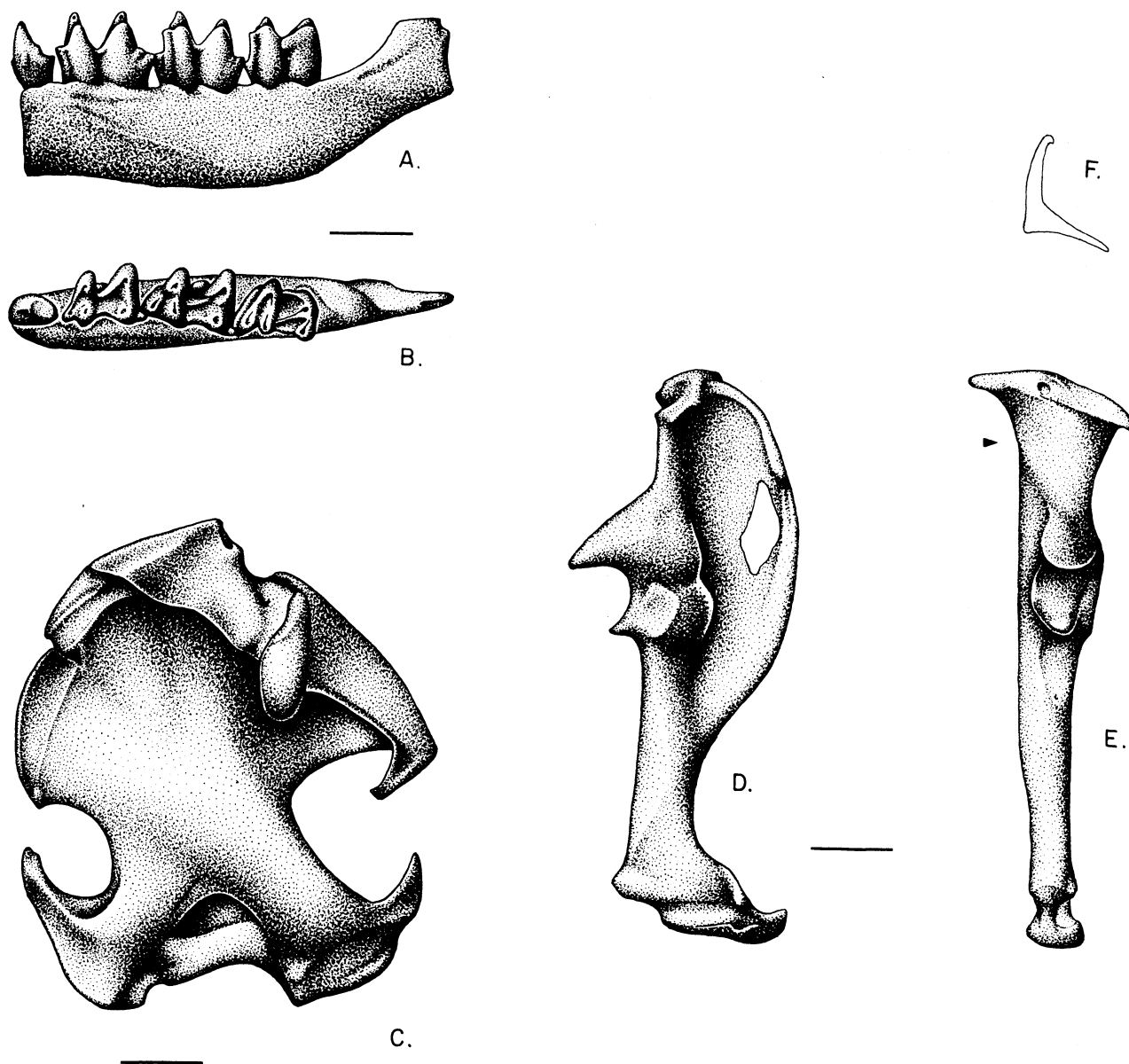


Figure 2. *Scalopus (Hesperoscalops) mcgrewi* n. sp. from the Santee local fauna, late Hemphillian, Knox Co., Nebraska.

- A. Holotype right ramus, U.N.S.M. 51700, lingual view.
- B. Same, occlusal view.
- C. Right humerus, U.N.S.M. 51800, posterior view.
- D. Left ulna, U.N.S.M. 51802, lateral view.
- E. Same, anterior view.
- F. Cross section of same at site marked.

Drawn by Martha Haack. Line = 3 mm.

M1/'s but not in other species. A small cuspule arising from the protocone partially blocks the lingual valley (protofossa) in all specimens of *S. (H.) mcgrewi*.

Six M2/'s are sufficiently well preserved to be described. As in M1/, the teeth are larger but similar to those of *S. (S.) aquaticus* in overall appearance. They are distinct, however, in the invariable presence of prominent anterior and posterior labial cingular cusps and of broadly open parastyle-mesostyle and mesostyle-metastyle valleys. The small cusp noted above on the protocone of M1/ is also present on M2/. Also as in M1/, the cleft dividing the mesostyle into two parts is much less persistent in the fossil than in the Recent species.

The M3/ resembles that of *S. (S.) aquaticus* but has a more broadly open, parastyle-mesostyle valley, an almost undivided mesostyle, and complete closure of the protofossa by a crista running from the protocone to the cingulum at the lingual base of the metacone. No M3/'s of other *Hesperoscalops* species have been reported.

Maximum anteroposterior diameters (ectoloph lengths) of upper molars are 3.50–3.70 (mean 3.58) for three M1/'s; 3.30–3.50 (mean 3.38) for four M2/'s; and 2.75 for an M3/. (All measurements are in millimeters).

Three mandibular rami are sufficiently complete to reveal the lower dental formula of the new species. Antemolar alveoli in U.N.S.M. 51713 and U.N.S.M. 51801 show that two incisors, a canine, and three premolars were present as in *S. (H.) rexroadi* (Hibbard, 1953) and in most individuals of Recent *S. (S.) aquaticus*. The "missing teeth" are assumed to be I/3 and P/1 following Conaway and Landry (1958) and Ziegler (1971). In a third specimen, U.N.S.M. 51704, however, a small alveolus is present just anterolabial to that identified as the canine alveolus; presumably this held a vestigial I/3.

P/4 is represented only in the type. Like the molars, it is a unilaterally hypsodont tooth with the labial portion of the enamel-covered crown curving beneath the alveolar border of the jaw. Strong anterior and posterior cingula are connected to the apex of the tooth by sharp ridges. The latter define the slightly concave labial surface of the tooth. P/4 resembles that of *S. (H.) rexroadi* as figured by Hibbard (1953) except for the strong anterior cingulum.

The molars are essentially as in *S. (H.) rexroadi* and *S. (H.) sewardensis* except for larger size (Table I and Fig. 3) and stronger development of basal accessory cusps. Also, cement is present on both the lingual and labial portions of the molar crowns in *S. (H.) mcgrewi*, while it is absent on the lingual side in *S. (H.) rexroadi* according to Hibbard (1953:22). In members of the subgenus *Hesperoscalops*, the molar trigonids are anteroposteriorly compressed, compared with those in *Scalopus (Scalopus)*. The compression in the new species is more extreme than that in other described species.

The trigonid compression and, to a lesser extent, talonid compression in *Hesperoscalops* are responsible for a widening of the hypoflexid, i.e., it approaches a U-shape in contrast with the V-shaped hypoflexid of Recent *Scalopus*. The hypoflexid in the new species is occupied by a large, shelf-like cusp which plays an active role in molar occlusion as indicated by wear facets. This cusp is present but much weaker in *S. (H.) sewardensis*, variably present in *S. (H.) rexroadi* and *S. (S.) aquaticus* (see Fig. 1 in Hibbard, 1953).

The humerus is represented by no fewer than 50 examples in the collection. Most are somewhat abraded, but several are nearly perfect. The humerus of *S. (H.) mcgrewi* is larger than, but strongly resembles, that of *S. (S.) aquaticus*, differing only in detail. The brachialis fossa is exceedingly deep as in the Recent species, but in posterior view, the medial margin of the fossa appears less distinct because the sharp ridge running distolaterally from directly beneath the head in the Recent form is weak-to-absent in the fossil.

The radius is represented in the sample by four complete specimens. Except for larger size, they closely resemble radii of Recent *Scalopus*. The specimens range from 13.40 to 14.25 in extreme length, from 11.05 to 11.85 in shaft length, and from 6.00 to 6.75 in distal width. Tendinal scars similar in placement to those of *S. (S.) aquaticus* are present but are much more prominent. The dorsolateral surface is marked by well-defined scars for retaining the ligament for the tendon of *M. extensor carpi radialis*. The lateral surface is crossed by an extremely well-developed groove for the passage of *M. abductor pollicis*, as in Recent *Scalopus* and other strongly fossorial moles, but the groove is much stronger than that in any Recent material examined by me.

A notable distinction between the new species and Recent *S. (S.) aquaticus* can be seen in the ulna, which is well represented in the Santee sample. *S. (H.) mcgrewi* ulnae have a well-developed medial olecranon crest, a feature found by Hutchison (1968:29) to be present in all talpids except modern *Scalopus*. Presumably this is a derived character in *Scalopus (Scalopus)* not yet present in *Scalopus (Hesperoscalops)*. Additionally, a much larger triceps scar occupies the proximal crest in the new species than is the case in Recent *Scalopus* ulnae. In lateral view, the semilunar notch describes a slightly more open semicircle in the Santee species than in Recent *Scalopus*, resembling *Scapanus* in this respect (Hutchison, 1968:28).

The known metacarpals and phalanges of the new species are, like those of *S. (S.) aquaticus*, extremely fore-shortened. Larger size and more pronounced tendinal attachments are the only features separating the former from the latter. Much the same can be said for the tibia, only the distal end of which has yet been recovered.

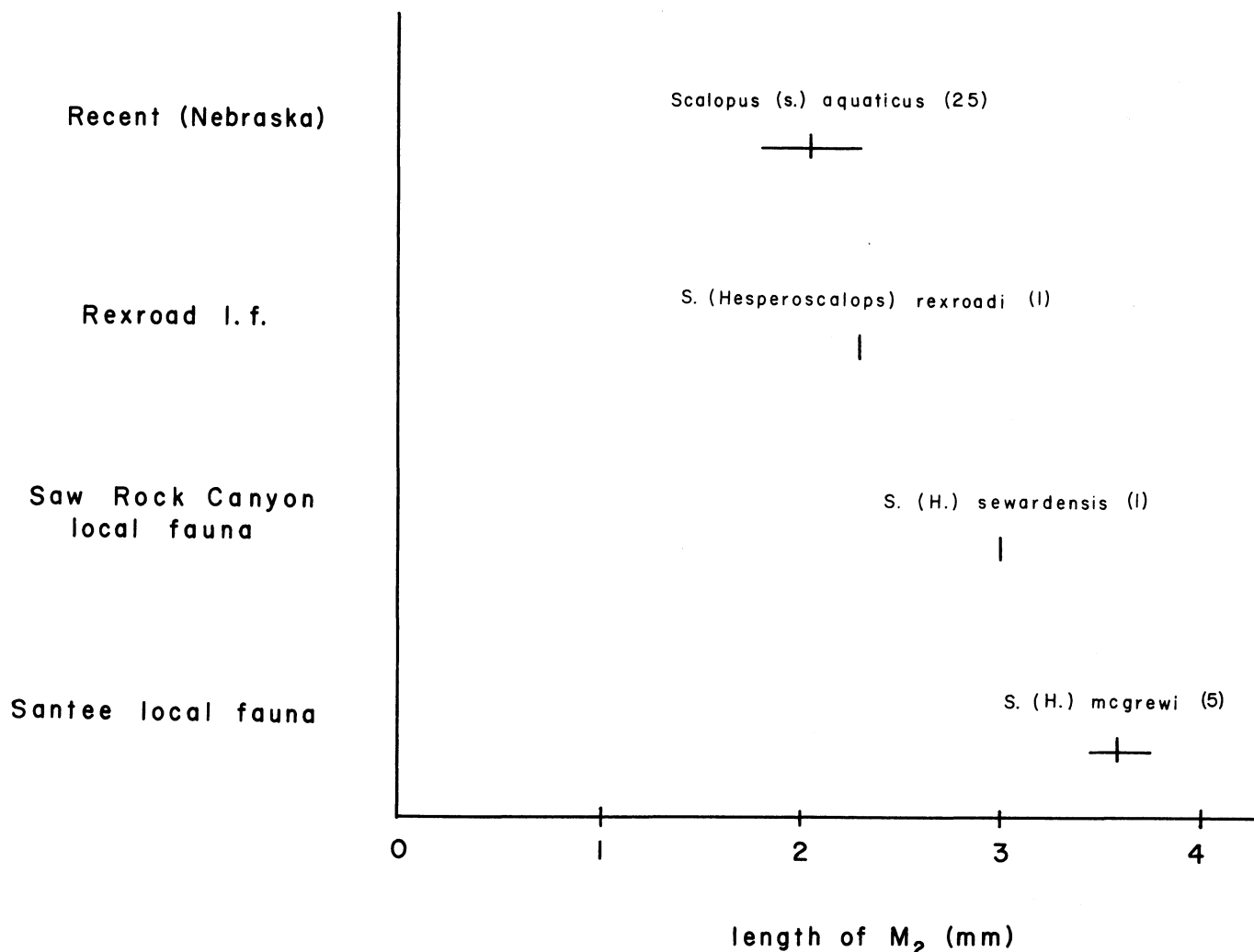


Figure 3. Variation in the length of the second lower molar in the known species of *Scalopus*. Horizontal line represents the observed range; vertical line is sample mean; number in parentheses is sample size. Measurements of *S. (H.) sewardensis* and *S. (H.) rexroadii* are from K.M. Reed (1962).

DISCUSSION

Progressive shortening of the distal elements of the talpid forelimb in more fossorial species has been noted by many workers (e.g., C.A. Reed, 1951:550). As Reed states "the mole has sacrificed speed for strength, with obvious advantages to its mode of life." One index to the degree of fossorial adaptation in moles is the ratio of radius shaft length to humerus length. The mean length of four complete humeri referred to *S. (H.) mcgrewi* is 17.5 (range 16.5 to 18.0) while the shaft length of the four radii given above is 11.5, yielding a humero-radial ratio of 1.52. Five specimens of Recent *S. (S.) aquaticus* measured by the writer displayed an almost identical ratio: humerus length (14.9) / radius shaft length (9.9) = 1.51. Shortening of the forearm in *Scalopus* had thus reached the modern condition by late Hemphillian time. *S. (H.) mcgrewi* was apparently a powerful digger and probably spent virtually its entire life underground, as does its modern relative.

cf. *Scalopus* sp.

A right humerus (U.N.S.M. 51799) is very similar to humeri of *Scalopus (Hesperoscalops) mcgrewi* but is much smaller (length 8.2). The specimen is both broken and abraded, so the measurement given is a minimum, but even allowing for postmortal size reduction by stream wear, the bone is much smaller than humeri of the larger species that have suffered equivalent damage. A high degree of fossorial adaptation is indicated by the great breadth of the specimen relative to its width. An otherwise unknown species of small scalopine talpid comparable to *Scalopus* in evolutionary grade appears to be represented by the specimen.

Table I:

Measurements (mm) of Lower Dentition of *Scalopus (Hesperoscalops) mcgrewi* n. sp.
From U.N.S.M. Locality Kx-111 (Santee Local Fauna) Late Hemphillian, Northeastern Nebraska

	P/4		M/1		M/2		M/3	
	AP	TR	AP	TR	AP	TR	AP	TR
U.N.S.M. 51700 (Type)	1.60	1.30	3.50	2.45	3.50	2.50	2.95	2.20
U.N.S.M. 51701	---	---	---	---	---	---	3.00	2.15
U.N.S.M. 51702	---	---	---	2.45	---	---	---	---
U.N.S.M. 51703	---	---	3.50	2.45	3.60	2.55	---	---
U.N.S.M. 51704	---	---	---	---	---	---	3.15	2.25
U.N.S.M. 51705	---	---	3.40	2.50	---	---	---	---
U.N.S.M. 51707	---	---	3.45	2.50	---	---	---	---
U.N.S.M. 51710	---	---	---	---	3.50	2.85	---	---
U.N.S.M. 51713	---	---	---	---	3.45	2.55	---	---
U.N.S.M. 51714	---	---	---	---	3.75	2.70	---	---
U.N.S.M. 51699	---	---	3.45	2.50	---	---	---	---

Measurements made to nearest .05 mm by ocular micrometer following method of Hutchison (1968). AP=distance between antermost and postermost extremities of tooth with respect to anteroposterior axis. TR=distance between lingual and labial-most extremities perpendicular to anteroposterior axis viewed normal to occlusal surface.

Subtribe Parascalopina

cf. *Parascalops*

A large, robust left humerus lacking the proximal end (U.N.S.M. 51797) is comparable with that of *Parascalops breweri* and *Scapanulus oweni* in overall shape. Although comparable in size to humeri of *Scalopus (Hesperoscalops) mcgrewi*, it differs greatly from the latter in its relatively long, narrow shaft and in the widely open notch between the teres tubercle and epicondyle. Among Tertiary fossils, the specimen most closely resembles humeri of *Domninoidea* (see Hutchison, 1968:80), but is considerably larger than any of a large sample of undescribed *Domninoidea* from the Valentine Formation in the U.N.S.M. collections. It is hoped that further collecting will uncover the dentition of this interesting mole.

cf. *Scalopoides*

A small, relatively unspecialized talpid is represented by (U.N.S.M. 51798) a left humerus lacking much of the proximal end. The specimen is long and slender and has a shallow brachialis fossa compared to the other mole humeri from Santee, thus suggesting a weakly fossorial habit. Humeri

of *Scalopoides* as described and figured by Hutchison (1968) most nearly duplicate the morphology observed in the Santee specimen. The known range of *Scalopoides* is Hemingfordian through Barstovian of the Great Plains (Wilson, 1960; Storer, 1975) and Barstovian through Clarendonian of the Great Basin (Hutchison, 1968). Postcranial material questionably referable to the genus is also known from three Hemphillian faunas in Oregon (Hutchison, 1968). As in the latter case, positive identification of the *Scalopoides*-like mole from Santee must await recovery of complete dentitions.

CONCLUSIONS

Talpid faunas from the later Tertiary of the Great Plains are not well known, particularly those of Hemphillian age. The only described and figured talpid fossils known to me from rocks of Hemphillian age on the Great Plains are a humerus from the Edson local fauna (Hibbard, 1939) and the fragmentary ramus from the Saw Rock Canyon local fauna, which became the type of *Scalopus (Hesperoscalops) seawardensis* (K.M. Reed, 1962). A humerus from the "Upper Snake Creek" beds was mentioned by Matthew (1924), but it was not described in detail. The evolutionary history of the Talpidae west of the Rocky Mountains is, in contrast, much

better known, thanks to the work of Hutchison (1968) who described no fewer than five talpid taxa from strata of Hemphillian age in Oregon.

The present study has shown that a mole fauna of comparable diversity also existed in the central Great Plains during the late Hemphillian, approximately 5 million years ago. Unfortunately, only one of the four talpids recognized in the Santee local fauna is represented by sufficient material for specific assignment. This species, described as new in the present paper, is an anatomically precocious member of *Hesperoscalops*, now recognized as a subgenus of *Scalopus*. With its fully hypsodont teeth and extremely short, broad forelimb elements, the new species was apparently well adapted to the completely subterranean niche now occupied by *Scalopus* (*Scalopus*) *aquaticus*.

ACKNOWLEDGMENTS

Collecting fossils invariably involves a combination of pleasurable excitement and hard labor. Karl S. Osvald and Jane Voorhies have shared with me a high measure of both in making the collection at Santee. I have benefited greatly from discussions with my colleagues in the Division of Vertebrate Paleontology, University of Nebraska State Museum. Harvey Gunderson provided access to Recent talpid skeletons. Martha Haack prepared Figure 2; the others were prepared by Jane Voorhies. Gail Littrell typed the manuscript.

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ENGINEERING

INDOOR WING CONFIGURATIONS FOR FÉDÉRATION AERONAUTIQUE INTERNATIONALE COMPETITION

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Indoor model aircraft are extremely light and fragile, free-flying craft—flown, as the name implies, indoors in large (often unsuitable) buildings with performance measured by flight duration. The model is designed and adjusted to fly a circular path to avoid sidewall collisions, climbing at the outset when the motive power is high and then slowly descending. Model fragility precludes flight under conditions where even very mild atmospheric disturbances could collapse the delicate structure of the ship.

Because reduction in weight results in easily discernible improvement in duration, evolution of these models has been largely empirical, concentrated on weight reduction with only scattered aerodynamic design criteria having been developed. The problem of weight reduction has, in fact, been attacked so enthusiastically for years that now a skilled technician can produce a flyable model having a wing spanning up to three feet but with an overall structural weight less than half that of a dime. The best of these large models will climb two hundred feet or more and fly upwards of forty-five minutes with duration limited not by model but by flying site. These models will be powered by twisted rubber strands of minute cross section, turning a propellor having a diameter roughly two-thirds of the wing span. Even at 100% efficiency, the total amount of energy available from such a motor—which normally weighs about as much as the model itself—would lift a brick only a strong hand's width, yet it will sustain the model in flight for well over a half hour.

The 1976 World Championships were held in England with fifteen countries participating. Of the 236 official flights, almost one-quarter were over a half hour. The six best official flights of the winning American team totalled only fifteen seconds more than those of the fourth-place Czechoslovakian team. On the average, the difference was only two and one-half seconds per flight for flights over thirty-five minutes, only one-tenth of one percent separating first and fourth place. Under these conditions one strives for perfection in every detail.

Indoor models fly at very low speeds, well under three feet per second, so the principles and formulas of strictly

classical aerodynamics apply. However, these models differ in several essential respects from man-carrying ships, such as in the damping effect of the relatively large mass of air affected by a virtually weightless model, and in the use of a horizontal tail surface for lift as well as for stability by positioning the center of gravity well aft of the mid-point of the wing-cross section. Thus, the performance and design procedures which have been developed for man-carrying aircraft cannot be employed directly. Nonetheless, suitable analyses based on classical aerodynamics can provide valuable design information. In previous papers the author has presented computerized solutions for the optimum area of the horizontal tail surface and the fore-and-aft location of the center of gravity, and for the experimental verification of the computer solutions. Another critical problem created by regulations governing the World Championships is that of optimum wing area for the competition models.

American rules classify indoor model aircraft solely by wing area. There is no weight restriction; the model can be as light as the builder's abilities, both in construction and flying, permit. Under these conditions, one always employs a wing of the maximum-permitted area for a given class and strives for the lightest model one can successfully handle. However, the Fédération Aéronautique Internationale, which establishes regulations and homologates records for all international aircraft competition, man-carrying as well as model, places different restrictions upon the models flown in the international competitions. Ships flown in the world championships are span-restricted; the maximum allowable wing span is 70 centimeters. Furthermore, the model, sans motor, must weigh a minimum of one gram. The problem, then, is this: Does one use a slender or bulbously outlined wing? Now long, slender wings are very efficient aerodynamically; witness, for example, the sailplane. Unlike F.A.I. competition models, however, the sailplane is actually operating under a fixed wing-area requirement with the span limited only by the need for structural integrity. With a fixed span an increase in supporting surface area will reduce the flying speed but increase the "wetted" area. Reduced speed tends to reduce the power required; increased wetted area, to increase it. Is there, then, some optimum wing size?

From classical aerodynamics we can derive a result which will provide us the answer to the question. We can do this in relatively direct fashion by developing a formula for the power required. Power is force—in this case the drag of the wing—times velocity.

$$P = D \times V \quad \text{Now } \frac{D}{L} = \frac{D}{W} = \frac{C_D}{C_L}$$

$$\text{So } D = \frac{C_D \times W}{C_L}$$

$$\text{And } V = (W / (C_L \times \frac{\rho}{2} \times S))^{1/2}$$

By substitution we have

$$P = \left(\frac{C_D}{C_L} \times W \right) \times (W / (C_L \times \frac{\rho}{2} \times S))^{1/2}$$

$$\text{However } C_D = C_{DI} + C_{DO}$$

$$\text{and } S = \frac{B^2}{AR}$$

Hence, directly

$$P = \frac{(C_{DI} + C_{DO}) \times W^{3/2}}{(C_L)^{3/2} \times \left(\frac{\rho}{2}\right)^{1/2} \times \frac{B^2}{AR}}$$

$$\text{Since } C_{DI} = \frac{C_L^2}{\pi \times AR}$$

we have, by substitution and clearing,

$$P = \frac{\left(\frac{C_L^2}{\pi \times AR} + C_{DO} \right)}{(C_L)^{3/2}} \times (AR)^{1/2} \times \frac{W^{3/2}}{B} \times \left(\frac{2}{\rho}\right)^{1/2}$$

This complex-appearing formula is the end point of our brief derivation. It contains all of the elements necessary to evaluate the theoretical optimum wing aspect ratio, and to provide this information in graphical form, easily understood. This was accomplished the easy way, by computer. While calculus might have been employed to establish a new formula for minimum power, such a new formula would have had, in itself, very restricted use and would have required

additional analysis to determine, for example, how rapidly power requirements change with changes in aspect ratio. The computer program enabled swift calculation of power requirements, not only for changes in aspect ratio, but also for changes in other variables.

There are several terms in the derived formula which are either aspect ratio independent or actually fixed in value. These terms were assigned suitable values in the computer program and then the power requirement calculated over appropriate ranges of the terms of interest. The air density, for example, was fixed at its sea level value. The wing span is obviously fixed. The overall weight, W , of the model includes the motor weight, and so changes in the latter would alter the overall weight. As a very close rule of thumb, however, the motor weight is approximately equal to the structural weight of the model itself. For the calculations, therefore, W was set equal to twice the F.A.I. model weight.

Very little is known about the coefficient of profile drag for indoor models. Because of the extremely limited application to technical and commercial use at extremely low air speeds, the behavior of this coefficient is largely uninvestigated. Values calculated from some limited, published experimental work on indoor wings were in the vicinity of 0.10; values calculated from flight tests by the author were in the vicinity of 0.13 for the complete model. Normally this coefficient seems to remain virtually constant for a given wing or aircraft, regardless of flight attitude. In the computer analysis, therefore, three distinctly different values for C_{DO} —0.06, 0.10, and 0.13—were used simply to provide a check over the apparent range of this coefficient.

However, the coefficient of lift increases directly with increases in the angle between the wing and the relative wind up to the angle at which the air-flow pattern about the wing collapses and stalling occurs. Because of the ease of the computer calculations, a wide range of C_L values (from an unlikely, extreme low of 0.2 to the value of 1.0—about as high as is found in normal flight) was used.

A computer program to evaluate the power required for the various chosen values was developed. This provided immediate numerical answers which could be graphed to show precisely the effect of the several variables upon the power. These results have been plotted in the graphs of Figures 1, 2, and 3. The graphs show the variations in required power for changes in aspect ratio for incremental values of the coefficient of lift. Figure 1 is based on the profile drag coefficient of 0.06; Figure 2, on the coefficient of 0.10; and Figure 3, on the coefficient of 0.13.

We can immediately generalize from the graphs that in all cases high coefficients of lift result in low power consumption. The higher the coefficient of lift, the lower the power required. From the builder's point of view, this means simply that the wing should be set at the highest possible

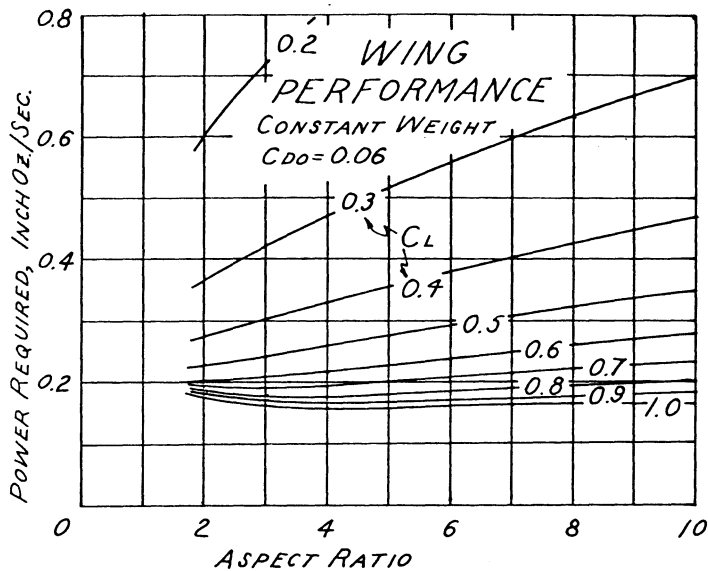


Figure 1. Wing performance constant weight $C_{DO} = 0.06$.

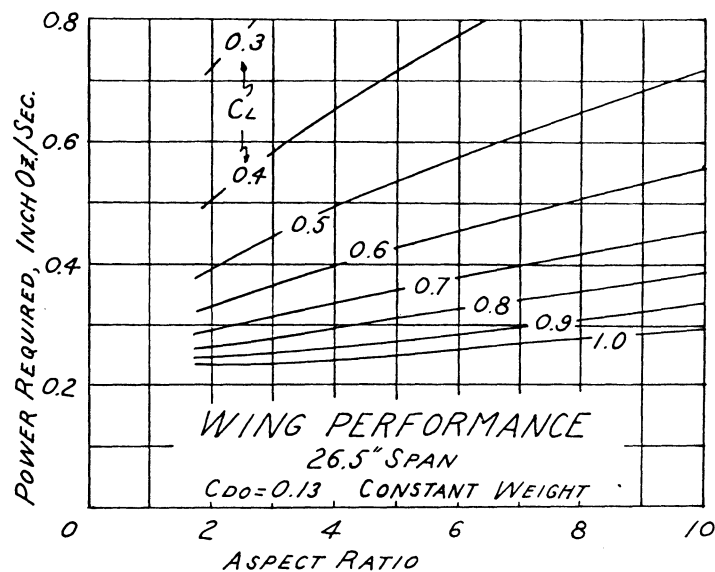


Figure 3. Wing performance 26.5 inch span $C_{DO} = 0.13$ constant weight.

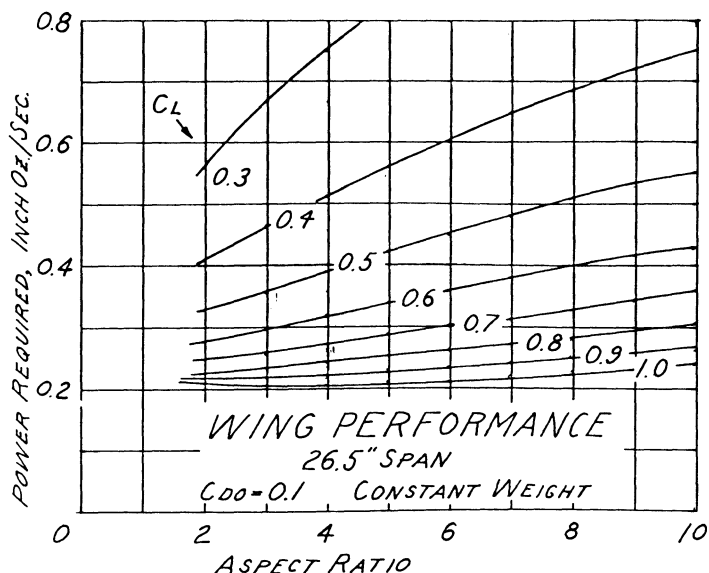


Figure 2. Wing performance 26.5 inch span $C_{DO} = 0.1$ constant weight.

angle since, at these low speeds, the coefficient of lift increases uniformly with the angle between lifting surface and relative wind up to stalling. This optimum wing setting can be most easily obtained experimentally through glide tests. The wing angle is increased by small increments after successive glides until the model no longer glides smoothly but stalls and has an erratic flight pattern. Then the wing angular setting is diminished slightly. The result is the setting with the highest usable coefficient of lift.

The fact that the highest lift coefficients result in greatest efficiency also makes it possible to generalize from the graphs about the optimum aspect ratio. For the high coefficients of lift aspect ratios in the vicinity of three to five result in lowest power consumption by the wing. This is most fortunate since structural integrity precludes very low aspect ratios. The delicate, flimsy wing structures are notoriously weak in torsion and must be maintained in accurate alignment by substantial amounts of microscopically thin, tungsten-wire bracing. Pudgy wing outlines are virtually impossible to brace satisfactorily. (It is true that the frameworks are also very weak in bending, but this bending in itself is not particularly bothersome. The major difficulty is caused by non-uniform fore and aft lift distribution over the wing, resulting in twisting of the wing. Anyone who has watched the wings of a large passenger carrying aircraft in flight has certainly seen the wings flexing up and down, but never twisting. Structural design must absolutely prevent this.)

The computer solution which has been developed has provided a thorough insight into the performance of the wing of the F.A.I. World Championship competition indoor model. When one considers the entire model, however, another important item affecting wing size appears. This is the power plant. Wings of high aspect ratios are of low area and must travel more swiftly to provide the same lift. Thus, even though the wing, per se, may not require more power for high aspect ratios, the remainder of the model does.

For non-lifting elements, the power required increases as the cube of the velocity. This becomes another persuasive argument favoring the lowest possible aspect ratio which can be satisfactorily used.

SYMBOLS USED

ρ = Air density

P = Power

V = Velocity

D = Drag

W = Weight

L = Lift

S = Wing Area

B = Wing Span

AR = Aspect Ratio, Ratio of span to average chord

C_L = Coefficient of lift

C_{DI} = Coefficient of induced drag, due to generation of lift

C_{DO} = Coefficient of profile drag, due to shape and skin friction

C_D = Total coefficient of drag, $C_{DI} + C_{DO}$

From Classical Aerodynamics

$$L = C_L \times \frac{\rho}{2} \times S \times V^2$$

$$D = C_D \times \frac{\rho}{2} \times S \times V^2$$

$$C_{DI} = \frac{C_L^2}{\pi \times AR}$$

$$AR = \frac{B^2}{S}$$

HISTORY OF SCIENCE

HERMANN LEBERT'S CONTRIBUTIONS TO THE UNDERSTANDING OF CANCER AND CANCER GENETICS

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Hermann Lebert (1813-1878) was born in Breslau, Germany (now Poland). His medical studies took place in Berlin and later in Zürich, Switzerland. In 1836 he studied in Paris under Dupuytren and Louis. In 1838 he began the practice of medicine at Bex, Switzerland, followed by work in Berlin, Paris, Zürich, and Bex again, and finally, Breslau. He wrote prolifically in both German and French and is best known as one of the first anatomists of the 19th century to use the microscope for pathology studies. Among his many research efforts, he distinguished between tuberculosis and cancer, which until that time had often been confused as the same disease. In Paris from 1857-1861, he produced an atlas of pathologic anatomy entitled, *Traité D'Anatomie Pathologique, Générale et Spéciale*, in which he may have been one of the first to describe premalignant polyps of the colon, rectum, and stomach. Cancers of all sites were described grossly and microscopically. He believed that only 7% of cancers were hereditary, citing Napoleon's family history of gastric cancer as one example.

† † †

INTRODUCTION

Hermann Lebert was born on June 9, 1813 in Breslau, Germany. He studied medicine in Berlin, later in Zürich, Switzerland, under Schonlein, where he received his doctor's degree at the University of Zürich in 1834. He also studied botany in Switzerland. Then, from 1834-1836 he studied in Paris with Dupuytren and Louis. There, he came to know and work with Velpeau, Charcot, Laennec, Broca, and others. He went into private practice in Bex, Switzerland in 1838. After a short stay in Berlin during the winter of 1845-1846, he returned to Paris, received permission to practice medicine, and remained there until 1853 when he was appointed Professor of Medicine at the University in Zürich. In 1859 he returned to Breslau as Professor of Clinical Medicine where he remained until 1874 at which time he returned to Bex. He died August 1, 1878.

Lebert is noted for his numerous anatomical writings, keen observations, and accurate descriptions in pathologic anatomy. One of his best known publications was entitled *Physiologie Pathologique*, published with an atlas in 1845 and for which he received a prize from the French Academy of Sciences in 1848. In Paris, at the invitation of the French government, he and Professor Charles Robin made anatomical preparations for a new medical museum. In 1849 he published

Traité Pratique des Maladies Scrofuleuses et Tuberculeuses for which he received the Portal Prize of the French Academy of Medicine. In 1851 he published *Traité des Maladies Cancereuses* for which he also received a prize. In 1854 the first volume (a huge tome about 2 feet long, 1 foot wide, and 2-3 inches thick) entitled *Traité d'Anatomie Pathologique Générale et Spéciale* was published. The entire series, which was comprised of a second volume of text and two volumes of atlas, was not completed until 1862. Lebert's earlier writings were in French; his later ones were in German and included *Handbuch der allgemeinen Pathologie and Therapie*, second edition, published in 1875, and *Die Krankheiten des Magens* in 1878.

Lebert was one of the first to use the microscope for pathology studies. Therefore, his descriptions were of gross as well as microscopic aspects of diseased organs, tissues, and cells. He made special studies of tuberculosis, carcinoma, tumors of the uterus, and aneurysms, and was one of the first to differentiate clearly tuberculosis from cancer of the lungs and other organs (Lebert, 1845). Honors which he received included Chevalier de la Legion d'Honneur, Monthyon Prize, Lauréat de l'Institut de France et de l'Académie Impériale de Médecine, Member of Anatomical, Biological, Surgery, médicale d'emulation, médical d'observation Societies of Paris. He was a member of the Society of Natural History of Switzerland, Zürich, Berne, Geneva, Lausanne, Neuchatel, Wurzburg, Dresden, Leipzig, and other cities.

POLYPS—COLON AND OTHERS

A hereditary pre-cancerous disease, familial polyposis coli (hereditary polyps of the large intestine) was first described by Cripps in England in 1882 (Cripps, 1882). Though Lebert did not describe the hereditary nature, nor the fact that these polyps are pre-cancerous, he made accurate observations and descriptions of both nasal and intestinal polyps (Fig. 1). He described four kinds of polyps. These were: 1) protruding epithelial polyps which become vascularized and grow quite large; 2) hypertrophy of the glandular layer, particularly in the nasal and intestinal fossae. He described such polyps in the rectum as "large numbers of polyps, each the

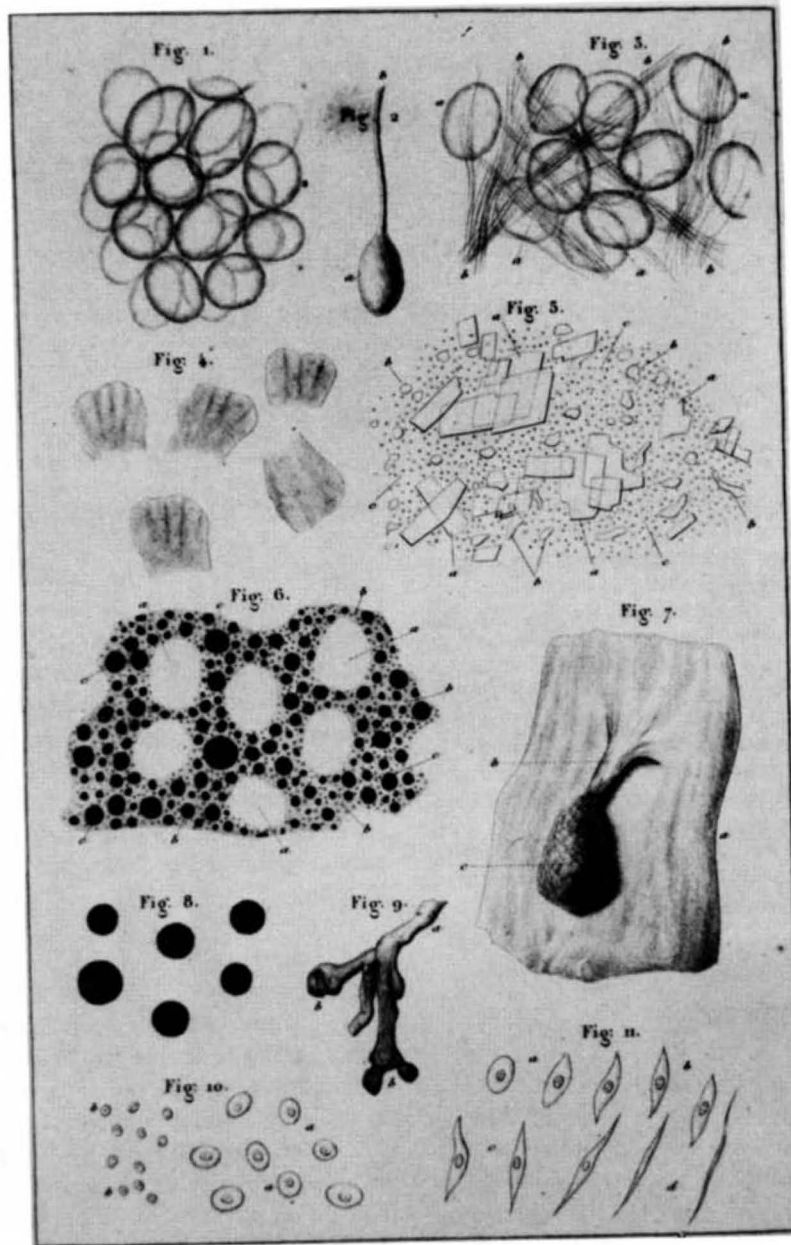


Figure 1. Copies of Hermann Lebert's original drawings of eleven types of cells, fibers and polyps found in the human digestive tract.

size of a hazel-nut, composed of elongated small glandules" (Lebert, 1857-61:266); 3) in the nasal fossae more often than in the intestines and bladder, he described polyps smaller in size than two above—the size of a pea or bean, composed entirely of hypertrophied mucous membrane. These polyps were gelatinous, semitransparent, and elastic; 4) sub-mucous polyps found in the nasal fossae and the digestive tract, of large dimensions and composed of connective tissue interposed with an amorphous gelatinous substance. He felt that these four kinds of polyps were not really distinct, but since one could find among polyps all kinds of intermediate degrees and fibrous tumors seemed to be related to the sub-mucous number four type of polyps, they might all be variations of the same thing (Lebert, 1857-61).

Lebert noted that polyps tended to be multiple in the stomach, intestines, and bladder, but that they were usually small in these locations—the size of a hazel-nut or a walnut. On the surface they were rounded and pedunculated at their point of attachment to the mucous membrane (Lebert, 1857-61:265).

CAUSE OF POLYPS

Lebert was as much in the dark concerning the cause of polyps as we are today. He stated that in the past they were attributed to a chronic inflammation of the bowel; but he speculated that they might be caused by something unusual in the diet or nutrition.

Polyps of the stomach were common in Lebert's practice. He described one patient with between 150 and 200 small polyps (the size of a pea) in the pyloric region of the stomach. (He also described one patient who had one large polyp in the cardia of the stomach.) The small pyloric polyps were usually sessile or pedunculated. Patients with gastric polyps were noted only rarely to have any symptoms.

Lebert described a case of multiple polyposis of the large intestine in a woman who died of marasmus following constant diarrhea for a year. All attempts to stop the diarrhea had failed (but surgery, with removal of the colon, was apparently not known at that time). He commented on a case of rectal polyps in a young girl, seventeen years old, and another in a 40-year-old woman (1850) in whose rectum an egg-sized tumor was removed. Previous doctors had made a diagnosis of hemorrhoids. Today we would surmise that both of these women, because of the young age when polyps were discovered, might have the hereditary kind of polyps, either familial polyposis coli or the Gardner syndrome, and we would instigate a family genetic study.

Lebert recognized that sebaceous cysts occurring on the head could be hereditary. He described in detail the appearance and the location of such cysts in a 35-year-old man and in his mother (Lebert, 1845, 2:35-36). It is too bad that he did not look for polyps in the colon in this family, because he might have been the first to describe what is now called the Gardner syndrome which consists of pre-malignant adenomatous polyps of the colon, sebaceous (or epidermoid cysts), osteomas, sometimes desmoid cysts, and other extra-colonic tumors.

Lebert described what is now known as juvenile polyposis in two children. One concerned a child who died of measles. At autopsy he found "a melanotic tumor, with a volume of a pea attached to the intestine by a pedicle 5 millimeters long." He described this polyp in minute detail (Fig. 1; illus. 6) and thought it represented hypertrophied cellular tissue in the sub-mucous layer of the intestine.

The second concerned a polyp in the small intestine of a three-year-old child who died of "tuberculosis" (Fig. 1; illus. 7). He described it as follows: "This black and compact tumor is attached to the small intestine by a pedicle 1 centimeter long, and 4-5 millimeters thick. The polyp is flattened, two centimeters long, 15 millimeters wide at its widest part and 5-7 millimeters wide at its point of insertion. The pedicle is reddish (the color of muscles) . . . is covered by a mucous membrane on which many crystals can be found. The surface of the polyp is covered with many crystals, blood vessels and melanotic cells" (Lebert, 1845, 2:114-115).

CANCER

Lebert thought that cancer differed from benign tumors by the fact that though benign tumors had all the charac-

teristics of the elements or tissues from which they stem, cancer was distinct and "quite different from all the other forms of globules which one finds in the normal state" (Fig. 2). His definition of cancer was: "a near heteromorphic accidental production with a tendency to become generalized (in the body), to become constitutional, and with a tendency to destroy all the tissues it surrounds, whose cells are different from normal cells in the body (Lebert, 1845, 2:211-240). He described a "hard" cancer of the stomach of a woman, age 69. She had been in good health until the age of 67 when she had a short period of dyspepsia which disappeared. She had no other symptoms until 11 months before her death when she began to vomit after meals—coffee ground material with her food. But she had no other symptoms of pain or discomfort in the stomach. At autopsy 11 months later, her stomach was thickened with a large hard tumor in the pylorus (Lebert, 1845, 2:364-365).

Lebert described benign and malignant tumors of cartilage and bone. He noted that sometimes after surgery for a large bony tumor, patients died "because of the production of a large number of tumors in various other internal organs, principally those of the chest cavity" (Lebert, 1845, 2:424-442). This seems to indicate a description of metastasis of sarcoma of the bone to lung.

In discussing possible causes of cancer about which he "confesses insufficient scientific knowledge of this subject" (Lebert, 1851), Lebert suggested a number, including: "external violence (blows and bruises), grief or depression, heredity, influences of age, sex, season of the year, nutrition or diet, economic status, living environment, excessive alcohol intake, state of health, and age at menopause in women (Lebert, 1851:516). For example, in discussing the causes of cancer of the stomach, he noted that cancer of the stomach occurred more frequently among the rich class than among the poor class. In 21 patients with cancer of the stomach in which wealth was noted, 15 were rich and 6 were poor (Lebert, 1851:520). He then concluded that there was actually no known cause at the time he wrote.

Concerning the influence of heredity, Lebert mentioned that a number of scientists had cited examples of hereditary cancer of the stomach, the most noteworthy being the family of Napoleon. In his own series of cases, Lebert reported that only 5 of 42 instances of stomach cancer appeared to be hereditary. Therefore, he felt that heredity, though sometimes a "cause" of cancer, was more the exception than the rule (Lebert, 1851:521-522).

Finally, Lebert's chief aim in all of his anatomical and pathological studies with the microscope was to "end the suffering and death of cancer victims (Lebert, 1851:XX).

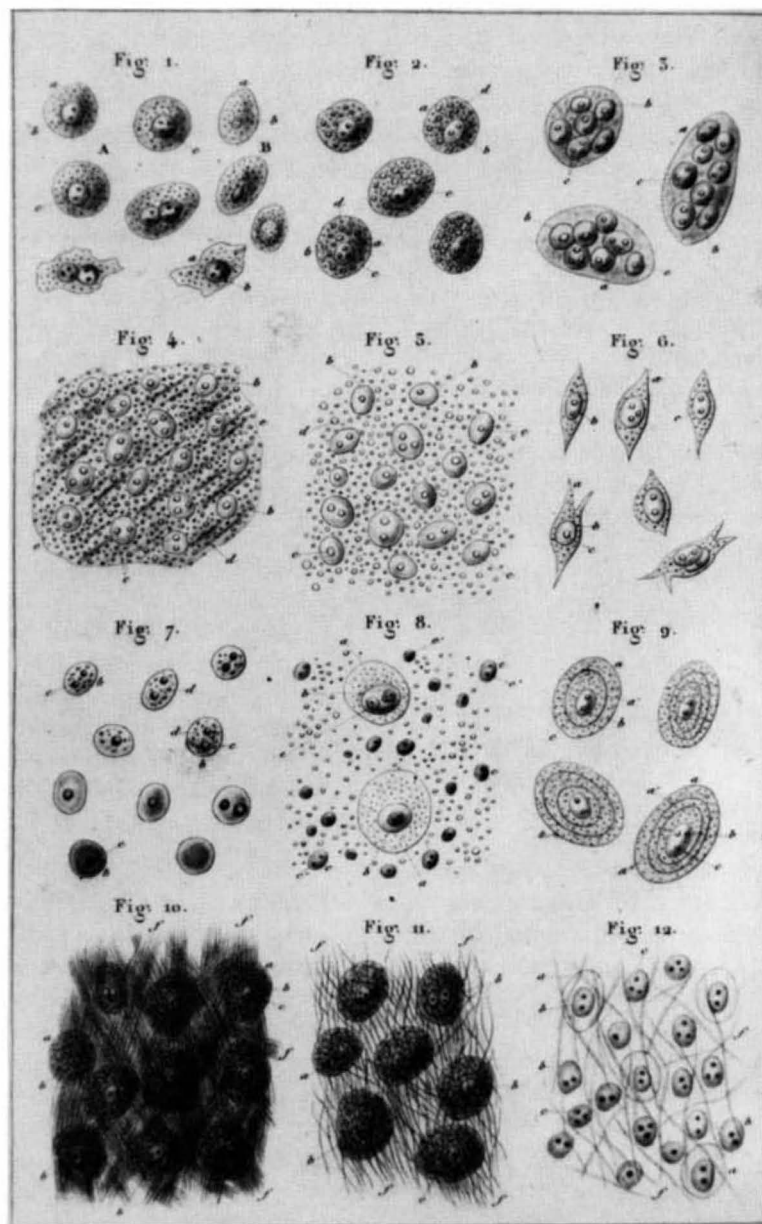


Figure 2. Copies of Hermann Lebert's original drawings of twelve types of cancer globules, cells, and tissue found in cancer of the human digestive tract.

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THE METHODOLOGICAL PRINCIPLES OF PLATO AND BERGSON

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Striking similarities in certain aspects of the doctrines of Plato and Bergson support the claim that, for both, intuition is the sole method of apprehending the ultimate object of epistemological certainty.

† † †

INTRODUCTION

One of the historically recurrent problems in philosophy concerns the idea of the Real: What is the Real and by what means (if any) can it be known? These fundamental metaphysical and epistemological questions have assumed central importance throughout the writings of most philosophers but are treated with especial brilliance and novelty in the philosophies of Plato and Bergson. For Plato, knowledge of the Real consists in the dialectical movement along the "upward path" from the world of appearances to the world of the immutable, unchanging Forms. Bergson, on the other hand, argues that the Real is pure duration, a heterogeneous, qualitative multiplicity that can be known only through an intellectual conversion whereby one gains an intuitive understanding of the Real. Although Plato and Bergson disagree as to the nature of the Real, there is a striking resemblance in methodology that both men advocate. This similarity in methodology is not historically interesting, but may well serve as a stepping stone in the unraveling of a supposed ambiguity within the Platonic Corpus. Whereas Bergson is quite explicit in setting forth a theory of philosophical method, Plato treats the issue in a rather cursory manner at various places in the Dialogues. Consequently, many interpretations have been put forth in an attempt to render consistent the various passages throughout Plato's works. But striking similarities in certain aspects of the doctrines of Plato and Bergson suggest an interpretation of Plato that does justice to the various relevant passages scattered throughout the Dialogues. Thus, I shall first make some general remarks about the methodologies of Bergson and Plato in order to set the stage for the comparison that I hope will shed light on Plato's method. Of course, in undertaking such a task, one must proceed in a vigilant manner, being careful not to force the thought of one philosopher into the Procrustean Bed of another. We must, in Bergson's words, "grasp the thought of a philosopher for what it really is" (1946:108).

I

Bergson, as is well known, distinguishes two profoundly different ways of knowing a thing: the way of analysis and the way of intuition. Analysis is the understanding of a thing through what it is not. It expresses the nature of an object in terms of other objects that are already taken to be known. It uses universal concepts only, and, therefore, by this method one can know of an object only by what it has in common with other objects, never by what is unique in it. Any object is more than a meeting place of a number of universals; but this addition that explains the meeting of them is precisely what conceptual methods cannot capture. Intuition, on the other hand, is an intellectual sympathy, acquired by no little effort, whereby one is projected into the object and identified with its being. It puts one in possession of some absolute, not as a point upon which universals are seen to converge, but as a point from which they are seen to radiate.

Thus, it appears that analysis and intuition are directly opposed to one another. Yet, in the life of knowledge, there is an organic bond between the two by virtue of which the one process pays into the other. Hence, the function of intuition can be best understood as a process complementary to analysis. In other words, the richness and the significance of an intuition is dependent upon the amount of analysis preceding it. An intuition gained by merely abandoning the work of concept-forming and concept-weaving is an unintelligible blur into which nothing has gone and from which nothing can emerge. To take one of Bergson's examples: one may read the adventures of a hero with a readiness of sympathy hardly to be distinguished from an ill-balanced sentimentality, or one may keep alert one's powers of criticism and analysis, studying the character from different angles and, finally, fusing those judgments in a way that puts one in a ready disposition to enter sympathetically into the character of the hero. The first would be an intuition that had ignored or rejected the work of analysis; the second, one that would have meaning because it builds upon and supplements that undertaking.

Like Bergson, Plato holds that knowledge of the absolute or Real is possible, but possible only if one is willing to employ a particular method. The particular method that Plato

discusses and recommends is called by him "the dialectical method" or "the power of conversing." Although Plato speaks of this method in various dialogues, the precise nature of the Dialectic is nowhere explicitly formulated. And while the *Phaedo* and the *Republic* provide the best source of examination in an attempt to understand Plato's methodology, many critics have found incongruities between the two texts.

In the *Phaedo*, Plato formulates a methodological principle that would enable one, by careful use of reasoning, to attain clear insight into the nature of all things. This "method of hypothesis," as it is called, involves the following features: (1) It is an hypothesizing in which one adopts opinions deliberately—he does not slide into them unconsciously; (2) It is a procedure in which one explores implications—drawing out the consequences of hypotheses—and carefully distinguishes premises from conclusions; (3) It is a method that consists in paying the utmost attention to the avoidance of contradiction, in rejecting any set of opinions that is self-contradictory; and, finally; (4) The hypothetical method consists in holding one's opinion provisionally, never dogmatically.

The method of hypothesis, therefore, seems to suggest a procedure of graduated approximation, whereby alterations are perpetually made in one's whole web of opinions as contradictions are revealed among them. In this manner, the inquiring mind renders these opinions more and more adequate. But it does not appear that they are ever rendered final; the possibility that another contradiction will turn up is always present. This method seems to provide no way of converting the provisional into the certain.

The topic of methodology is again treated in the *Republic*, especially in connection with the Divided Line and the Cave. And while much of the discussion in these passages is consistent with the hypothetical method of the *Phaedo*, Plato makes an addition: he now proposes that by means of this tentative and hypothetical attack, one may reach absolute certainty. It is not a matter of perpetual improvement and approximation as in the *Phaedo*, but of attaining incorrigible truth. Plato declares that a proper method, while recognizing hypotheses for what they are, can so manipulate them as to reach indubitable truth or the "unhypothesized beginning."

Thus, in the *Republic*, Plato advocates a passage from hypothesis to an unhypothesized beginning by way of an "upward path." The dialectical method alone proceeds in this upward manner, destroying inadequate hypotheses in the movement toward the Real. Now, while the upward path includes the hypothetical method of the *Phaedo*, it does not seem to exhaust the dialectic as Plato conceived it in the *Republic* because it does not give the infallible certainty or sure grasp of an "unhypothesized beginning" that is emphasized in the *Republic*. The characteristic and new element in the *Republic* is the claim to have a method that gives absolute certainty. The question to be raised here is: What method

has Plato determined in the *Republic*, in addition to the hypothetical method of the *Phaedo*, by which he thinks the dialectician can escape from the tentativeness of the *Phaedo*'s procedure and reach indubitable certainty? In order to answer this question, I want to explore the methodologies of both Plato and Bergson, hoping that the suggestiveness of this comparison will secure an answer.

II

It should be clear from what has been said that the philosophical methods of Plato and Bergson admit of comparison. Above, I claimed that analysis and intuition are intimately bound up with each other, such that analysis serves as a mental preparation for an intellectual conversion. Again, I held that while the hypothetical method of the *Phaedo* is incorporated into the dialectic, Plato argues that this latter method can lead one to absolute knowledge of the Real, whereas the former cannot. Thus, for both men, the Real is capable of being grasped intellectually by means of a special method. In this section I want to argue that for Plato, knowledge of the Real is to be attained by intuition, a method similar to the intellectual sympathy that Bergson repeatedly emphasizes. Thus, I shall proceed by carefully tracing Plato's theory of dialectic, making the appropriate connections to Bergson's thought.

The upward path of the *Republic* includes, then, the hypothetical method of the *Phaedo*, yet there seems to be an added element. Whereas the hypothetical method only secures tentative certainty, the dialectic arrives at absolute certainty. It is true that in the Line, Plato is pointing to a contrast of intellectual temperaments, and that the scientific habit of reasoning from unquestioned assumptions does differ from the philosophical readiness and ability to extend indefinitely the analysis of the presuppositions either of science or common sense; but it is false that this is all he is doing. Bergson seems to be in complete agreement with this when he discusses the contrast between science and philosophy. Science, for Bergson, uses symbols and proceeds by reducing objects to elements already known. Philosophy, on the other hand, must go beyond all concepts in order to grasp what is real. So long as one is confined to the realm of concepts, all knowledge is relative. Only a transcending of this scientific framework will yield knowledge of the absolute.

Plato seems to be arguing in a similar fashion. Science, for Plato, utilizes the hypothetical method. In the same way in which analysis for Bergson will never lead one to the Real, so for Plato, science proceeds by drawing consequences from hypotheses in an attempt to reach a more adequate hypothesis. But such a method cannot go beyond any "hypothetical beginning": no absolute knowledge is capable of being revealed.

It has already been noted that Bergson advocates a "going beyond" all conceptual analysis, a complete dispensing

with the symbols ordinarily used in everyday thought. Plato's theory of the Line conveys a similar outlook and can be interpreted as a method for "going beyond" the methods of science to grasp the absolute or what is unquestionable.

Another comparison will bring my point clearly into focus. In the first section of this paper, I was particularly concerned to stress the relationship between analysis and intuition, and I argued that the appropriate amount and kind of analysis may put one in a disposition to make the mental effort of intuition. Similarly, in the *Republic* Plato seems to be claiming that the man who competently and conscientiously practices this hypothetical method may one day find himself in the possession of an unhypothesized beginning. This final stage of cognizing the "unhypothesized" is not a proof; no demonstration is made of the absolute at all. Socrates speaks in terms of "proceeding" to a beginning, but this is not to say that one proves what is grasped absolutely. The "beginning" at which dialectic arrives is the Form of the Good; and Plato's view seems to be that the Good, far from being proved, is the presupposition of all proof that is not hypothetical. In the way in which the Real for Bergson is known through intuition, so for Plato; it seems reasonable to interpret him as saying essentially the same thing: Knowledge of the Good involves an intuition, a going beyond all analysis, a dispensing with hypotheses. Of course, for Plato, the process of the upward path is necessary for knowledge of the Good, though it is not sufficient.

If my interpretation of Bergson set forth at the beginning of this paper is essentially correct, then it is clearly reasonable to make a comparison between the relationships of analysis and intuition on the one hand, and of progression along the upward path and knowledge of the Good on the other. But one may question whether Plato should be held to an "intuition" theory of the upward path. Perhaps I have made use of the Procrustean Bed in my comparison of Plato and Bergson. Yet, I think other passages throughout the Dialogues may secure my claims concerning the dialectic so far.

If the upward path, like analysis, does not prove or lead one automatically to knowledge of the Real, of what use is it? In lieu of proceeding up this challenging path, why not begin at the beginning itself? The reason lies in what I take Bergson to be saying concerning analysis and intuition. I mentioned that intuition without analysis would be like someone naively sympathizing with the character of a novel where the intellectual sympathy involved could hardly be distinguished from ill-balanced sentimentality. In a similar manner, the prisoner released from the Cave goes through a series of objects graduated in brightness before he can look at the sun. This series of preliminary objects does not demonstrate the sun, but only enables him to see it. The prisoner gradually strengthens his eyes. Just so, the dialectician on the upward path is gradually strengthening his mental vision until he can fully comprehend the existence of each stage. Without

progressing along this series of objects graduated in brightness, one would be blinded and overcome by gazing at the sun, not unlike the person who naively enters into the character of the novel.

In "Philosophical Intuition," Bergson speaks of intuition as a negative process in which one rejects a certain idea as being simply impossible:

What a strange force this intuitive power of negation is! . . . Is it not obvious that the first step the philosopher takes when his thought is still faltering and there is nothing definite in his doctrine, is to reject certain things definitely? Later he will make changes in much of what he affirms, but he will vary only slightly in what he believes (1946:105).

Again, it seems that this negative aspect of intuition parallels one's progression up the Line. At each successive stage of the Line, one is greatly inclined to accept the appearances and take them to be Real. But it is the whispering of the word "Impossible!" into the philosopher's ear that compels him to reject as Real what each stage offers, "even though the facts and reasons appeared to invite you to think it possible and real and certain" (1946:110). Thus, as one moves up the Line, the hypotheses that present themselves are continually being altered and refined, rejected for what is more adequate.

Let us turn now to other Dialogues for support of my interpretation, which at this point may seem to rest on tenuous evidence. In the *Symposium*, Plato gives an account of the lover's progress to the Beautiful. Although the Beautiful is known through itself, a long apprenticeship among the many beautifuls is necessary before this direct knowledge can occur. A similar view is implied in the *Seventh Letter*. Plato says that:

It cannot be expressed like other learning, but after community of life with much discussion of the matter itself, it suddenly appears in the soul like light kindling from leaping fire, and thenceforth sustains itself (341c).

This is perhaps the clearest passage that lends credibility to my claims. Here, Plato, like Bergson, is saying that knowledge of what is Real is not to be gained in the way one approaches the sciences. Rather, one must go beyond all science and its methods to gain an intuition whereby the Real "suddenly appears in the soul." This "suddenness" suggests an immediacy, a dispensing with one's ordinary manner of symbolism, and an "entering into" or sympathizing intellectually with the Absolute.

Both in the *Republic* and the *Seventh Letter*, Plato seems to attribute the same quality of ineffability to one's

apprehension of the Good that can be found in Bergson's claims concerning the intuition of duration. For Bergson, one's experience of pure duration is essentially incommunicable!

. . . that which constitutes his [the character's] essence cannot be perceived from without, being internal by definition, nor be expressed in symbols, being incommensurate with everything else (1946:108).

In Plato this same inexpressibility of one's intuition of the Real is mentioned in the *Republic*. When Glaucon asks Socrates to tell him what the Good is, Socrates replies:

I am afraid it is beyond my powers; with the best will in the world I should only disgrace myself and be laughed at (506E).

Again in the *Seventh Letter* Plato, in talking about knowledge of the Good, writes:

But when it is "the fifth" about which we are compelled to answer questions or to make explanations, then anyone who wishes to refute us has the advantage and can make the propounder of a doctrine, whether in writing or speaking or in answering questions, seem to most of his listeners completely ignorant. . . . Those who listen sometimes do not realize that it is not the mind of the speaker or writer which is being refuted, but these four instruments mentioned. . . (343E).

The reservations that Plato expresses in both passages concerning the communicating of the Good stems from the fact that since the knowledge to be gained of the Good is inexpressible, any attempt to convey such knowledge is hopelessly obscure, if not silly.

In talking of "intuition," Bergson describes this experience as an "entering into" the object in order to understand what is unique in it. I think Plato has a similar point in mind in his repeated assertion that there must be a kinship between the mind of the enquirer and the ultimate objects of philosophical study. For example, in the *Seventh Letter*, Plato says:

In short, neither quickness of learning nor a good memory can make a man see when his nature is not akin to the object (344A).

Both men appear to be saying that intuition involves an immediacy that no amount of analysis or scientific research or method of demonstration can attain.

There is a final comparison I want to sketch con-

cerning Plato's conception of the downward path and Bergson's notion of moving from intuition to analysis. In "Philosophical Intuition," Bergson claims that as one seeks to penetrate more fully into a philosopher's thought instead of "moving around its exterior," his doctrines are transformed for us. In other words, by grasping what is essential to the thought of another *via* intuition, the whole of his thought is brought together "into a single point." The various aspects fit neatly together as the multifarious facets of the philosophy appear with new clarity and freshness. This is an example of a movement from intuition to analysis. A similar concept is to be found in the downward path that moves from one's grasping of the Good to the various lesser levels. Having knowledge of the Good, one possesses for the first time categorical, demonstrative knowledge. The downward path distinguishes the true from false hypotheses of the upward in a process that includes assimilating what is true and approaching it from an indubitable, unhypothesized standpoint.

To conclude, there are, no doubt, many more comparisons to be made here, but they will be left untreated in this paper. Of course, the reader should not be persuaded that everything that Plato and Bergson say on this issue coincide perfectly. My purpose is to elucidate those points of coincidence that I think useful in coming to a correct interpretation of Plato's dialectic.

ACKNOWLEDGMENT

This paper was written in the fall of 1974 under the auspices of Professor Robert Reinl, Arizona State University, whose helpful comments led me along the "upward path."

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PHILOSOPHY OF SCIENCE

THE GENERAL FORM OF THE NEW RIDDLE OF INDUCTION

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Nelson Goodman has maintained that a definition of confirmation which does not include a criterion of lawlikeness will allow the "confirmation" of any prediction whatsoever on the basis of any given body of data. Unfortunately, Goodman does not give an argument for this claim, but contents himself with illustrating it by examples. This paper supplies the argument which Goodman did not give, and thus shows that his claim is justified. My argument brings out what is essential to the construction of "grue"-type predicates, and thereby clarifies the nature of "the new riddle of induction."

† † †

Consider the following rule of inference:

- (R) x_1 , which is an A, has been observed to be B;
 x_2 , which is an A, has been observed to be B; . . . ;
 x_n , which is an A, has been observed to be B.
No A has been observed to be non-B.
Therefore, All A's are B.

Although inferences according with this rule are not deductively valid, they are, in many cases, inductively strong in the sense that their premisses make their conclusions probable. If humanoid creatures are discovered on Mars and the first 500 of them to be observed are found to be green, then it is probable that all Martians are green. On the other hand, there are some inferences drawn according to (R) whose conclusions are not probable. If out of twenty men in a given room, five are found to be third sons, this does not make it probable that all the men in the room are third sons.

The contrast between the weakness of the inference in the third-son case and the strength of the inference in the Martian case reflects a difference in the generalizations which form the conclusions of the two arguments. In one case we have an argument with the conclusion:

- (1) All Martians are green.

In another case we have an argument with the conclusion:

- (2) All the men in this room are third sons.

Now suppose we refer to statements of the form, 'x, which is an A, was observed to be B' as *instances* of generalizations

of the form 'All A's are B'. Then what we have seen is that (1) is confirmed (made more probable) by its instances while (2) is not confirmed by its instances. If we agree to call a generalization *lawlike* if and only if its instances confirm it, then we can put our finding even more succinctly: (1) is lawlike, but (2) is not. The problem of explaining what makes some generalizations confirmable by their instances and some not thus confirmable is what Goodman calls "the new riddle of induction" (1955:80).

Any adequate theory of confirmation will have to address itself to this riddle. Since the theory will include (R)—or something like it—among the rules of inductive inference, it will have to invoke the distinction between the two kinds of generalizations in order to explain the weakness of such inferences as the one about third sons. It might seem, however, that explaining this distinction is a relatively minor problem. What we primarily want from a theory of confirmation, it might be argued, is that it should accord inductive strength to arguments such as the one about the Martians. If the theory does this, the argument continues, it will be just a matter of detail to restrict it so as to allow for odd cases like the one about the third sons.

Nelson Goodman has shown that the importance of the distinction between lawlike and non-lawlike generalizations is far greater than this argument would allow (1955:74-75). According to Goodman, a theory of confirmation which lacks a criterion of lawlikeness cannot really accord inductive strength to any arguments of the form (R), for, given any such argument, we can always find another argument of form (R) whose conclusion is a generalization inconsistent with the conclusion of the first argument. Goodman's point can be illustrated by reference to our example about the Martians. Suppose we introduce the predicate "grue," defined as follows:

- (D) x is *grue* if and only if x is examined before _____ and green or not examined before _____ and blue.

Strictly speaking, this is not a definition of a single predicate "grue," but a recipe for constructing a whole family of "grue"-type predicates. To obtain the appropriate predicate, fill in

the blank with an expression designating whatever time it is when you read this. Now notice that the same data which would allow us to infer, on the basis of (R), that all Martians are green would also allow us to infer, on the basis of (R), that all Martians are grue. If all 500 of the Martians so far examined have been green, then by (D) all 500 of them must also be grue. Thus, (R) allows us to construct not only the argument:

(A₁) x_1 , which is a Martian, was observed to be green;
 x_2 , which is a Martian, was observed to be green;
 \dots ; x_{500} , which is a Martian, was observed to be green. *Nothing which is a Martian* was observed to be non-green.
 Therefore, all Martians are green.

but also the argument:

(A₂) x_1 , which is a Martian, was observed to be grue;
 x_2 , which is a Martian, was observed to be grue;
 \dots ; x_{500} , which is a Martian, was observed to be grue. *Nothing which is a Martian* was observed to be non-grue.
 Therefore, all Martians are grue.

On the basis of (A₁), we would predict that the next Martian to be observed would be green; on the basis of (A₂) we would predicate that the next Martian to be observed would be grue. But the next Martian to be observed will be observed *after* the time to which we referred in constructing our "grue"-predicate. Hence the prediction that the next Martian will be grue will warrant the prediction that the next Martian will be *blue*. This shows that if a theory of confirmation lacks a criterion of lawlikeness, we can take no comfort in the fact that the theory assigns inductive strength to (A₁). For the theory will also assign inductive strength to (A₂), and will thus warrant predictions incompatible with those we would make on the basis of (A₁).

Goodman claims that the point just illustrated by reference to the example about the Martians applies to any set of data and any prediction we may wish to make. Suppose that we have defined the relation of confirmation in such a way that generalizations are confirmed by their instances (in other words, inferences proceeding via rule (R) are accorded inductive strength), but that our definition does not include a criterion for excluding non-lawlike generalizations. Under these conditions, says Goodman,

\dots our definition not merely includes a few unwanted cases, but is so completely ineffectual that it virtually excludes nothing. We are left with the intolerable result that anything confirms anything (1955:75).

"Anything confirms anything" is an overstatement. What Goodman means is that given any set of *observational*

data, any *prediction* concerning future observation we may wish to make will be "confirmed" according to the definition. Still, the claim is a striking one. And what is even more striking is that Goodman offers no argument for it. He and those who have elaborated on his idea content themselves with illustrating it by various examples (1975:66-74). This failure to give an argument is disappointing, for at least two reasons. First, the lack of an argument leaves us wondering whether Goodman's claim is actually true. Second, since giving an argument would involve showing how to construct, for any given body of data and any given prediction, a predicate which would make the data "confirm" the prediction, the absence of an argument leaves us in the dark as to what is essential for the construction of 'grue'-type predicates. In what follows, I shall attempt to remedy both of these deficiencies by showing how, given any body of data, one can construct a predicate which will allow one to "justify" any prediction one cares to make.

Let us assume that we are dealing with a set of objects, o_1, \dots, o_n, o_{n+1} , all of which may be characterized by the predicate 'F.' Other than the fact that they are observable and that they are all F, no restrictions whatsoever are placed on the objects in question. We assume, furthermore, that by observing the first n objects, we have determined that they satisfy, respectively, the predicates, ' P_1 ' \dots , ' P_n '. Again no restrictions whatsoever are placed on these predicates. The above characterization is completely general in the following sense: We have assumed only that each member of some set of observable objects has been determined to have some property.

Our task now is to show that on the basis of the described observations of o_1, \dots, o_n we may confirm any hypothesis whatsoever about the next object, o_{n+1} . More specifically, where 'Q' is any predicate whatsoever, we want to show that the data described "confirm" the following: ' o_{n+1} is Q.' This may be shown as follows. Let 'D' be any predicate (there is sure to be at least one) true of o_1, \dots, o_n but not of o_{n+1} . And let us define a predicate 'G' as follows: (x) [(x is G iff (x is P_1 and D) or (x is P_2 and D) or \dots (x is P_n and D) or (x is Q and not D)]. Now, clearly, the data at our disposal are instances of and, therefore, "confirm"—in the absence of any criterion for excluding non-lawlike generalizations—the hypothesis: All F's are G's. We may, therefore, conclude that the next object to be observed, namely, o_{n+1} , which is an F, is a G. But, given the definition of 'G' and given that 'D' is not true of o_{n+1} , it follows that o_{n+1} is Q. q.e.d.

Let us take an example. Suppose o_1, \dots, o_n are all pieces of copper which at some time have been touched by a human being, and suppose it has been determined that each of them conducts electricity. Suppose, moreover, that o_{n+1} is some object untouched by human hands. Taking each of $P_1 - P_n$ to be 'conducts electricity' and 'D' to be "has been touched by a human hand," we may conclude that o_{n+1} has

any property whatsoever. If, for example, o_{n+1} is an untouched piece of gold, we can conclude from our data that o_{n+1} does not dissolve in aqua regia by letting $Q =$ is not soluble in aqua regia. Of course this result is absurd. But that is just the point. Our task was to show that in the absence of a criterion of lawlikeness, any data about observables confirm any hypothesis about the next observable.

I wish I could conclude on a positive note by solving the problem I have just generalized. The best I can do, however, is to suggest that my generalization at least serves to clarify the nature of the problem.

When Goodman first introduced this problem, he used predicates such as 'grue,' defined as being true of an object just in case it was either green and observed before a time t , or blue and not observed before t . Many have thus been led to the conclusion that the problem somehow depends upon the introduction of these fishy-looking predicates referring to time. Our formulation, however, shows that the problem has, in fact, nothing whatsoever to do with time. This point is illustrated by the example just given. In that case the predicate 'G' needed to derive the conclusion that the evidence "confirms" the presence of any property whatsoever in o_{n+1} makes no reference to time whatsoever. And, in general, our analysis shows that all we need to construct 'G' is some predicate, 'D', which happens to apply to $o_1 \dots, o_n$ but not to o_{n+1} . 'D' may, of course, refer to a time, but it need not do so. Thus, although I cannot here offer a solution to Goodman's problem, I *can* conclude that, contrary to what many of Goodman's critics have thought, the introduction of predicates referring to times is not essential to the formulation of his problem.

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ENARGEIA: A CONCEPT FOR ALL SEASONS

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INTRODUCTION

Aristotle, writing in the fourth century B.C., defined rhetoric as the "faculty of discovering in the particular case what are the available means of persuasion" (Aristotle, 1932, 1:2). He then proceeded to classify proofs intrinsic to the art of speaking into three modes—*logos*, *ethos*, and *pathos*. Consistent with his "scientific" point of view, he deplored writers of the arts of speaking who ignored argument; and his treatise emphasized the logical element in persuasion. As he said, persuasion is "effected by the arguments, when we demonstrate the truth, real or apparent, by such means as inhere in particular cases" (Aristotle, 1:2). That the purpose of much public, popular discourse throughout the ages has been to persuade or convince is obvious. However, the question of how the speaker or writer is to establish belief in his proposition and, in addition, appeal to the emotional and imaginative side of his audience has offered much scope for theorizing among rhetoricians. Naturally, as conceptions of human knowledge and human nature changed, theories of suasive discourse changed, too. Not all later rhetoricians agreed with Aristotle that enthymematic reasoning formed the body and substance of persuasion.

The ancient-rhetorical notion of *enargeia* (clearness, distinctness, vividness), however, played a very influential role in many theoretical discussions among later thinkers. Literary critics and aestheticians also considered *enargeia* as a quality of writing that could arouse emotions and give aesthetic pleasure. Finally, *enargeia* was revived by Descartes and the Cartesians as a criterion of truth and played a prominent role in philosophic discussions in the seventeenth and eighteenth centuries.

ENARGEIA IN RHETORICAL AND LITERARY THEORY

The Greeks were the first to offer a theory of imaginative appeal which, they thought, could produce the desired response in a listener or reader. Although Aristotle stressed the enthymeme as an engine of persuasion, he was keenly aware of the functional, rhetorical effect of language on listeners. In Book III of the *Rhetoric*, he considers linguistic devices which promote vivid description and lively or popular sayings. He claims that audiences like words "that set an event before their eyes; for they must see the thing occurring now,

not hear of it as in the future. In style, accordingly, the speaker must aim at these three points: Metaphor, Antithesis, Actuality" (Aristotle, 3:10). Metaphors, he claims, give liveliness and vividness to composition. He puts particular emphasis on placing objects before the mind's eye as though they were living and moving. He writes, "But we have still to explain what is meant by setting things 'before the eyes,' and how this is to be affected. What I mean is, using expressions that show things in a state of activity. It is a metaphor, indeed, to say that a good man is 'four-square,' . . . but the metaphor suggests no activity. There is, on the other hand, a sense of activity in the expression 'with his vigor fully blooming'" (Aristotle, 3:11). Thus, we find in the Aristotelian treatment of rhetorical style an emphasis on linguistic devices which promote vivid description and a lively or vivid representation of the facts. The orator is to set things before the audience's eyes; he is to paint verbal pictures.

The great Roman rhetorician, Quintilian (1960, 6.2: 29-30), clearly stated the relationship between vivid description (or *enargeia*) and emotional arousal which also contributes to belief in the reality or actuality of the scene being described.

But how are we to generate these emotions in ourselves, since emotion is not in our own power? I will try to explain as best I may. There are certain experiences . . . the Romans [call] visions, whereby things absent are present to our imagination with such extreme vividness that they seem actually to be before our very eyes. It is the man who is really sensitive to such impressions who will have the greatest power over the emotions. . . . This power of vivid imagination, whereby things, words and actions are presented in the most realistic manner . . . is a power which all may readily acquire if they will. When the mind is unoccupied or is absorbed by fantastic hopes or daydreams, we are haunted by these visions of which I am speaking to such an extent that we imagine that we are traveling abroad, crossing the sea, fighting, addressing the people, or enjoying the use of wealth that we do not actually possess, and seem to ourselves not to be dreaming but acting. Surely, then, it may be possible to turn this form of hallucination to some profit.

And in a later passage Quintilian (1960, 6.2:32) writes: "From such impressions arises that *enargeia* which Cicero calls *illumination* and *actuality*, which make us seem not so much to narrate as to exhibit the actual scene, while our emotions will be no less actively stirred than if we were present at the actual occurrence." Although Quintilian is pointing to the emotional efficacy of clear and vivid word pictures, he also relates *enargeia* to illumination and actuality.

Next, I would like to turn to another great Greek critic, probably of the same century as Quintilian, whose writings belong to the poetic as well as the rhetorical tradition—i.e., Longinus. In the fifteenth chapter of *On the Sublime*, Longinus talks of *enargeia*. He is discussing the second of his five sources of sublimity, viz., vehement and inspired passion. Longinus (1962:2) says that in his time the word imagination

has now come to be used predominantly of passages where, inspired by strong emotion, you seem to see what you describe and bring it vividly before the eyes of your audience. That imagination means one thing in oratory and another in poetry you will yourself detect, and also that the object of poetry is to enthrall, of prose writing to present things vividly, though both aim at this latter and at excited feeling.

After citing some examples from poetry which "show a romantic exaggeration, far exceeding the limits of credibility," Longinus says that the proper use of imagination in oratory is to convince the audience of the "reality and truth" of the speaker's assertions. He quotes passages from Demosthenes where, he claims, imagination persuades by going beyond argument: "When combined with argumentative treatment," it not only convinces the audience, "it positively masters them" (Longinus, 15:9).

From these few passages in Aristotle, Quintilian, and Longinus, then, it is clear that the ancient rhetoricians advocated the vivid description of objects, persons, scenes, or events in discourse. Such concrete verbal portraits, they thought, could serve at least four important functions: (1) they aroused the emotions and the passions; (2) they created aesthetic enjoyment; (3) they helped to hold attention and interest; and, finally, (4) they even contributed to *belief*. Lively and vividly descriptive language can raise the ideas of the imagination to almost the same vividness of sense impressions. *Enargeia* can "almost compel the audience to see what . . . [the author] imagined" (Longinus, 15:3).

Naturally, in poetic and rhetorical discourse, it is by the proper use of language—particularly figurative language—that the writer or speaker must seek to raise the imaginative description to the vividness of actual sense perception. Certain figures were recommended in rhetorical treatises as partic-

ularly important for such purposes—metaphor, simile, vision, and ocular demonstration. In Lane Cooper's translation of Aristotle (1932) there are two figures which are derived from the Greek doctrine of *enargeia*: *descriptio* or vivid description; and *demonstratio* or ocular demonstrations: "when an event is so described in words that the business seems to be enacted and the subject to pass vividly before our eyes."

Although the notion of vivid description seems to have originated with the rhetoricians, it was later to become firmly entrenched in poetic theory, too. One reason for the popularity of descriptive passages in poetry, no doubt, was the Latin notion of *ut pictura poesis*. Horace had said that poetry is like painting, and most Renaissance literary critics repeated the cliché that poetry is like a picture. Because of this parallel between the arts, it was common to describe the poet's (or rhetorician's) task in language in terms of painting. If the verbal arts are similar to painting, then they should be speaking pictures. Thus, the imagery of color came into discussions of poetic and rhetorical compositions. Writers and speakers were urged to "paint in living colors," or to "paint before the eyes," with verbal portraits.

From the time of the early Greeks and Romans, the advice to speakers and writers was to paint before the eyes of the audience with clear, distinct, and vivid, verbal portraits. These commonplaces about the importance of ocular demonstration were repeated throughout the Renaissance and the seventeenth century in almost all treatises on rhetoric and poetry. The doctrine of vivid description was very popular in the eighteenth century. An index to how widespread the notion was can be found in the following passage from Reid (1969:397-98):

It seems easier to form a lively conception of objects that are familiar, than of those that are not; our conceptions of visible objects are commonly the most lively, when other circumstances are equal. Hence, poets not only delight in the description of visible objects, but find means by metaphor, analogy, and allusion, to clothe every object they describe with visible qualities. The lively conception of these makes the object to appear, as it were, before our eyes. Lord Kames, in his *Elements of Criticism*, has shown of what importance it is in works of taste, to give to objects described, what he calls *ideal presence*. To produce this in the mind, is indeed the capital aim of poetical and rhetorical description. It carries the man, as it were, out of himself, and makes him a spectator of the scene described. This ideal presence seems to me to be nothing else but a lively conception of the appearance which the object would make if really present to the eye.

Having discussed what might be called the rhetorical and aesthetic aspects of the doctrine of *enargeia*, I would now like to consider what might be called the epistemological dimension of this term and its synonyms. I have already mentioned that, even among ancient rhetoricians, vivid description was considered one device to convince the audience of the reality and truth of the orator's statements and to persuade an audience by getting them to "see before their eyes" what the speaker wants them to believe.

Although Descartes is often considered the father of modern philosophy, some recent writers have considered his system as an attempt to overthrow the doubts of the Sceptics. Descartes proceeded with his method of doubt to look for an indubitable truth, which he found in his famous *Cogito, ergo sum*. By inspecting this one truth, Descartes finds the criterion of truth. He comes to the conclusion that there is nothing in the proposition "I think, therefore I am" which assures him of the truth except that he sees very clearly and distinctly what is affirmed. Descartes (1965:29) wrote: "Certainly in this first knowledge there is nothing that assures me of its truth, excepting the clear and distinct perception of that which I state. . . . And accordingly it seems to me that already I can establish as a general rule that all things which I perceive very clearly and very distinctly are true." The *cogito* strikes us so strongly with its clarity and distinctness that we cannot doubt it—it carries its own evidence with it or is self-evident. (It is interesting to note that Cicero used the Latin word *evidentia* for the Greek *enargeia*.)

Descartes' opponents, of course, often attacked his system on the matter of clear and distinct truths. "A central theme of these criticisms [of Gassendi and Mersenne] is to question whether the fact that Descartes claimed to be certain, to perceive clearly and distinctly that the propositions he advanced were true, sufficed to make them true. Perhaps, they suggested, in spite of how Descartes felt about these propositions, it might still be the case that they were false" (Popkin, 1964:204). In a note to the article on "Pyrrho" in Bayle's *Dictionary*, Popkin (1965:199) remarks: "In seventeenth-century discussions, *l'evidence* is the mark of truth, which, when present, makes it impossible to doubt a proposition. In Furetière's *Dictionnaire universel* (1727 ed.) the following entries are offered to explain the meaning of *l'evidence*: 'Manifest certainty, the quality of things that makes them clearly visible and knowable, as much to the body's eyes as to its mind. The consent which arises from *l'evidence* of a thing is more unshakeable than that which faith exacts (Huet). One has to accept *l'evidence*, which cannot be resisted as soon as it makes itself felt in us (Le Clerc). . . .'"

In these passages it is clear that *l'evidence* is a synonym for *enargeia*, derived, of course, from Cicero's rendering of that Greek term with the Latin *evidentia*. *L'evidence* is shorthand for the clear and distinct ideas of reason which are

incontrovertibly true.

Following Descartes, Leibniz, and Wolff, the Continental rationalists (and many English writers, too) continually propounded the notion of clear and distinct ideas. Sometimes, as in Descartes, the "clear and distinct" ideas of reason were separated from the "obscure and confused" ideas of sense. Most of the popular logics of the seventeenth and eighteenth centuries included long discussions of the nature of clear, distinct, and vivid ideas.

In Germany, Leibniz and Wolff constructed a whole chart of ideas. "Knowledge is either *obscure* or *clear*; clear ideas again are either *indistinct* or *distinct*; distinct ideas are either *adequate* or *inadequate*, *symbolic* or *intuitive*; perfect knowledge, finally, is that which is both *adequate* and *intuitive*" (Leibniz, in Wiener, 1951:283). According to these philosophers, if we follow the proper procedure, we progress from obscure and confused ideas to clear and distinct ideas. This progress from "*dunckeler Begriff*" to "*klarer Begriff*" provided the often overlooked technical meaning for the origin of the term "Enlightenment." As we move from "dark" to "clear" concepts, we use the light of reason to enlighten our knowledge.

A quotation from a popular French book on logic, that was also translated into English, will reveal all of the common synonyms for *enargeia* used in a brief passage. Jean Pierre de Crousaz (1724, 2:3) wrote:

The Distinction of Ideas into *clear* and *obscure*, *distinct* and *confused*, offers itself first. And indeed it is one of the most usual and important Distinctions. . . . Every Idea is an Act, which perceives itself; and therefore it has essentially some Life and some Activity; it affects us with some Force. Since it is known and perceived, it has some Clearness, some Evidence. . . . I grant that all our Ideas do not discover to us their Objects with the same Clearness and the same Exactness. . . . Wherefore every Idea has essentially some Clearness and some Distinctness; but the most lively, that is, those which are best perceived, are the clearest, and for that reason the most distinct. We distinguish more easily what makes a more lively Impression upon us, because it raises a greater Attention. Thus Clearness and Distinctness are two different Characters; but one of them is always a Consequence of the other.

In this passage, clearness, distinctness, vividness, and evidence are all variations on our old rhetorical term, *enargeia*. Force and liveliness are two terms that were often used as substitutes for vividness.

If we turn to the British philosophers of the eighteenth century, we will find that they, too, used the Cartesian cri-

terion in a modified form, but applied it to sense impressions rather than intellectual concepts. Hume (1888:1) was very concerned with trying to differentiate between impressions and ideas. The very first paragraph of his *Treatise* begins:

All the perceptions of the human mind resolve themselves into two distinct kinds, which I shall call Impressions and Ideas. The difference betwixt these consists in the degrees of force and with which they strike upon the mind and make their way into our thought or consciousness.

In Hume's analysis there are three kinds of perceptions; they are differentiated by their force, vivacity, or liveliness. Sensations are the most vivid; ideas of memory have less vivacity; and ideas of the imagination are the least vivid. "And as an idea of memory, by losing its force and vivacity, may degenerate to such a degree as to be taken for an idea of the imagination; so on the other hand an idea of the imagination may acquire such a force and vivacity as to pass for an idea of the memory. . . ." (Hume, 1888:86).

In discussing the different force of ideas, Hume also reverts to the term "distinct" and the imagery of color so familiar to us. "'Tis evident at first sight, that the ideas of the memory are much more lively and strong than those of the imagination, and that the former faculty paints its object in more distinct colours, than any which are employ'd by the latter" (Hume, 1888:9).

Hume's definition of belief or assent is dependent on his adaptation of the Cartesian criterion of truth. "Thus it appears, that the belief or assent, which always attends the memory and senses, is nothing but the vivacity of those perceptions they present; and that this alone distinguishes them from the imagination" (Hume, 1888:86). Hume states his definition of belief as follows:

When you wou'd any way vary the idea of a particular object, you can only increase or diminish its force and vivacity. . . . An opinion, therefore, or belief may be most accurately defin'd, A LIVELY IDEA RELATED TO OR ASSOCIATED WITH A PRESENT IMPRESSION (Hume, 1886:96).

Hume, obviously, felt some discomfort with his definition of belief as consisting in the vivacity of ideas. In an appendix to the *Treatise*, Hume (1888:628) adds the following corrective passage:

This operation of the mind, which forms the belief in any matter of fact, seems hitherto to have been one of the greatest mysteries of philosophy. . . . For my part I must own, that I find a considerable difficulty in the case. . . . I am at a loss to express my meaning. . . . An opinion or belief is nothing

but an idea, that is different from a fiction, not in the nature, or the order of its parts, but in the *manner* of its being conceiv'd. But when I wou'd explain this *manner*, I scarce find any word that fully answers the case. . . . An idea assented to *feels* different from a fictitious idea, that the fancy alone presents to us. And this different feeling I endeavour to explain by calling it a superior force, or vivacity, or solidity, or firmness or steadiness. . . . And in philosophy we can go no farther, than assert, that it is something *felt* by the mind, which distinguishes the ideas of the judgment from the fictions of the imagination.

It seems that the young Scotsman was unaware that his solution to "one of the greatest mysteries of philosophy" was a very old one indeed. Both the Stoic and Epicurean philosophers had assumed that all knowledge came from sense perceptions. Epicurus "has *aisthesis* serve as the guarantor of its own validity, and this by reason of its clear and self-evident nature (*enargeia* . . .)" (Peters, 1967:52). When Hume compares the greater vividness of ideas assented to with the less vivid fictions of the imagination, he has returned to the old criterion of *enargeia*.

Hume's opponent, Reid (1969:618) could not agree with Hume that "to believe in the existence of anything, is nothing else than to have a strong and lively conception of it." But in his attempt to combat Hume's scepticism, Reid argued for a large class of intuitive judgments or propositions that need no argument to support them. These intuitive judgments or self-evident principles, he often refers to as the principles of Common Sense. Reid admits that since the time of Descartes, philosophers have tried to get along with as few self-evident judgments as possible. He was convinced, however, that the classes of intuitive judgments had to be widened in order to combat Hume's scepticism. In describing some of the principles of common sense, Reid (1969:559) claims that they have *l'evidence* and therefore do not need to be proven: "All knowledge, and all science, must be built upon principles that are self-evident; and of such principles, every man who has common sense is a competent judge when he conceives them distinctly." In discussing some of the first principles that he introduces directly to combat his interpretation of Hume's scepticism, Reid uses variation of distinctness as a criterion of truth. To guarantee the testimony of memory, Reid (1969:622) relies on the first principle, "that those things did really happen which I distinctly remember." The existence of objects in the world and veridical perception is assured by the first principle that "those things do really exist which we distinctly perceive by our sense, and are what we perceive them to be" (Reid, 1969:625).

It is rather ironic that philosophers of such differing outlooks and with such different philosophies as Descartes, Hume, and Reid all used concepts derived from the old rhetorical and philosophical term *enargeia*. No doubt, one could

write a long history of this idea as Lovejoy did on the Great Chain of Being, or Monk did on The Sublime. Suffice it to say that *enargeia* played a significant role in rhetoric, poetry, and philosophy. In poetic theory, vivid descriptions were advocated by literary theorists because they provided aesthetic pleasure, commanded attention, operated on the emotions, and were longer remembered. In rhetorical theory, orators were enjoined to set things before the audience's eyes, to paint in living colors, to describe vividly, and to give an ocular demonstration of the facts. The goal, of course, was not only to hold the hearer's attention and interest or to arouse the emotions, but also to get the audience to see and believe the speaker's proposition. Among philosophers, the various synonyms and derivatives of *enargeia* were often used as criteria for truth or belief.

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WITTGENSTEIN'S "LANGUAGE-GAME"—A TOOL FOR COGNITIVE DEVELOPMENTALISTS

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During the last seventeen years of his life, Ludwig Wittgenstein, in several works, set out his remarkable concept of the "language-game"—a notion of understanding language that focused attention upon the ways in which we use language in actual situations as one might focus on the ways players move pieces in a game. I propose that this concept (with slight modifications) be included among the cognitive developmentalist's tools for analysis. It is useful in describing the growth of some important communicative abilities an individual develops from infancy to fluency in the uses of expressions of the language of his culture. A sketch of the salient features of the "language-game" is presented, along with examples of its application to some typical samples of data.

As an analytic instrument, the "language-game" concept possesses sufficient flexibility to deal realistically with the various conceptual patterns one meets in ordinary situations and allows enough clarity of description to make replicability of application readily possible. These are exactly the qualities the developmentalist needs in instruments with which he must make sense of data gathered within the dynamic surrounding of ordinary human communicative activities.

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INTRODUCTION

In his later philosophical works (post-1933), Ludwig Wittgenstein presents his notion of the "language-game" as an essential part of his method in working with difficulties which he thought resulted in philosophical problems. In this paper I shall present the key aspects in the concept of "language-games" which would enable one to recognize specific instances of a language game and to describe them; then I shall illustrate the steps by which a person develops his competence in operating within a given language game. The point will be to show how the "language-game" concept may provide an instrument for the comparison of language behavior at different levels of development so as to define what sorts of behavioral changes constitute cognitive or conceptual "growth."*

The following are key aspects of Wittgenstein's "language-game" concept. First, the focus of this concept is on the "speaking of the language" as only one part of an activity

which has some point, or end, to which the speaking markedly contributes (P.I.:§23). Second, the child develops his understanding of his mother-tongue by way of his participation in the various forms of the activities in which speaking has a role (Bl.B.:17). Third, learning a new language is learning new behavior with regard to a particular end (P.I.:§244). Fourth, if we organize our observations of ordinary activities that involve language according to the place of the words in relation to the point of the activity, the aspects of "system" and "regularity" appear, much as we would expect them in the playing of a "game" (P.I.:§207). Early in *The Brown Book*, Wittgenstein (B.B.:81) sketches descriptions of different sorts of activities in which vocal expressions are used with regularity, along with gestures, in the course of pursuing some end. He refers to these as "systems of communication," saying:

They are more or less akin to what in ordinary language we call games. . . . When the boy or grown-up learns what one might call special technical languages, e.g., the use of charts and diagrams, descriptive geometry, chemical symbolism, etc., he learns more language games. . . .

What sorts of activities Wittgenstein has in mind may be seen if we do as he suggests:

. . . Review the multiplicity of language-games in the following examples, and in others:
Giving orders, and obeying them—
Describing the appearance of an object, or giving its measurements, . . . Reporting an event—
. . . Forming and testing a hypothesis—
. . . Making up a story; and reading it—
. . . Playacting—
. . . Asking, thanking, cursing, greeting, praying."
(P.I., 23)

These are to be regarded as quite ordinary to human behavior, for ". . . Commanding, questioning, recounting, chatting are as much a part of our natural history as walking, eating, drinking, playing" (P.I.:§25). The character of the surroundings which are part of the context for our playing these "games" have direct bearing on the character of the games, the point of the activities, etc. (P.I.:§142, re: "normal" and "abnormal cases").

*Since every reference used in this paper is to one of the works of Wittgenstein listed at the end, only specific citations will be given in the text: P.I. will be used for *Philosophical Investigations*; Bl.B. for *The Blue Book*; and B.B. for *The Brown Book*.

Several of the "language games" Wittgenstein mentions are activities in which the players interact in a certain sequence so that taking turns is not an uncommon characteristic of the playing, particularly in stylized games involving more than one player. In such situations, each player's turn within the whole activity may be looked on as a "move"; his adeptness within a game, as a quickness or finesse in his "moving"; his competence in playing, as measured by his "knowing how to go on." And something like a sense of moving in space is brought into the notion of "going on" by way of analogies with "finding one's way about" in a labyrinth (P.I.:§203) and in a section of a city (P.I.:§18), as though there were decisions to make along the way occasioned by the encounter of a "barrier" in the "pathway."

All the above characteristics must be integrated in order to provide a guide for recognizing specific sets of behaviors as cases of the playing of a specific language game. It will be most strikingly apparent in examples. Here are descriptions of activities which we may consider instances of persons engaged in the first type of language game mentioned by Wittgenstein in the passage above (P.I.:§23)—the game of "giving orders and obeying them."

- I. Think of the 9- to 12-month-old child who is able to get around his home by crawling and to reach articles on the tables by pulling himself up near them. Adults in charge of the surroundings in which the baby must negotiate are quite often levying orders in the form of rules—"Don't touch!" and "No, No!"—along with the slap on the hand, the shake of the head, and the stern look.
- II. Around 18 months, having begun to use specific sound patterns in connection with specific activities, the baby, coming up to a table covered with objects, may be observed to reach out and touch one and then withdraw his hand, shake his head, and say, "No, No, No!" Then perhaps he goes on to other parts of the room and other activities.
- III. Further, in an encounter between that child and another some months later (about 30 months of age), the former slaps at the hand of his friend who has reached out to pick up the figurines on the table. The first acts in this sequence: first, saying, "No. No touch!"; then, if the friend does not react in a specific way (i.e., by leaving the things alone), pushing the other out of the way, taking the figurine from his hand, and returning it to the table—all the while shaking his head "No."
- IV. At 4 years old, the child asserts his authority over others in a play situation in which he's pretending to be the parent of another child and, in the acting out, sets himself in the role of giving the other

the order, "Don't touch the glasses." When his playmate does not respond (in the acting out) so as to obey the command, but rather proceeds to pick up and play with the forbidden objects, the first child employs the hand slapping and—if that does not bring forth the reaction of "leaving the objects alone"—the further response of "spanking the disobeying child."

At such a point, children may well be seen to enact and re-enact this set of activities many times—and to take turns playing the roles of orderer and obeyer as well as disobeyer and punisher. And in the course of these actings-out, there may appear a number of sets of expressions, including: "I told you not to do that."—"You naughty boy!"—"I'm going to have to spank you."; or "If you don't quit that, I'm gonna give you a beating!"—"You better be good and don't touch them things!" There will, of course, be a number of variations in the ways specific children grammatically express themselves which will reflect the dialectal aspects of the societal groups to which they belong and, thus, the dialects with which they are directly familiar.

- V. At about the same time or very soon after the above, repeated role-playing occurs in the activities of the child; he begins to explore another sort of reaction to the order-giving act—i.e., the use of the question "Why?" to lead the order-giver to provide some expression of the forcefulness or importance of the order's being followed. During the ensuing 4 to 5 years, various sorts of possible "answers" occur in the game. Those grow to include the assertion of the "giver's" authority—"Because I say so"—the expression of the "giver's" desire or wishes—"Because I want to have it done"; and the laying out of probable consequences to the act that are wanted or not-wanted—"Because if you don't, you will get hurt."
- VI. After the child is capable of entering into the facet of the game in which he concerns himself with possible "justifications" for the order-giving, he may enter into a similar consideration of the action which is a consequence of the following or the not-following, the obeying or the disobeying. Thus, the result is the child's practice of judging the "fairness" or "fittingness" of the "reward" or "punishment." The child's concern proceeds in line with the growth of his socialization in that he goes from evaluation of the fairness of the reward or punishment on the basis of whether *he likes* or *wishes* the action or object given, to the evaluation of the degree of severity of punishment in relation to the degree of diver-

sion of the individual's reaction to the order, taking into consideration other points of view, measures other than his own personal likes or dislikes.

Review of the above examples of the child's behavior reveals that within his first four or five years he has picked up the following ways of handling himself within this sort of context: (1) turn-taking or sequencing actions where the "order-giving" behavior is expected to be followed by "following" behaviors; (2) the order-giver acts to give some sort of force to bring the follower to comply in some way or other; thus, (3) the "following" is not automatic, making room for the order-giver to wait to see if the follower behaves "properly"; further, (4) the possibility of non-following behavior ("violating" or "disobeying" behavior) brings forth a place for retributive action by the giver, thus "punishment" and, alternatively, "reward" get fitted into the conceptual arrangement; (5) in addition, the evaluative consideration of alternatives in orders and justifications for orders and later of alternative retributive actions and their weights in relation to the behavior in pursuance of the order-giving are integrated into the whole activity at points which are conceptually appropriate to the language of the adult.

In summary, I have indicated how Wittgenstein's concept of "language-game" may be used to clarify certain aspects in the growth of the individual's competence in an area of his language. The aspects with which I have been concerned are of importance to the cognitive developmentalist, since they are involved in the development of the child's ability to operate within the communicative systems prevalent within his society. What is revealed in the development of the ability within the language game of "giving orders and following them" may be seen as the growth of the child's grasp of the conceptual grammar of that and similar activities of human interaction.

I see in this an instrument for schematizing data of the child's activities with his mother-tongue which is both solid enough to allow the developmentalist reliability in applying the "game" model to data, and yet flexible enough to allow the points of actual behaviors to become the focus for any "game" description so that a comparison across ages is possible, as is essential for the developmentalist's instruments.

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**THE FUTURE OF FREE AND DEMOCRATIC INSTITUTIONS:
A CRITIQUE OF ROBERT L. HEILBRONER'S
*AN INQUIRY INTO THE HUMAN PROSPECT***

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In his recent book, *An Inquiry into the Human Prospect*, Robert L. Heilbroner argues that the current use of scientific technology by the industrialized nations is so rapidly exhausting the world's resources that free and democratic institutions must give way to authoritarian regimes with the power to control economic production, population size, and the expression of ideas, or mankind will perish. While acknowledging the seriousness of the problems noted by Heilbroner, I contend that free and democratic institutions can, and probably will, provide solutions. To support this contention, I note that Heilbroner's pessimism about our institutions is based upon a conception of human nature akin to that held by Thomas Hobbes. Like Hobbes, Heilbroner believes that human nature is such that authoritarian solutions are necessary, especially when men face problems of scarcity. By arguing that such a view of human nature is false, the grounds for Heilbroner's pessimism with respect to the future of free and democratic institutions is removed.

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Heilbroner (1974) has touched upon problems and fears which many of us have felt but not verbalized. So successfully has he stated some of the central issues which must concern anyone who cares about the future of mankind and his institutions that his book has achieved a quite unexpected popularity, selling 80,000 copies within a few months of its publication.

What does Heilbroner tell us which provokes such widespread interest? Without wishful thinking, he calls attention in Chapter Two to three problems with a high potential for human tragedy.

First, there is the continued growth of the world's population—a growth which realistically may be expected to continue at an alarming pace, despite well-intentioned but largely impractical efforts to introduce effective birth-control programs.

Second, the prospects are excellent that nation-states will continue to seek a solution of their conflicts with one another through war. According to Heilbroner, such wars may be limited to two or more nations engaged in a relatively local conflict. For example, few of us would be surprised to learn over the next fifty years that war between Israel and her Arab neighbors occurred periodically. We would not be surprised at similar news about the Greeks and Turks on Cyprus or about the peoples of North and South Vietnam. Given the

deeply-entrenched attitudes of hostility between peoples living near to one another throughout the world, the list of limited wars which are likely to occur is a discouragingly long one. Even worse, there is a considerable probability that we shall have major wars exceeding the destructiveness of anything mankind has yet witnessed. It is almost certain that nuclear weapons will be possessed within a few years not only by the major powers but also by some of the important under-developed nations. During the period when only the major powers have nuclear weapons, there is sufficient cause for pessimism when one considers the possibilities of conflict present in the varying relationships among Russia, China, and the United States. When the under-developed nations have nuclear weaponry, however, Heilbroner observes that for the first time we may experience "wars of redistribution" in which the poor nations attack the rich in an effort to gain a larger share of the world's wealth (1974:43).

While the two problems of population growth and war are sufficient to make the human prospect gloomy, there is yet a third danger which promises to be even more important in shaping the future of mankind. This danger arises from the fact that the current use of scientific technology by the industrialized nations is so rapidly exhausting the world's resources that man's ability to survive will be in jeopardy. The problem here has many aspects. We are using up the materials needed to produce goods; we are exhausting our energy resources; and we are polluting the means of sustaining life: our land, our water, and our air. To take but one illustration, Heilbroner cites figures to show that if we continue the present pace of heat-producing activities, we shall so increase the earth's temperature within 250 years that the earth will no longer be suitable for human habitation (1974:51).

Happily, Heilbroner does not predict that the history of mankind has its end in the foreseeable future. Nevertheless, he does conclude that the "threats of runaway populations, oblitative war, and potential environmental collapse, can be seen as an extended and growing crisis induced by the advent of a command over natural processes and forces that far exceeds the reach of our present mechanisms of social control" (1974:57).

Heilbroner then turns to the question of whether our

present socio-economic systems have the adaptive capacity to meet the crises so clearly coming upon us. He observes that there are two major socio-economic systems which influence human behavior in our time: capitalism and socialism (1974: 63). Discussing capitalism first, Heilbroner notes that the demands of survival require that economic growth cease or be drastically reduced. When fewer material goods become available, capitalist societies will experience internal crises as their members struggle with one another for what they regard as their proper share of the goods available. According to Heilbroner:

The struggle for relative position would not only pit one class against another, but also each against all, as lower and middle groups engaged in a free-for-all for higher incomes. This would bring enormous inflationary pressures of the kind that capitalism is already beginning to experience, and would require the imposition of much stronger control measures than any that capitalism has yet succeeded in introducing—indeed, than any that capitalist governments have yet imagined.

In bluntest terms, the question is whether the Hobbesian struggle that is likely to arise in such a strait-jacketed economic society would not impose intolerable strains on the representative democratic political apparatus that has been historically associated with capitalist societies. (1974:88-89).

On the next page, Heilbroner then answers his own blunt question by saying that most capitalist nations will find that the task exceeds the capabilities of representative democracy. In similar fashion, he tells us that democratically-governed, socialist nations will face the same kind of internal crisis and will also be forced to authoritarian political systems (1974: 92). As a further consequence of the move to authoritarian regimes, Heilbroner envisions a time when our present freedoms of expression shall give way to a demand from our leaders for a quasi-military devotion and sacrifice which brooks no disagreement with the official line (1974:26, 110).

In sum, the human prospect for Heilbroner is one in which mankind will survive at a considerably lower standard of living than is now enjoyed by most persons in the advanced industrial nations. To achieve that survival, free and democratic institutions will give way to authoritarian political systems with the power to control economic activity, population size, and the expression of ideas.

If we reflect now upon this prospect, can anything be said to alleviate the bleakness? We can dream that our scientists will be so inventive in the next 100 years that ways will be found of increasing economic productivity, of feeding a continuously expanding population, and of ceasing to pollute the environment. But we must admit that we should only

be dreaming. At present, there are no realistic possibilities of the coming of a scientific Savior. Accordingly, I think we must agree with Heilbroner that we face a declining standard of living and a greater measure of social control with respect to economic production and population size.

At the same time, I cannot agree that the type of social control required involves the loss of the free and democratic institutions we now possess. Let us return to that portion of Heilbroner's argument where he foresees the demise of representative democracy and examine it again. He tells us that when goods become more scarce, we shall have a struggle of "one class against another" and "each against all" (1974: 89). Such a struggle will impose an intolerable strain on representative democracy and will be brought to an end only when authoritarian institutions come into being with sufficient power to enforce whatever decrees are necessary.

Heilbroner's reasoning is strikingly reminiscent of Thomas Hobbes' famous description of the natural condition of mankind in Chapter 13 of the *Leviathan* (originally published in 1651). There, Hobbes says: "... during the time men live without a common Power to keep them all in awe, they are in that condition which is called Warre; and such a warre, as is of every man, against every man" (1929:96). Moreover, in such condition, one finds "the life of man, solitary, poore, nasty, brutish, and short" (1929:97). Hobbes goes on to argue that if rational men were in such a state of nature, they would recognize that the only way to establish the common power needed for security is for each person to give up his right of governing himself to an absolute Sovereign (1929:131-132)—a Sovereign empowered, among other things, to censor the expression of any opinion endangering the peace of the commonwealth (1929:136-137). If one then asks why Hobbes believed such a complete surrender of self-governance to be necessary, he finds the answer in Hobbes' conception of human nature. For Hobbes, men will by nature quarrel with one another unless they have such a common power "to keep them all in awe" (1929:96).

Fortunately, we have ample evidence from history to know that Hobbes was wrong. Men can, and have, lived peacefully with one another without the complete surrender of those rights thought necessary by him. We also have ample evidence from psychology and the social sciences to know that Hobbes was wrong. Men are, in large part, the products of their social upbringing. On the one hand, if a society teaches its members to quarrel and to reach for their guns when it is time to divide the economic assets, they will do so. Then, peace can be restored only by a power sufficiently immense to keep them all in awe. On the other hand, if a society teaches its members to press their economic demands by the use of democratic procedures and to accept the lawful policies thereby enacted, there may be strain, frustration, riots, but it is not likely that there will be revolution.

So far as I can see, Heilbroner's pessimism with respect

to the future of free and democratic institutions assumes an estimate of human motivation akin to that held by Hobbes. Moreover, just as the testimony of history and of the sciences has already refuted the Hobbesian view, so also does this same evidence provide good reason for thinking that people, trained by long habit in the use of free and democratic institutions, will meet the economic crises to come. This being so, there is more hope in the human prospect than Heilbroner would lead us to believe.

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ON THE STATUS OF THE CONCEPTS OF MASCULINITY AND FEMININITY

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Observer bias is considerable in studies investigating differences between the characters of the sexes, partly because "masculinity" and "femininity" are not empirical concepts. Instead, they function to sort out phenomena by determining a range of significance, thus encouraging discriminatory evaluation of human action.

To support this I argue:

1. Particular character traits are assessed (valued and understood) differently depending on whether they apply to men or women.
2. Counterexamples to the generalization, "All men are masculine," are not accepted as real counterexamples, but are rather regarded as abnormal (subnormal, not rare).

† † †

INTRODUCTION

Many scientific studies address, in one way or another, the issue of differences between the characters of the sexes; and the concepts of masculinity and femininity, as they are used in scientific literature, are assumed to be based on findings. As such, the issue is presupposed to be a purely factual one, and tests are designed to discover what the differences are, as well as what their source or sources are, in order to better understand male and female natures. Observer bias in these sorts of studies is considerable; women entering the sciences are documenting it.

Naturally, one wonders why observer bias is prevalent. In fact, it arises because "masculinity" and "femininity" are not empirical concepts: They do not arise as a result of, nor are they susceptible to, empirical investigation. Instead, they are evaluative concepts which function to categorize and interpret behavioral data.

I

Evidence is being amassed which points to serious observer bias prevalent in tests seeking a biological basis for the alleged phenomena of masculinity and femininity. In the first place, as Kaplan and Bean (1976:99ff) point out, scientists exaggerate male-female differences by attempting to correlate traits thought to be masculine with testosterone, a male hormone, while failing to look for correlates of the same traits in female biology. Rarely are attempts made to discover hormonal correlates of aggression in females. Further, scien-

tists often define aggression by how it is manifested in or manipulated by males, seek male patterns of aggression in females, and conclude that females are not aggressive. Rather than investigate male and female patterns of aggression, which may differ due to situations available for expressing aggression, scientists report that aggression is a male trait—the very assumption on which the research was based. In the name of establishing fact, scientists perpetuate cultural value.

Other aspects of observer bias are indicated when one compares results of similar hormonal studies conducted at different times by different scientists. Rosenberg (1973) surveyed studies of castrated male guinea pigs that had been injected with estrogen. As published by one group, this resulted in increased mounting activity. According to another, it resulted in decreased mounting and increased receptive postures. A third group reported a decrease in any sexual behavior. Rosenberg (1973:114) notes: "When three different laboratories get three different results on nearly identical experiments, observer bias, even in guinea pigs, is very likely." The history of research on sex differences indicates that experimental methods are fraught with cultural bias.

Yet another aspect of observer bias has been brought to light by Horney (1974). When mapped on a bell curve, the results of tests designed to indicate the presence of analytic ability, such as Whitkin's rod and frame test, yield far greater statistical differences between individuals within one sex than between the sexes. Nevertheless, differences between the sexes are deemed significant, purportedly indicating a sex difference in analytic ability. But the results defy predictability of individual behavior and do not justify differential treatment, thus revealing that the alleged statistical significance is illusory. (Dr. Horney proposes looking for differences of character traits within situations, not within biology. In this way, one need not regard Golda Meir or Indira Gandhi as abnormal females, but rather as normal heads of state.)

Grave consequences of observer bias become apparent when male scientists are asked whether political restrictions on women are biologically justifiable. Hall (1976:81) notes that biologists are frequently called upon "to evaluate the extent and significance of biologically controlled differences between the sexes." Nineteenth-century scientists provided "professional" opinions with respect to women's capacity to reason. One outstanding example of observer bias in the late

nineteenth century, noted by Klein (1971:42-43), was the certainty of brain anatomists that the frontal lobe, which was then believed to be the seat of thought, was more developed in males than females. (And it was not until scientists no longer believed the frontal lobe to be the seat of thought that they admitted the male frontal lobe is not larger than that of the female.) As Whitbeck (1976) points out, the "women-are-undeveloped-men" view pervades scientific theory.

Scientists "found" femininity to be incompatible with rationality, and this was used to justify political restrictions on women. As Korsemeyer (1976) explains, seventeenth-century liberal philosophers such as Locke justified the rights of citizenship on the basis of man's ability to reason, an ability which distinguishes him from (other) animals. Naturally, if women were not prone to rationality, there were no grounds on which to bestow the rights of citizenship, i.e., to remove political restrictions.

II

Observer bias, thus, is a serious problem prevalent in studies investigating character differences between men and women. This is not simply due to failings of individual scientists. A conceptual confusion is involved, for the status of "masculinity" and "femininity" is not empirical. The concepts do not arise from empirical investigation and discovery, nor are they really susceptible to disputation.

In the first place, character traits paradigmatic of "masculinity," such as aggression, are assessed differently depending on whether they apply to men or women. Aggression is normally considered a flaw in women while regarded as an asset in men. On the surface, this appears to be insufficient indication that "masculinity" and "femininity" are not empirical. By analogy, fragility is valued differently when applied to various forms of glass; it is considered a flaw in windowpanes and an asset in wine glasses. Nevertheless, the basis for the valuation is empirical. Windowpanes require sturdiness to be effective weathering agents, while the purposes for which wine glasses are designed make sturdiness a defect.

However, the analogy does not hold. Windowpanes are designed and manufactured by people for a certain purpose. Men and women are not designed or manufactured by people for a certain purpose. To claim that aggression as valued in men but not in women is analogous to sturdiness as valued in windowpanes but not in wine glasses, is to commit a form of the naturalistic fallacy. The implication is that men and women, while not designed by people, are designed by nature, as if the fact that aggression is valued in men but not in women is justified by (natural) fact, by the natural purposes for which they were designed and used. However, since people did not design men and women—if, indeed, it even makes sense to talk of men and women being designed—any purpose for which they might be used is determined only from observing what they are capable of. (This is not true of window-

panes.) And as not all things men and women are capable of are valued (e.g., women are capable of aggression), there is no basis in (natural) fact for valuing aggression in men but not women. So, the matter is not analogous to the valuation of sturdiness in windowpanes but not wine glasses. Hence, that traits paradigmatic of "masculinity" and "femininity" are valued differently, depending on whether they apply to males or females, suggests that such traits do not play a legitimate role in correlations seeking biological bases of sex differentiation. It also indicates that "masculinity" and "femininity" are not based on empirical findings.

In the second place, character traits paradigmatic of "masculinity" and "femininity" are not only assessed differently in that they are valued differently in men and women, they are also understood differently. (This is not true of fragility in glass.) An aggressive male is normally seen as confident and ambitious. Aggression in a woman is normally viewed as indicative of frustration and neurosis. As confidence is rarely equated with frustration, researchers are bound to "find" that male and female natures differ, which is to say that such findings are not the result of empirical discovery but rather of cultural biases. And this is, at least in part, because the concepts of masculinity and femininity encourage discriminatory perception and evaluation of human action such as aggressive behavior. As such, the concepts themselves do not arise from empirical investigation, nor are they really susceptible to disconfirmation.

III

Perhaps the easiest way to detect the status of a concept is to form a generalization and test it by counterexample. If a concept is empirical in nature, that is, susceptible to research, the generalization will be susceptible to refutation. For example, the generalization, "All bachelors are unmarried men," is unlike the generalization, "All grass is green," in that the latter is subject to empirical investigation, while the former is not. Novelist Willa Cather describes the reddish prairie grass of Nebraska, and one could discover upon investigation that, in fact, not all grass is green. In this case, a counterexample proves the generalization false. Further, red prairie grass is no more and no less a subnormal strain of grass than is green crab grass or Kentucky bluegrass. All are real grass, even if there are some differences in chemical composition.

Alternatively, should a novelist attempt to describe bachelors who are married, this is not the sort of topic about which investigations might be conducted. The truth of "All bachelors are unmarried men" stems from the words themselves. Anyone claiming to have a counterexample has simply not learned what "bachelor" means. Nothing will function as a counterexample, which is to say that the concept is not subject to scientific research. It is not empirical. It is analytic.

Now consider the statements, "All women are feminine" or "All men are masculine." When a novelist describes a man

who is not masculine, the situation is not entirely analogous to the bachelor example; the temptation is not actually to claim that this person does not understand what "men" means. However, it is equally true that one does not react as in the grass example. The result has not been a simple discovery, perhaps with surprise, that not all men are masculine. Instead, the counterexamples are acknowledged, but are not accepted as "real" men. Somehow these men are abnormal, "effeminate." Only certain traits are applicable to "real" men, even though other traits are found in men. This is to say that the basis for selection lies in cultural value and not in empirical investigation and discovery.

One might object, by analogy, that a counterexample to "All cats are four-legged" is also regarded as abnormal; hence, that counterexamples are not readily accepted does not show that a given claim is not empirical. Yet, the analogy does not hold. In the first place, the abnormality arises due to the fact that the cat was once four-legged and has since lost a leg due to an accident. Further, a cat having three legs as a result of an accident is not thereby less of a "real" cat. And should a three-legged strain of cat develop, one would come to discover that not all cats are four-legged. Three-legged cats would eventually be viewed as no more an abnormal, i.e., substandard, strain of cat than red grass is viewed as an abnormal strain of grass, rare, perhaps, depending on numbers, but not substandard, not any less a real cat.

Others might object that there is a significant difference between generalizations (All men are masculine) and generalities (Most men are masculine), and while a counter example to the former is regarded as abnormal rather than a "real" counterexample, it is because in fact the generality is true. This, however, begs the question.

The distinction between a generalization and a generality is useful only when one is trying to prove a generality false. One bit of red grass proves that not all grass is green, but it does not disprove the generality, "Most grass is green." Yet, this does not salvage the generality from the issue raised here. When a counterexample is uncovered in science, while it can potentially prove a theory false, it may, in fact, be used to prove the theory false, or it may be discounted as an exception. But there are limits to discarding counterexamples, beyond which they become significant. In the case of investigations of differences between men and women relating to the characters of the sexes, the discarding of counterexamples, even in "objectively measurable" areas, is carried to extremes. Thus, scientists were once convinced that female frontal lobes were slightly smaller than male frontal lobes, discounting as an exception any female frontal lobe larger than a male frontal lobe. This occurred not only in spite of the fact that the generalization is false, but also in spite of the fact that the generality is false.

Further, if an appeal to generality attempts to justify why a counterexample is regarded as abnormal, at most it

might explain why a counterexample is regarded as abnormal, i.e., rare. But in questions about traits paradigmatic of "masculinity" and "femininity," counterexamples are not regarded as rare; they are treated as exceptions to be discounted because they are abnormal, i.e., substandard. In truly empirical investigations, just a few of a sort of x do not make those x's any the less "real" x's. Thus, an appeal to generalities to salvage "masculinity" and "femininity" as empirical concepts fails; the evaluative nature of these concepts equally affects the generality and the generalization.

IV

"Masculinity" and "femininity" are limiting concepts unlike "greenness" and not entirely unlike "material object." They function to sort out phenomena by determining a range of significance, and, in that sense, they limit perception. They facilitate interpretation of human action—action that is otherwise interpretable—by throwing a certain light on it (as is true of any prejudgmental concept). Thus, for example, the actions of a wife who puts raw eggs in her husband's lunch pail will be viewed as indicative of feminine dizziness (though not professional absent-mindedness) rather than a conscious or non-conscious aggressive act of sabotage in a situation devoid of real power for self-determination. The former fits the model of femininity.

Until "masculinity" and "femininity" are disregarded and discredited and the paradigms lose their preferred status, there will be no objective investigation relating to the characters of males and females. There is a conceptual confusion underlying the attempt to conduct studies to discover characteristics peculiar to women, for example, in order to discover the true nature of femininity, when the perception of these characteristics already depends on a concept of femininity. No wonder there is observer bias. "Masculinity" and "femininity" do not function as empirical concepts; hence, studies investigating paradigmatic traits, or phenomena relating to paradigmatic traits, will only reinforce existing valuations while appearing to locate findings in fact.

ACKNOWLEDGMENTS

I wish to thank Phil Hugly, Elizabeth T. Carpenter, and Julia P. Stanley for helpful comments and criticisms.

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THE NATURE AND FUNCTION OF FUNDAMENTAL PROPOSITIONS IN ACCOUNTING THEORY CONSTRUCTION

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Accounting scholars such as Chambers, Ijiri, Mattessich, Moonitz, and Sterling emphasize the central importance of fundamental propositions in accounting theory construction. Theory building in accounting has proceeded, however, without the insight provided by delineation of the respective natures and functions germane to different types of fundamental propositions. Accounting theorists have not gone far enough in identifying the unique roles of the various statements used as basic assumptions in theory construction. Accordingly, premises, axioms, and postulates are differentiated in harmony with philosophic substance. Premises are closely linked to systems of formal deductive logic and the inherent processes of valid inference. Axioms are used in theoretical systems to specify the formal aspects of theories. Taken together, axioms define the formal structure or syntactical aspect and the formal interpretational rules or semantical aspect. Postulates explicate nonformal aspects or subjective dimensions of theoretical systems. They capture the essential imperatives or obligations of theory building in a specific field and are, thus, normative in nature. Ijiri's axiomatic accounting system is chosen as a vehicle to illustrate both the unique roles of axioms and postulates as well as the complementary nature of these two types of fundamental propositions in accounting theories. Ijiri's system contains three axioms which are patterned after Euclidean geometry in a manner similar to theoretical systems in natural sciences. Nonformal postulates are added to this axiomatic system and are shown to perform a different, but supporting function.

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INTRODUCTION

Fundamental theoretical research in accounting has been accorded high priority since the reorganization of the American Institute of Certified Public Accountants' (AICPA) research effort in 1958. At this time, the Special Committee on Research Program recommended to the Council of the AICPA the establishment of a research staff whose immediate research priorities were envisioned as:

. . . a study of the basic postulates underlying accounting principles generally, and a study of the broad principles of accounting. The results of these, as adopted by the [Accounting Principles] Board, should serve as a foundation for the entire body of future pronouncements on accounting matters (1958:64).

The quantity of continuing research subsequently directed toward delineation of the foundation of accounting (variously referred to as basic assumptions, premises, axioms, or postulates) indicates the importance attached to funda-

mental research by accounting scholars (see Buckley, Kircher, and Matthews, 1968:276-279). Chambers (1960), Ijiri (1965), Mattessich (1972), Moonitz (1961), and Sterling (1970) all emphasize the central importance of fundamental propositions to accounting. Similarly, the American Accounting Association's Committee on Accounting Theory Construction and Verification (1971) and Committee on Foundations of Accounting Measurement (1971) accord fundamental research a critical role in accounting theory development.

Unfortunately, despite all the attention devoted to identification of fundamental propositions in accounting, the visible results are meager. In fact, a considerable degree of disenchantment and skepticism surrounds research of this type in accounting circles today. Such disenchantment and skepticism do not stem from relegation of fundamental research to a role of minor significance in theory construction; rather, it results primarily from the inability of the research to identify broad, serviceable fundamental propositions. Delineation of the natures and functions of different types of fundamental propositions is an important first step in providing accounting theories with a systematizing framework.

NATURE AND FUNCTION OF FUNDAMENTAL PROPOSITIONS

Throughout accounting literature, the terms "assumption," "premise," "axiom," and "postulate" tend to be used interchangeably. The thread linking these terms is their common level of conceptual abstraction which places them at the very foundation of fields of theoretical knowledge. Correspondingly, the characteristics of consistency, coherence, contributiveness, independence, completeness, and economy are widely recognized as being the requirements to which such propositions must individually and collectively adhere in order to be accorded fundamental status. Of these above, two require further elucidation. The characteristic of coherence is an extension of the characteristic of consistency. Consistency is traditionally associated with systems of formal logic and mathematics. However, in about 1930, Gödel demonstrated that even within a formalized deductive system, strict consistency is impossibly rigorous (Stabler, 1953:146, 251). Fortunately, the concept of derivation led to a more flexible interpretation of the characteristic of consistency. Derivation encompasses both the deductive rules of formal logic as well

as the problematic rules of induction. Consequently, "any extension of . . . deduction to the concept of derivation has to be accompanied by an extension [of the requirement] of consistency to [the requirement of] coherence" (Leinfellner, 1974:14-15). Coherence is a broader, more flexible, requirement than is logical consistency (Edwards, 1967, 6:476). The requirement of coherence admits "highly" confirmable, probable propositions to a system and allows for systematic relationships of a statistical nature between propositions of the system. Coherence demands only conceptual tractability which can be either deductive or probable (Leinfellner, 1974: 15).

Of these six characteristics, some are essential while others are only desirable. Taken together, however, they comprise the necessary criteria for identification of fundamental propositions. It does not follow, however, that these terms may be used interchangeably. On the contrary, their indiscriminate use fails to recognize useful distinctions in their respective natures and functions (for a detailed discussion of these characteristics or requirements, see Langer, 1953; Eves and Newsom, 1965; Stabler, 1953; Queenan, 1962; Mautz and Sharaf, 1961; and Lambert, 1973).

Assumption

An "assumption" (or basic assumption) is a proposition that is taken for granted. It is the most general or most primitive of the four terms. Operationally, this means that in the definitions of the other terms, "assumption" is used as a descriptive word (for example, the term "postulate" is defined as an assumption which . . .). The terms "premise," "axiom," and "postulate" denote special types or specific interpretations of "assumption."

Premise

A "premise" is an assumption which forms the starting point in logical argument. Rules of deductive logic are applied to premises to reach logically valid conclusions. Thus, the term "premise" is associated with systems of formal deductive logic and their inherent processes of valid inference (Barker, 1974:6-7).

Axiom

An "axiom" is an assumption which specifies a relation (function or operation) which is permissibly applied to the elements (sets or properties) of the system. Axioms explicate the *formal* aspects of a scientific theory. Taken together, they define the formal structure (syntactical aspect) and the formal interpretational rules (semantical aspect) of a theory (Leinfellner, 1969:110-20). In short, syntactical axioms capture the so-called "pure theory" which has no connection with the real world, while semantical axioms specify the meanings necessary to connect the syntactical structure with the real world.

Postulate

A "postulate" is an assumption which explicates certain *nonformal* aspects or subjective dimensions of a system. Aristotle introduced postulates of reality, evidence, truth, deduction, a priority, consistency, and explanation as non-formal propositions clearly distinguishable from the premises of logic and formal axioms (Leinfellner, 1966:199-203). Similarly, the *Dictionary of Philosophy* alludes to the non-formal nature of postulates in its definition of a postulate as an "indemonstrable practical or moral hypothesis, such as the reality of God, freedom, or immortality (Runes, 1960: 244).

Postulates identify relevant aspects of a discipline's environment. These aspects include both properties of that environment as well as inter-relationships between the environment and the discipline. Postulates provide the critical, background perspective needed to guide the theoretical systematization of a discipline. They isolate and explicate, in nonformal language, the essential imperatives or obligations inherent to theory construction in accounting; they create an awareness of critical biases, prejudices, and presuppositions which previously lay hidden, partially concealed, or entangled in the maze of empirical propositions characteristic of accounting.

Postulates are clearly differentiated from premises. However, the distinction between postulates and axioms is not as apparent. Ijiri's axiomatic accounting system provides a vehicle for illustrating both the unique roles of axioms and postulates as well as the complementary nature of the two types of fundamental propositions in accounting theories.

AN ILLUSTRATION DIFFERENTIATING AXIOMS AND POSTULATES

Ijiri's (1965) axiomatic system is one of the simplest and most concise explanations of historical cost accounting. The set of axioms is patterned after Euclidean geometry in a manner similar to theoretical systems in natural sciences. By examining current accounting practice and abstracting from these, Ijiri derives a system composed of three axioms and three measurement rules. The three axioms specify the syntactical structure or logical aspect of accounting in terms of elements and relations defined on those elements:

Axiom of Quantities: There exists an accounting set U , that is, a set of objects that may be partitioned into a countable collection of measureable classes.

Axiom of Ownership: The property set A of a given subject at any time t can be uniquely determined at that time or later.

Axiom of Exchanges: For any object that is added to or subtracted from the property set A_t , an exchange

that has caused the addition or subtraction of the object can be uniquely identified; and all exchanges that have occurred are identifiable, countable, and can be ordered completely and uniquely according to the time of their occurrence.

Essentially, these axioms assume that objects can be quantified via measurement, that the property set of a subject can be identified, and that changes in a property set of a subject can be recognized by means of exchanges.

Since accounting is an applied discipline, it must go beyond syntactics and also embrace meanings or semantics. Thus, the terms in the pure theory are given real world substance in accordance with the intended application of the syntactical structure:

Definitions:

i) A *subject* is any identifiable thing that is capable of owning other things.

ii) *Objects* are any identifiable things that are capable of being owned by a subject.

iii) *Time* is a real variable; a smaller value of time means an earlier time, and a larger value a later time.

iv) A *physical measure* is a non-negative set function that is defined on a class of objects and all of its subsets such that it is *countably additive*—it takes zero on the empty set—and that two sets of objects in a same class are substitutable if they are of a same value of the physical measure. A class with such a function is called a “measurable class.”

v) An *accounting set* is a set of objects that may be partitioned into a countable collection of measurable classes.

vi) *Ownership* is a well defined relationship between a subject and objects at a given time by which for any object it is uniquely determined whether or not the object belongs to the subject at the given time.

vii) A *property set* of a subject at time t is a subset of an accounting set and consists of all objects that belong to the subject at time t .

viii) An *exchange* at time t is a phenomenon at time t which results in adding a set of incoming objects (all belonging to a single class) to the property set A_{t+} and subtracting a set of outgoing objects from the property set A_{t-} , where t_+^+ and t_-^+ .

Unfortunately, a number of critical propositions essential for guiding the development of accounting theory are not

captured and explicated by Ijiri's axioms. Such propositions comprise the postulate complementation or background perspective for accounting. While it is not practical in this paper to attempt a complete postulate complementation, four plausible postulates are offered to illustrate the function such propositions perform.

Postulate of Objective: The primary objective of accounting should be to provide information useful for making economic decisions.

Postulate of Logic: Accounting measurement should be embedded in a probability framework.

Postulate of Structure: Accounting measurement should be based on general systems theory.

Postulate of Human Abilities: Decision makers can differentiate between two non-identical sets of objects, can identify an object as belonging to a given subject, and can identify exchanges.

Essentially, these postulates add normative obligations to Ijiri's system in the form of an objective of accounting measurement and epistemological, ontological, and behavioral commitments. They illustrate the type of complementation which any pure axiomatic system must have in order to be completely effective as a framework for accounting. Such propositions provide essential perspective for both theoretical development as well as empirical confirmation. If these presuppositions are allowed to remain undetected in the empirical language, observations, meaning, facts, measurements, and experiments are likely to be distorted, inconsistent, and perhaps misleading. Additional postulates may be added to those presented, or others may be offered as alternatives. The important point is, however, that these fundamental propositions should be separated from the empirical language and distinguished in nature and function from syntactical and semantical axioms.

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TOWARD A METHODOLOGY FOR AUDITING

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The nature and practice of auditing is described within the context of the social, economic, and political dynamics of the last 100 years. Auditing developed upon a predominantly pragmatic foundation. Within the last decade, auditing scholars such as Mautz, Sharaf, Silviso, Newmann, and Carmichael have attempted to undergird auditing with theoretical substance. This attempt has been hampered by the absence of an appropriate methodology. Reflection suggests that for a discipline to reach maturity, it must embrace a methodology germane to its particular needs and activities. Efforts to find such a methodology have focused exclusively on the methods of the physical sciences with emphasis on the cognitive-descriptive aspects of theories. The disappointing results of these efforts strongly suggest that the search must take a new direction. An emerging, more powerful, methodology designed to cope more effectively with the almost infinite complexity of theory construction in the social sciences provides that new direction. These methods—which are based on value theory, decision theory, and game theory (Newmann, Morgenstern, Marschak, Churchman-Ackoff, Luce-Raiffa) as well as recent developments in the philosophy of science, especially the methodology of theory construction (Carnap, Hempel, Suppes, Leinfellner)—accord economic, social, and political aspects a viable role in theory construction. The application of these fresh techniques holds great promise for moving auditing toward its own customized methodology.

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THE NATURE OF AUDITING

Auditing is defined as:

. . . a systematic process of objectively obtaining and evaluating evidence regarding assertions about economic actions and events to ascertain the degree of correspondence between those assertions and established criteria and communicating the results to interested users (*A Statement of Basic Auditing Concepts*, 1973:2).

In essence, auditing encompasses two fundamental processes, namely, an investigative-evaluative process and a communicative process. These processes are guided largely by generally accepted auditing standards and procedures promulgated by the American Institute of Certified Public Accountants. Generally accepted accounting principles serve as the primary criteria by which assertions about an economic entity are evaluated. The communicative process makes known the results of the investigative-evaluative process to interested users in the form of an auditor's professional opinion.

The distinction between accounting per se and auditing should be made clear. Accounting involves management's generation of economic information about an entity. This management activity culminates in the creation of summary financial statements referred to as the Balance Sheet, the Income Statement, and the Statement of Changes in Financial Position. Auditing, on the other hand, investigates and evaluates the assertions contained in the financial statements for the purpose of forming a professional opinion about their credibility as management's representations of an entity.

THE HISTORICAL EVOLUTION OF AUDITING

A brief survey of the historical evolution of auditing in the United States reveals how extensively the practice is embedded in the economic, social, and political dynamics operative during the century of its development. After the Civil War, the rapidly expanding American economy attracted large amounts of British capital. In fact, much of the early auditing performed in this country was done by visiting British auditors retained by British investors. Hence, American auditing initially was patterned after the British stewardship audit which emphasized detailed verification of bookkeeping accuracy in its search for defalcations, embezzlement, and fraud (Moyer, 1965:3).

With the industrial revolution came increased size and complexity of business entities, widespread public ownership of these entities (i.e., the corporation), and the corresponding separation of ownership and management (Brown-Salquist, 1972:6-7). Auditing practice responded dramatically to these changes during the first one-third of the 20th century. The auditor became increasingly concerned as to the credibility of management assertions about financial condition and entity earnings, and less preoccupied with defalcations, embezzlement, and fraud. Testing of a limited sample of clerical matter began to replace detailed verification, and the internal control procedures of the auditee became the key input in determining the necessary size of the sample (Brown, 1965: 16-17).

By the 1930's, auditing practice and its environment had developed to the point where they required explicit legal and political attention. The *Ultramares Corporation v. Touche, Niven & Company* case (1931) extended auditor liability for

the first time in the United States to third parties—not within the contractual relationship of the audit—who were injured by auditor fraud or gross negligence (Causey, 1973:64-65). This common law interpretation was given statutory status with the passage of the Securities Act of 1933 and the Securities Exchange Act of 1934. More importantly, these Acts, in lieu of more direct governmental controls, established the free enterprise system of the United States upon a regulatory foundation that embraced disclosure of material financial information (Chatfield, 1974:133-134). This regulatory posture solidified the social, economic, and political importance of the audit function in American society. Simultaneously, during the 1930's, auditing practitioners emerged as a viable force, having at least the rudiments of professionalism. The auditing profession accepted the primary responsibility for improving financial disclosure, and it initiated programs directed toward the continuing formulation of accounting principles, auditing standards and procedures, and ethical norms (*Statement on Auditing Standards No. 1*, 1973:200-205).

In the years that have followed, auditing practice has remained sensitive to social, economic, and political needs. It has continued to experience pragmatic refinement, yet the basic nature of the audit function in the United States has remained essentially as it emerged from the 1930's.

AN EPITHEORETICAL METHODOLOGY FOR AUDITING

Within the last fifteen years, attempts have been made to undergird, with theoretical substance, auditing's pragmatic foundation. Attention has been drawn to the incongruity apparent "in the existence of a professional group drawing its status primarily from the practice of auditing, but having no perceptible body of theory to support that practice" (Mautz-Sharaf, 1961:1). Unfortunately, attempts toward theory development in auditing have been hampered by the absence of an appropriate methodology. Efforts to delineate such a methodology rely almost exclusively upon the adaptation of methods utilized in the physical sciences, methods which emphasize the value-free, cognitive-descriptive aspects of theories. Physical science methodologies, however, do not function well with the basic nature of the audit function and its inherent relationship to its social, economic, and political environments. In short, auditing must free itself from the methodological limitations imposed by the physical sciences and embrace a methodology germane to its particular needs and activities.

Epitheoretical analysis provides such a methodology. It is specifically designed to cope with the multi-dimensional aspects of theory construction in the social sciences. Leinfellner contrasts this broadened methodology with the methods used in the physical sciences as follows:

. . . the dogma of a value-free science can be

regarded as another consequence of the mere syntactical and cognitive view of science. These dogmas have served as a strait jacket and have prevented any analysis of norms, values, obligations, ideologies and even religious aspects of science. In contrast to it, the epitheoretical method offers a systematic complementary approach to . . . analysis [of each of these aspects] of science which is an indispensable requirement for understanding social theories (Leinfellner, 1974: 9-10).

Fig. 1 provides an overview of the epitheoretical complementation of traditional axiomatic analysis within the context of theory construction in auditing. The stratification of the total scientific language into its theoretical and empirical components via axiomatization is a well established technique of the physical sciences (Hempel, 1970:142-152). As a process, axiomatization utilizes metatheoretical or metalinguistic analysis which employs a higher-level (and more abstract) theory or language in order to analyze a primary theory or language—i.e., the empirical language in Fig. 1 (Russell, 1940:62-63). Such stratification enables the specification of two formal aspects of a theory, namely, the vocabulary or semantic aspect and the grammar or syntactic aspect.

As was previously pointed out, however, auditing, like other social sciences, is permeated with objectives, norms, values, obligations, and paradigms. While these epitheoretical aspects fall outside the range of semantical and syntactical analysis, they are of critical importance to auditing theory construction. These nonformal aspects comprise the all-important background knowledge in which the more formal aspects of auditing theory (i.e., semantics and syntactics) are embedded. Epitheoretical aspects, which are depicted in Fig. 1 as the periphery surrounding the axiom center, have the nature of meta-level assumptions and are termed "postulates" in order to distinguish them from semantic and syntactic assumptions called "axioms." The postulates describe properties of the economic, social, and political environments along with interrelationships between these environments and auditing. Together, these nonformal postulates provide the critical perspective for theoretical systematization of auditing.

Epitheoretical analysis proceeds by first mapping the domain of auditing onto a scientific language. Empirical and theoretical propositions are given a hierarchical structuring in accordance with their generality and abstractness. As the schema emerges, additional, more fundamental, propositions (i.e., epi-level propositions) become evident and necessary to the theory of auditing. The established requirements of postulates (i.e., the characteristics normally associated with fundamental propositions, including consistency, coherence, contributiveness, independence, completeness, and economy) are then used to isolate and identify the subset of such

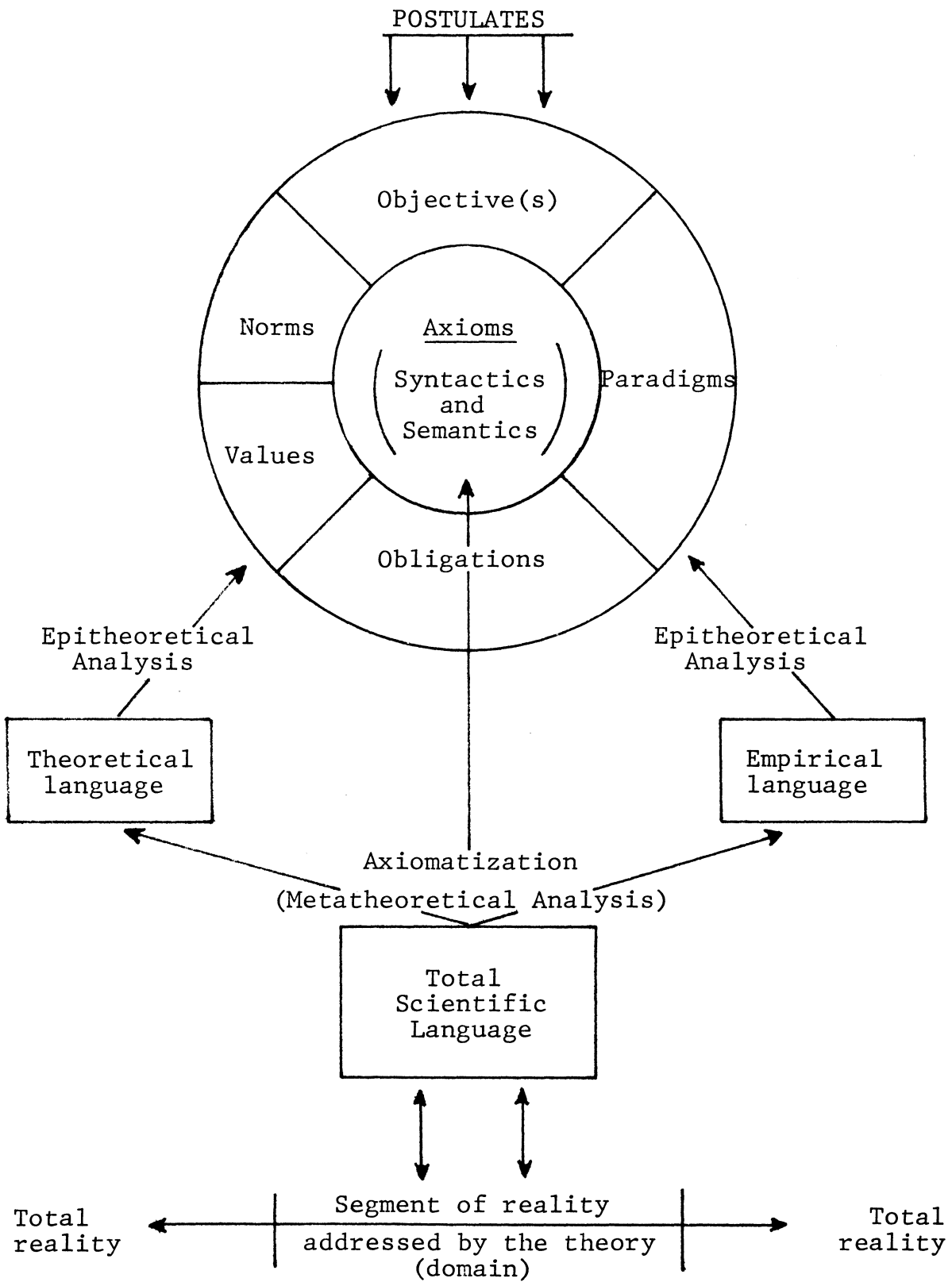


Figure 1. Framework for Axiomatization and its Epitheoretical Extension.

propositions which constitute the epitheoretical postulates of auditing. These postulates, in turn, provide normative guidance for the theoretical enrichment of auditing.

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A LINGUISTIC VIEW OF HABERMAS' THEORY OF COMMUNICATIVE COMPETENCE

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Habermas' view of language has been widely discussed in Europe and, to some extent, by rhetoricians and philosophers in the United States. Here we will present the linguistic point of view.

Habermas' theory is heavily influenced by concepts taken from hermeneutics and Habermas' own sociological views. For instance, Habermas uses his concept of "systematic distortion" (i.e. ideological distortion in a specific sense) and introduces it into the theory of communicative competence.

Habermas calls his view of language a "theory of communicative competence"; but even though he derives "competence" from Chomsky's "linguistic competence," the former's concept of competence is not to be understood entirely in the sense of transformational grammar.

In the theory of communicative competence, Habermas operates with the concept of a pragmatic truth—the "consensus theory of truth," as he calls it—and what he calls "pragmatic universals." He outlines the ideal speech situation which is the one to bring about "true" consensus and which is free of external and internal coercion. An ideal speech situation is characterized, among other things, by the fact that the "roles" of the speakers are interchangeable, that there is no systematic distortion, and so on.

Even from those few remarks, it becomes clear that Habermas is not an empiricist, neither from the linguistic nor from the sociological standpoint; and this is where part of the weakness of the entire theory stems from and where linguistic criticism can start.

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DISCUSSION

Habermas' theory of communicative competence (1971: 101-141) has been widely discussed in Europe and, to a lesser extent, in the United States. A philosopher's critique of the theory of communicative competence unfolds in Bar-Hillel (1973:1-11). Here we will present the linguistic point of view.

Habermas begins by using the now famous discrimination between linguistic competence and linguistic performance. Already, linguistic criticism could be a propos, because psycholinguistic data have not wholly supported the differentiation between (innate) competence and performance (compare e.g. Jerome Bruner's address to the 21st International Congress of Psychology, Paris). Already a casual inspection of the speech behavior of children reveals that they are not that linguistically competent. (This is exemplified nicely

by a little "school daze" joke—Note left on the teacher's desk: "Dear Teacher: I have written 'I have gone' a hundred times, as you have told me. So now I have went home.") But since the competence-performance problem is the responsibility of the linguist or psycholinguist, one should not blame the sociologist Habermas for not having solved it.

Habermas then introduces his own idea that the competence-performance distinction has to be enlarged by the concept that the general structures of possible speech situations can themselves be brought about by linguistic acts. Those structures are said neither to belong to the extralinguistic conditions under which an utterance is uttered nor to be identical with the linguistic entities that are produced by means of linguistic competence. Their purpose is the pragmatic embedding of a speech or speech act (1971:101).

It is obvious that Habermas, thus, aims either at the philosophical distinction between utterance and sentence or at the linguistic distinction between token sentence and type sentence or at some other linguistic or philosophical distinction between the empirical and the theoretical level (e.g., word vs. lexeme, etc.). Habermas resorts to the utterance-sentence distinction and creates some confusion by calling utterances "situated sentences" and by speaking of sentences as parts of speech acts, i.e. sentences as parts of specific kinds of utterances. Although the distinction utterance-sentence has so far proven quite satisfactory, Habermas feels himself compelled to introduce a four-fold distinction: 1) An utterance is concrete, if it is uttered in a certain empirical situation; its meaning is determined also by contingent factors —by the personalities of the speaker and the listener and by the roles they play in the society (1971:106-107). A linguist might say that at stage one connotation is important. According to Habermas, this concrete utterance is the subject matter of what he calls empirical pragmatics, that is, psycholinguistics and sociolinguistics (1971:108). The empirically minded linguist will, nevertheless, ask: What about, for example, statistical semantics, articulatory and acoustic phonetics, lexicography, . . . ? 2) If we abstract from the variable elements of a concrete utterance, then we obtain the elementary utterance, which is, according to Habermas, the pragmatic unit of speech (1971:107); it is obviously identical with a speech act (1971:104). The elementary utterance is the subject matter of a discipline Habermas wishes to introduce and which he

calls "universal pragmatics" ("Universalpragmatik"; 1971: 108) or "theory of communicative competence." 3) In a second step we abstract from the performance and, thus, retain the unit of linguistics, the elementary sentence (1971: 107-108). 4) By a final step of abstraction, where we do away with the performative and other pragmatic linguistic elements of stage three, we obtain another elementary unit: the propositional sentence or the elementary proposition ("elementare Aussage"; 1971:107). The elementary proposition is used—according to Habermas—to reproduce states of affairs ("Sachverhalte"; 1971:107); and according to him, it is predicate logic that deals with the elementary proposition. It is to be noted that we use "proposition" here as translation for "Aussage," not to be confused with the proposition as the platonistic meaning of a sentence.

There are various linguistic questions connected with those three abstractions. Since Habermas does not, on the one hand, tell us what those variable elements of stage one are that are to be removed by abstraction in order to produce the elementary utterance, or, on the other hand, why the elementary utterances are still utterances, i.e. something that falls in the category of performance—we plainly do not know what the elementary utterance is. Is it speech without the "ahs" and "ums," without gestures, without personal style and personal mannerisms? Or is the third stage, won by abstraction from stage two, purely linguistic? If we interpret Habermas here, we have to add that the elementary sentence is un-uttered by any empirical speaker. It seems to me that Habermas takes here the concepts of generative grammar all too seriously (1971:107). The idea of restricting linguistics to the study of elementary sentences—and elementary sentences only—is untenable, even if we do not consider a linguistics of the Firthian type where, for example, meaning is the whole complex of functions a linguistic form may have. If we stick to Habermas' opinion on the subject matter of linguistics, then linguistics never deals with empirical facts, but with something that is already the result of a two-step abstraction. It is, however, linguistics, besides others, which—starting with empirical discovery procedures—performs the abstraction from the concrete utterance to more theoretical concepts like the lexeme, the type word, the moneme, or, expressed more generally, to the level of the *langue* (de Saussure). This is the basis of structuralistic linguistics and of linguistics as an empirical science as well. If we remove the empirical basis of linguistics by removing the concrete and the elementary utterance (the speech act), then linguistics severs its connections with the empirical languages.

Stage two is characterized by the fact that so-called pragmatic universals become visible; Habermas calls them "pragmatic universals" because they can be correlated with universal structures of a speech situation, i.e., the structure that each speaker requires a listener (1971:109). Looked at closely, it seems that the pragmatic universals are of a similar nature as the lexemes because Habermas simply presents them as a list of words and refuses to assign them to a

meta-language (1971:109). Under those circumstances, it seems quite unnecessary to introduce three levels of abstraction and a specific science, called "universal pragmatics" or "theory of communicative competence."

Let us now have a linguistic look at the speech act (the elementary unit of speech = the elementary utterance) as conceived by Habermas. According to Habermas—who tries to resort here to Austin and Searle—a speech act is always composed of two "sentences" (we should better say: linguistic elements, parts, etc.)—a performative "sentence" and a propositional "sentence." We have to add here that Habermas' pragmatic universals can also be non-performative (i.e., *deictic*; 1971:109). There is one exception to the division performative "sentence"—propositional "sentence": institutionalized speech acts do not have to contain a propositional "sentence" ("I thank you" / "I curse you"—Habermas' examples; 1971: 113). Here a strong idealization occurs because Habermas assumes that all sentences, without exception, contain a performative element, either empirically, or (still empirically hypothetical) in a deep structure. If we take the standpoint that linguistics is an empirical science, then the empirical absence of something—e.g., the absence of "I know" from "(that) the flower is red"—does not imply that we can simply say: if it is not here, it is in the deep structure. By the way, a problem of the same order arises when Habermas says that institutionalized speech acts are dependent upon other speech acts, which, as a rule, are not verbalized (1971:113). This is a serious empirical problem that, *mutatis mutandis*, also plagues other sciences: Because the theory demands that there is an empirical entity (e.g., a luminiferous ether), one assumes it has to be someplace; and in linguistics, the most convenient "someplace" is the deep structure.

A speech act thus divided in two parts can be further characterized by the fact that the propositional content of the propositional "sentence" stays the same when, for example, questions are transformed into commands and commands into confessions (1971:106). It is not entirely clear what Habermas means by "propositional content," but it seems that the propositional content is some platonistic or idealistic meaning. If so, such a concept must be refused in empirical linguistics where one substitutes either the empirical descriptive meaning for it or the meaning as used in the language. A further empirical argument—and this argument also concerns a good deal of today's linguistics—starts with the observation that, if nothing else changes when we "transform" (e.g., questions into commands), at least the syntactic structure of the propositional "sentence" changes ("Are you leaving?"; "Leave!"; "I confess that I am leaving"; or better, perhaps: "I confess that I left."). One could now put forth a hypothesis: 1) The syntactic change indicates a change in meaning, a view supported by certain findings in historical linguistics. This reverses, of course, the relationship between syntax and semantics as it is usually conceived, or it gives at least syntax a semantic aspect; 2) We could draw the conclusion that the two utterances—"The water is running" and "I believe the

water is running"—do not share a common "element" of meaning, namely, the meaning of "the water is running," but that they are two linguistic entities with two different semantic structures. Wittgenstein has argued that in the examples, "I expect he is coming" and "He is coming," "he is coming" has in both instances the same meaning because our hopes can be fulfilled (1953:130^e, § 444). But what about hopes that can never be fulfilled because they belong to some never-never land? And what about the examples, "I dreamt that the cows ate square roots" and "The cows ate square roots," where the latter is in conflict with current (English) language use and thus meaningless in language-immanent semantics as well as in empirical. One could imagine that the first case—" (that) the cows ate square roots"—has some meaning, although no empirical meaning. It is obvious that a meaningful and a meaningless sentence or part of a sentence cannot have the same meaning. It would be preferable to say, first, that in the case of the example given by Wittgenstein, the sameness of meaning is accidental or fictitious as long as we are on the language-immanent level and, second, that we have to stress that such questions cannot be solved solely by a semantics where meaning appears as a language-immanent use of the language; we also have to apply an empirical descriptive semantics.

Despite the recent criticism that has been heaped upon interpretative semantics, it seems that a refined interpretative semantics (minus the mentalism à la Katz) or a structural semantics could deal with those problems most adequately. (One should not forget that a good deal of computer semantics is interpretative; compare, for example, Wilks, 1972, and Minsky, 1968.) On a language-immanent level, the ontological abyss between intension and extension (one of the characteristics of an empirical descriptive semantics—or, in Habermas' terms, the distinction between the performative "sentence" and the propositional "sentence") would be diminished or take another shape. For example, the difference between "I see that those flowers are red" and "I believe that those flowers are red" would not lie in the fact that the first sentence is intentional and the second assertive, but in the fact that "see" and "believe" associate—according to present (English, German, . . .) language-use with different sets of words.

Those considerations are essential for Habermas' theory of communicative competence also for another reason: He uses a consensus theory of truth rather than a correspondence theory, an issue which is a philosophical one and which we are, therefore, not going to discuss here.

The last problem we are going to deal with is the problem of Habermas' ideal speech situation. He states the following: 1) The significance of a speech act lies in the fact that two people act in agreement or communicate about something; 2) Communication means the bringing about of true consensus. For Habermas' concept of true consensus, we refer to Habermas' writings themselves, since true consensus is not a linguistic problem; 3) True consensus can be dis-

criminated from false consensus only with reference to an ideal or idealized speech situation, i.e., agreement is to be reached under ideal conditions which Habermas says are counterfactual (1971:136). The serious empirical linguist begins to wonder that perhaps a counterfactual condition of an empirical speech act is a *contradictio in adiecto*. It's as if a physicist would say: Perform this mechanical experiment in the open air under the (counterfactual) condition that there is no air friction. Habermas justifies the idealization of a speech act and its ideal preconditions by saying that this is an anticipation ("Vorgriff"; 1971:136 ff.); this reminds us of hermeneutic philosophy. In hermeneutic philosophy, however, one has to justify one's anticipations by means of that which follows, be that which follows the interpretation of a given text or a series of actions or speech acts. But since the anticipation here is counterfactual, it can never be justified, and is, therefore, not even an heuristic device.

A speech situation is ideal if it is neither hampered by external, extra-linguistic circumstances (e.g., political ones), or by internal, linguistic circumstances; the latter includes the absence of what Habermas calls "systematic distortion" ("systematische Verzerrung"; 1971:137). According to Habermas, a systematic distortion does not imply that one is deceived by means of language, but that language in itself—for example, ideological language—is deceptive. This presupposes that, in the case of political, ideological language as a medium of power and social control, its ideological character is not revealed by those in power (1970:287). If we read in a philosophical dictionary that socialist democracy originates and develops together with the working class' rise to political power and with the establishment of the dictatorship of the proletariat, then we know that this must be a dictionary compiled by a Marxist (Klaus and Buhr, 1964:102b). But is this explication of "democracy" really distorted and—if it is distorted—distorted in comparison to what? A "western" explication of "democracy"? But "democracy," as the word already implies, practically always justifies power and is, thus, always ideological. Therefore, from a linguist's standpoint, we could say, with like credence, that a "western" explication of democracy is systematically distorted compared to a Marxist one, if—and only if—the Marxist and the "western" use of language have been firmly established and the denotations have been agreed upon. The linguist can do nothing else but state a change of meaning in case the "western" and the "Marxist" basic languages are essentially the same, as is the case in East and West Germany. "Democracy" in different languages can be compared only with great difficulty. Otherwise, the linguist has to resort to the venerable but false notion that some speech shows "true" meanings, whereas other forms of speech do not. Language itself has to be considered as a neutral vehicle, quite innocent of all the crimes it has been blamed for, including ideological distortion.

Essentially, Habermas argues that the structure of communication itself produces no coercion when—and only

when—for all communicators there is a symmetrical distribution of chances to select speech acts and to perform them. Then, the roles played by the participants in a dialogue can be exchanged, and the communicators will be in a state of equality with respect to the performing of roles in a dialogue (1971:137). If this is an idealization, it does not add anything to the improvement of our speech acts since it is said to be counterfactual. And if we remove the counterfactuality of this statement and apply it to empirical speech situations, we will see that—in most instances—it is plainly false. Language conceived in such a way would be partly reduced to the symmetrical exchange of pleasantries or of informations about well established facts, where the persuasive power of speech plays no role; in general rhetoric as the art of persuasion would have to disappear. Another possibility is what we might call a “theorizing” dialogue, i.e., a dialogue where people try to reason together and where the symmetrical distribution of chances to select and perform speech acts is preserved. Such a dialogue would be evenly flowing and would appear as if staged. If we try to give an example of such a dialogue, we might think of the staged dialogues of Plato or of Galilei’s *Dialogue Concerning the Two Chief World Systems*. But a closer look at, for example, the Platonic *Cratylus* reveals that Cratylus’ contributions to the dialogue are often reduced to “Yes”; “No; I do not”; “Certainly”; “What do you mean?”; “Most assuredly”; whereas Socrates plays a dominating and domineering role. This is, of course, even more so in real life. Speech situations as conceived by Habermas would presuppose that all men are not only equal before the law and with respect to their chances in society (and even those two equalities exist empirically only in a restricted form), but that they are also equal with respect to their intellectual capabilities, their linguistic fluency, their wit, etc., and that they are all dispassionate, even apathetic. Thus, speech is almost always asymmetrical, due to the differences in the nature of men, and because of the practical demand of avoiding excessive expenses and excessive amounts of time and nerves.

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KANT AS INTERNALIST: THE SYNTHETIC A PRIORI PROPOSITION OF KANT'S ETHICAL THEORY

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Kant claims that his categorical imperative is a synthetic, a priori proposition, but he does not make clear what makes this proposition synthetic or a priori. In this essay it is argued that in Kant's view the proposition is synthetic a priori because it states a quasi-psychological fact: that rational beings are capable of acting from purely moral motives. This means that Kant is an "internalist" in W.D. Falk's sense.

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I

Kant tells us that the categorical imperative is a synthetic a priori proposition (1902-42, 4:420). We know from the *Critique of Pure Reason* that such propositions are likely to be very important but also very difficult to justify. And, indeed, we find that Kant believes the categorical imperative to state a very important proposition and to be very difficult to justify (1902-42, 4:420, 444-445). Further, he believes it important to justify this proposition, because if it cannot be justified, then morality may be merely a "phantom of the brain" (1902-42, 4:445). Although Kant covers much difficult and important ground in moral theory in the first two chapters of the *Grundlegung*, he leaves the task of justification of the categorical imperative to the notoriously difficult and obscure third and final chapter.

In this paper I wish, first, to set forth briefly an interpretation of what the synthetic a priori proposition *is* that Kant is seeking to justify. What this proposition is is not obvious; indeed, though little has been written on this subject in recent literature, there is potential for controversy and dispute. It seems important to understand just what this proposition is because without such knowledge we cannot understand Kant's attempted justification of the proposition.

Second, I will discuss briefly some consequences of my interpretation, and in particular the idea that Kant is an "internalist" in Falk's (1947-8) and Frankena's (1958) sense of that term.

Finally, in an appendix I will mention a textual problem faced by this and other interpretations of Kant on this point.

II

As is well known, Kant states a number of different

formulations of the categorical imperative, which he claims are equivalent to what is commonly called the "first formulation." He (1902-42, 4:413) says:

There is therefore only a single categorical imperative and it is this: "*Act only on that maxim through which you can at the same time will that it should become a universal law.*"

The emphasized proposition might not seem a promising candidate for a synthetic a priori proposition. For one thing, it is an imperative. Usually only sentences in the indicative are said to be either synthetic or analytic, but this is easily remedied, for Kant says that "imperatives are expressed by an ought." Thus we may rewrite the categorical imperative:

(Persons) ought to act only on maxims through which they can at the same time will that it should become a universal law.

And, to make the subject-predicate nature of the proposition more explicit, we might further rewrite it:

(Persons) are things that ought to act only on maxims, etc.

We might further ask just what Kant intends the subject of the sentence to be, the subject which we have so far indicated with an expression intended to be as neutral as possible—"Persons." There are strong textual indications, both in the *Grundlegung* and elsewhere, that Kant intends the subject to be "rational beings" or "a rational being" (1902-42, 4:420n, 426-427, 435, 438, 440; 5:46; 4:26-28).

Furthermore, let us alter our predicate so that we may concentrate our discussion on the issues of present interest. In Chapter One of the *Grundlegung*, Kant analyzes the concept of the good will, showing by conceptual analysis (admittedly controversial) that a good will acts only from the motive of duty and that the principle of actions from the motive of duty is the purely formal principle that is stated by the first formulation of the categorical imperative (1974). The point of this analysis, it seems to me, is to analyze the general concept of morality, or the idea of what it is to be in possession of a moral nature. I propose to substitute the pre-

analytic concept of having a moral nature for the analyzed formulation of the categorical imperative, because the issues I wish to consider in this essay do not deal with whether the Kantian analysis of these concepts is correct or with, for example, relations between the different formulations of the categorical imperative, but rather with these pre-analytic concepts and the light that consideration of them may throw on the nature of "the categorical imperative." Thus, we have the following principle, stated in largely pre-analytic terms, a principle which is presupposed by the categorical imperative:

A rational being is a being with a moral nature.

This proposition, then, is synthetic *a priori* (1902-42, 4:26-28).

But just what does it mean to be in possession of a moral nature? I would like to suggest three possible meanings:

- (1) To be subject to the moral law in the sense of being morally responsible for one's actions.
- (2) To be aware of moral principles, moral considerations, on occasion to judge one's own and others' actions by moral principles, perhaps on occasion to feel guilt, indignation, and other moral feelings.
- (3) To be capable of acting from purely moral motives.

Kant pretty clearly intended (1) as part of the meaning of morality. Surely for Kant to be a moral being and not to be accountable for one's actions would be a contradiction. At times Kant seems even to use "accountable" and "moral" as synonyms (1902-42, 4:26-28).

It also seems that the kinds of things mentioned under (2) are, in Kant's view, associated with having a moral nature. Kant discusses moral emotions, in particular "respect," as an important ethical concept and an indispensable moral emotion (1902-42, 4:400; 5:71ff). The idea that we are conscious of a "moral law within" ourselves is a recurring idea in Kant's moral philosophy (1902-42, 5:29-30, 161); this consciousness serves a key role in the very justification of the categorical imperative in the second *Critique* (1902-42, 5:29-31). Finally, when we read Kant's lectures on education (they are primarily on *moral* education), we find that he believes that the moral law is within each of us; education consists only of leading it out and bringing it to full consciousness (1902-42, 9:437-500).

But it might be asked: Are these characteristic moral phenomena *analytically* or *synthetically* associated with the concept of a moral being, or of morality as such? Perhaps, for example, respect, though in Kant's view clearly associated with morality for all human beings, is not, according to

him, part of the concept of morality, but rather simply an associated phenomenon. I think this objection is difficult to answer. Some of the things mentioned under (2) may well have been intended by Kant to be part of the concept of morality or of a moral being, but it would be, I believe, difficult to show. Thus, for the present we must leave the question of meaning (2) unresolved.

Is (3) a part of the meaning of "moral being"? Before trying to answer this question, let us consider briefly what it means if the answer is "yes." One of the more interesting consequences is that Kant would be an internalist, in the meaning of that term used by W.D. Falk (1947-8) and William Frankena (1958). An "internalist" believes that a reference to the existence of motives in the agent must be made in the analysis of a moral judgment; the "externalist" denies this (1958:41). If (3) is true, i.e., if to be a moral being one must be capable of acting from purely moral motives, then, since moral judgments are true only of moral beings, one of the truth conditions for any moral judgment (and hence part of its meaning) will be the proposition that the agent is capable of acting from purely moral motives. (Perhaps it is worth noting here that Kant believes that even the morally evil and depraved man will be moved to act out of moral motives in cases where such action will not conflict with his own selfish desires and interests; hence in Kant's view, moral motivation will not be a mere theoretical capability, but a dispositional motive in the sense of "an occurrent motive under certain conditions.")

Let us ask again, Is (3) also part of the meaning of "moral being"? I think the correct answer is "Yes." Throughout the *Grundlegung* Kant is concerned with moral motivation when he is discussing the categorical imperative. For example, at the beginning of Chapter Two, when he is considering the question of whether morality may not be a "phantom of the human imagination" (1902-42, 4:407), the question he considers is whether a morally *motivated* action has ever been performed (1902-42, 4:407-408). And Kant—when he raises in Chapter Two the question of whether the categorical imperative is "possible"—seems to be asking, once again, a question about the possibility of moral motivation (1902-42, 4:417-420). Again, his discussion of autonomy is largely in terms of *motivation*; heteronomy is said to be the will's being determined by something outside itself; whereas, autonomy is the will's self-determination (1902-42, 4:431-433). Also, in the second *Critique*, the question is stated: Can pure reason be practical? And if pure reason can be practical, this means, Kant tells us, that "... of itself and independently of everything empirical it [i.e., pure reason] can determine the will" (1902-42, 5:42). So, once again, the question concerns "determination of the will" and, hence, motivation.

If (3) is, indeed, correct, that is, if to be a moral being is to be capable of acting from purely moral motivation, and if Kant, in justifying the categorical imperative, is mainly trying to justify the proposition that all rational beings possess

this capability (in virtue of their being moral beings), what follows?

A. We might ask, why should Kant feel the necessity of some purely rational, non-sensuous motivation necessarily connected with morality? There are, no doubt, many reasons. One set of reasons surrounds his discussion of autonomy; any motivation *other* than such a purely rational, moral motivation would be heteronomous, would come from outside; hence, in following it, we would not so much be acting as be acted upon. But perhaps just as interesting is a related point: Heteronomous motives are only contingently related to morally required actions; perhaps we will have the heteronomous motivations necessary to do what is morally required of us (e.g., perhaps we were born and/or bred to be kindly persons)—but then again, *perhaps not*. There is no necessity that any heteronomous, sensuous motive will be adequate to move us to do what is morally required; and if these were the only motives available to us, there would be no certainty that, in a given instance, we *could* have done what was morally required of us. But a purely rational, moral motive, if it exists, is always and in every case capable of providing a motive adequate to bring about our doing an action that is otherwise in our power (e.g., not beyond our physical capability). Thus, the capability of acting from purely moral motives brings with it a guarantee of moral responsibility.

B. This interpretation makes Kant an “internalist,” as we have already remarked, but not one who will have to “trim obligation to the size of individual motives” (1958: 80), since, in Kant’s view, the capability for purely moral motivation will not limit our obligations but will, rather, serve to guarantee them. I cannot adequately consider here whether the kind of motivation which Kant claims lies at the basis of morality really is a possible kind of motivation (1965:301-349). I am inclined to believe that such motives are possible and that this can be seen when we once understand such motives: They cannot be interpreted metaphysically, as Kant did; I find it hard to take seriously Kant’s metaphysical story of noumenal causes of moral action. But perhaps a formula such as the following may be useful, as well as Kantian in spirit: One acts from morally good motives if he does what is right for the reasons that it is right. All that this formula for morally good motives requires is that the justifying reasons (those features of the situation in virtue of which an action is correctly concluded to be right, wrong, etc.) be one and the same as motivating reasons. This may not be an impossible demand.

APPENDIX

There is a text in Kant which directly conflicts with the interpretation of the synthetic a priori proposition of Kant’s ethical theory that I have just put forward, and which conflicts, I believe, with most other reasonable interpretations of Kant. I propose to mention and briefly discuss this text, without being able to propose any very satisfactory way of inter-

preting it or dealing with the problems that it presents to the interpreter.

A text is more significant for a given point of interpretation, the more explicit it is on that point and the more prominently placed in the author’s text the point is. I must say, however, that I believe that no text, no matter how explicit or prominently placed, can by itself overturn an interpretation that is broadly based on a variety of other textual and argumentative sources; thus, I do not believe that this text confutes the interpretation of Kant that I have just proposed. (It may be added that one reason I feel this way is that I do not see *any* plausible interpretation for this text; there seems to be *no* way to make very good sense of it.)

The text occurs in the third paragraph of Chapter Three of the *Grundlegung*. Kant (1902-42, 4:447) proposes to state explicitly what the synthetic, a priori proposition to be justified in this chapter is:

Nevertheless the principle of morality is still a synthetic proposition, namely: “An absolutely good will is one whose maxim can always have as its content itself considered as a universal law”; for we cannot discover this characteristic of its maxim by analyzing the concept of an absolutely good will.

This passage certainly rates high in both explicitness and prominence. But it is hard to make sense of what Kant has here said. The proposition that he says is synthetic, a priori is, or seems to be, the same one that Kant’s argument of Chapter One of the *Grundlegung* attempted to show to be an *analytic* proposition (1974). Thus, I cannot at all see why Kant says what he says in this passage; he seems to misspeak himself. And perhaps, finally, that is the most reasonable interpretation of this passage, as a misspeaking, or as a slip of the pen. I wish I had a more satisfying proposal to make concerning the text.

Let me just note, in conclusion, that if instead of “good will” in the alleged synthetic a priori proposition, Kant had written “rational will,” this sentence and the discussion of it that follows would make much more sense.

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TWO VIEWS OF QUANTIFICATION

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In this paper I discuss the distinction between the referential and substitutional interpretations of one of the basic concepts of modern logic—the concept expressed by “for all x .” I try to bring out what is at stake in choosing between the two. Finally, I argue for the referential interpretation on the grounds that the substitutional interpretation allows defective formulation of sound principles.

† † †

One remarkable thing about modern logic is that the entire apparatus rests on just three basic concepts: the statement connective “not both . . . and _____” “for all x ” (“ (x) ” for short) and “ $=$ ”. There is controversy regarding the second of these concepts. One view has it that

- (1) A universally quantified statement $(x) A$, is true just in case every object satisfies A .

This is the referential view. Another view has it that

- (2) A universally quantified statement, $(x) A$, is true just in case every substitutive instance of A is true.

This is the substitutional view.

You may think that the distinction between (1) and (2) is trivial. You would be wrong. Consider the innocuous claim

- (3) $(Ex) x > 0$

“Something is greater than 0.” The quantifier “ (Ex) ” is defined as “not (x) not.” This definition gives us these results. If you take (1) as your understanding of “ (x) ,” then (3) is true just in case there exists at least one object greater than 0. This means we have to admit the numbers greater than 0 into our ontology as actually existing! The mind boggles. If you take the substitutional view, all you have to say is that (3) is true just in case some sentence of the form “ $x > 0$ ” is true. And you can say this without thereby admitting that numbers actually exist.

At this point, one probably favors (2). But the problem is that there are good reasons for not adopting (2). A major contribution to the study of formal languages has been made by Alfred Tarski. Tarski proposed that any definition of the set of true sentences in a language, L , must be such that, for any sentences x and S , if S gives the truth conditions of x in L , then

$$x \text{ is true in } L \equiv S$$

should be derivable from the definition. This has been referred to in the literature as convention T. The use of convention T has led to some really remarkable work in the study of formal systems. Recently, it has been shown that, in the case of languages at least as rich as elementary number theory, convention T cannot be satisfied using (2). It can be satisfied only if (1) is adopted.

The defender of (2) can say: So much the worse for convention T. We simply have the challenge now of finding something in its place.

My purpose in this paper is to raise doubts as to whether it is worthwhile even to try to meet this challenge. I shall argue that the use of (2) allows defective formulation or sound principles. It should be rejected on these grounds alone.

I take as a starting point an argument recently proposed by Snyder (1971). Snyder argues that the absurdity, “All meaningless sentences are both true and false,” could be deduced from four very plausible principles, which he uses the following formulas to express.

- (4) $\vdash p \supset$ is true $\equiv p$
 (5) $\vdash p \supset$ is false $\equiv \neg p$
 (6) $\vdash p \supset$ is true $\supset \vdash p \supset$ is meaningful
 (7) $\vdash p \supset$ is false $\supset \vdash p \supset$ is meaningful.

The formulas tautologically imply

- (8) $\neg \vdash p \supset$ is meaningful $\supset \vdash p \supset$ is true & $\vdash p \supset$ is false.

Letting the letter “ p ” range over sentences (8) is supposed to symbolize “All meaningless sentences are both true and false.”

The basic problem with all this is traceable to the fact that “ $\vdash p \supset$ ” means “the result of putting p for the letter ‘ p ’ in ‘ p .’” That is,

- (9) $\vdash p \supset = p$.

Rewriting (4) and (5) in accordance with this fact yields

p is true $\equiv p$

p is false $\equiv \neg p$

which makes one doubt the interest of Snyder's deduction. Seen in this light, (4) and (5) have as instances notoriously ill-formed sentences (e.g., "Snow is white is true \equiv snow is white"). Of what interest, then, is Snyder's point?

The interest comes out when we seek other verbalizations of the principles that (4)–(8) are supposed to express. Suppose we adopt the substitutional view of quantification. Then the expressions we seek are these:

(10) $(p) (p \text{ is a sentence} \supset \cdot p \text{ is true} \equiv p)$

(11) $(p) (p \text{ is a sentence} \supset \cdot p \text{ is false} \equiv \neg p)$

(12) $(p) (p \text{ is a sentence} \& p \text{ is true} \cdot \supset p \text{ is meaningful})$

(13) $(p) (p \text{ is a sentence} \& p \text{ is false} \cdot \supset p \text{ is meaningful})$

These sentences entail

(14) $(p) (p \text{ is a sentence} \& \neg p \text{ is meaningful} \cdot \supset p \text{ is true} \& p \text{ is false})$

which is our new expression of "All meaningless sentences are both true and false."

Just how interesting or paradoxical it is that (14) follows from (10)–(13) depends upon how plausible one finds (10)–(13) to be. The latter set of sentences is certainly defective in some respect since it entails a sentence that is not true. Two options are open at this point. First, one might agree that (10)–(13) correctly express the relevant principles concerning meaningfulness, truth, and falsity; the defectiveness of (10)–(13) would then be traceable to these principles. Second, one might disagree that (10)–(13) correctly express the relevant principles; the defectiveness of (10)–(13) would then be traceable to the fact that we have used the substitution interpretation of the quantifiers in trying to express these principles.

I think the second explanation is the better one. To support this contention, I shall argue that plausible expressions of the four principles can be obtained using the referential interpretation of the quantifiers, and that, so expressed, the principles do not have the absurd result that all meaningless sentences are both true and false.

The expression of the first principle is this:

$(x) (x \text{ is a sentence} \supset \text{the result of putting } x \text{ for the letter "x" in "x is true"} \equiv x \text{ is a true sen-}$

tence).

Using quasi-quotation, this can be expressed less cumbersome:

(15) $(x) (x \text{ is a sentence} \supset \ulcorner \text{"x" is true} \equiv x \urcorner \text{ is a true sentence})$.

The rest of the principles are expressed as follows:

(16) $(x) (x \text{ is a sentence} \supset \ulcorner \text{"x" is false} \equiv \neg x \urcorner \text{ is a true sentence})$.

(17) $(x) (x \text{ is a sentence} \& x \text{ is true} \cdot \supset x \text{ is meaningful})$.

(18) $(x) (x \text{ is a sentence} \& x \text{ is false} \cdot \supset x \text{ is meaningful})$.

It is a simple matter to prove that

(19) $(x) (x \text{ is a sentence} \& \neg x \text{ is meaningful} \cdot \supset x \text{ is true} \& x \text{ is false})$.

does not follow from (15)–(18).

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DROUGHT AND THE MODEL OF A QUATERNARY TERRACE-CYCLE

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The concept of a "terrace-cycle" in the Quaternary history of the Central Great Plains was first proposed by us at the 1944 "Symposium on Loess," sponsored by this Academy (1945). However, certain aspects have never been fully presented, particularly (a) the relations of drought to this "terrace-cycle" concept and (b) as a recurrent phenomenon in this and similar continental regions. There also may be a possible relation to the fixation of sodium salts in vegetation and to selenium and nitrogen poisoning. Prediction requires scientific data not only from the near past, but also from the distant past. It is now obvious that erosional breaks in the younger valley-fills in the terrace sequence coincide with breaks in the cultural and faunal successions.

The research of two former Academy members—John E. Weaver and Harry E. Weakly, and their associates—has supplied much background on drought. Also, the works of Donald B. Lawrence (1958) and Edward G. Gibson (1973)—with respect to sunspot minima of the 11-year, sunspot cycle—seem to be very important in relation to glaciation as well as to drought.

† † †

INTRODUCTION

Drought is a topic of particular concern this year in Nebraska and in the many other drought-stricken regions of the world. The economic impact upon some counties in Nebraska and South Dakota has been devastating, perhaps the worst since the drought of the mid-1930's, so much so that many have been declared "disaster areas." Elsewhere, as in Britain and Russia and other parts of Europe, as well as in Asia and Africa, the effects have been even more disastrous, as we have read in newspaper and magazine accounts for many months.

Although the causes of drought remain as elusive as ever, facts are accumulating, and there seems to be increasing evidence suggesting that severe droughts are recurrent, that they are but aspects of more general climatic fluctuations, and that they, like glaciation, may be linked to the sunspot cycles. However, some lag effects are to be expected so prediction requires scientific data from both the near past and the distant past.

It is the latter with which we are here chiefly concerned, since Weakly (1962; Table I) has already summarized certain data on droughts in the Central Great Plains since the thirteenth century. Fortunately, careful study was given also to the drought of the mid-1930's in many papers and several

Table I:

Periods of Drought of Five or More Year's Duration,
Number of Year's Duration of Each Drought,
and Number of Years Between Each Drought
for a Period of 738 Years
at Ash Hollow, Garden County, Nebraska.*

First Year	Last Year	Duration of Drought	Years Between Droughts
<i>years</i>			
1220	1231	12	
1260	1272	13	29
1276	1313	38	3
1383	1388	6	33
1438	1455	18	16
1493	1498	6	38
1512	1529	18	13
1539	1564	26	10
1587	1605	19	23
1626	1630	5	20
1668	1675	8	38
1688	1707	20	13
1728	1732	5	21
1761	1773	13	29
1798	1803	6	26
1822	1832	11	25
1858	1866	9	25
1884	1895	12	18
1906	1913	8	10
1931	1940	10	17
1952	1957	6	11
Average		12.8	23.9

*From Weakly (1962), but see also Weakly *in* Champe (1946) and Roberts *in* Bandeen and Maran (1975).

books by John Weaver and associates. Although Harry E. Weakly and John E. Weaver, both deceased, were the pioneers in drought studies of this region, and also long-time members of this Academy, neither was really aware of the *geologic* importance of their work.

Following the drought and "dust-bowl" conditions of the mid-1930's, the view was widespread that the marginal land of western Nebraska and adjacent states should never again be plowed and that the Federal agencies should do something about this. In August, 1939, the Under-Secretary of Agriculture, Milburn L. Wilson, asked us to lead a field trip through western Nebraska to study the problem first-hand. On the excursion, we were able to demonstrate to Wilson and other leaders of the United States Department of Agriculture that drought was a recurrent phenomenon in the Great Plains and that agricultural practices were not primarily responsible.

Curiously, the same problem was vigorously discussed for this same region a century earlier. Even as late as 1878, the myth was widely held that "Rain Follows the Plow" (Smith, 1947). It was proposed chiefly here in Lincoln by Samuel Aughey of the Department of Geology, University of Nebraska, and by Charles Dana Wilber of Lincoln (Manley, 1967). Only slightly earlier, Aughey had advocated and then had given up the idea of Ferdinand V. Hayden, a noted geologist, who said that rainfall could be increased by the extensive planting of trees. In a sense, this proved to be a forerunner of the "Shelterbelt Project," unfortunately now largely abandoned at a time when there has been much destruction of timber, together with increased plowing and leveling associated with the development of pivotal irrigation. With prolonged drought and the inevitable, associated drop of the water table, an economic disaster would result.

The present symposium is the latest in a series of symposia and conferences treating of the changing climates of the Great Plains and Central Lowland, with particular regard to those of the Quaternary or Great Ice Age. [Quaternary includes both Pleistocene and Recent (Holocene), but frequently (perhaps correctly) Pleistocene and Quaternary are regarded as essentially synonymous. We may be still in the Great Ice Age!] The first of interest here, likewise sponsored by the Nebraska Academy of Sciences, was the "Symposium on Loess," held at Lincoln on May 6, 1944 and published a year later in the American Journal of Science. At that time, more than three decades ago, the concept of a "terrace-cycle" was introduced (Schultz and Stout, 1945); the principal illustration is reproduced here (Fig. 1).

THE QUATERNARY TERRACE-CYCLE

Figure 1 shows a climatic interpretation of a terrace-cycle, which may be summarized as follows. Following the onset of drought, soil almost ceases to develop, and the reduced, vegetative cover results in gullyng. Then, widespread colluviation and alluviation occur, accompanied by

deposition of loess (dust) on all available surfaces. As the drought wanes, the vegetative cover is largely restored, and soil-forming processes are resumed. This has been repeated several times since the Sangamon (say, in the last 90,000 years or so), but the illustration concerns only the post-Peorian episodes.

From this, it is deduced that the soil-forming times were characterized by plentiful moisture, equable spring and summer temperatures, and abundant vegetation—thus, the soils record the "good years." Conversely, the erosional or cutting episodes record the droughts, with reduced vegetative cover due to lessened moisture during the growing seasons, so that the infrequent "flash floods," accompanied by much dust, would be then most destructive. The thicker buried soils may be taken to record the longer "good times," just as the most prominent cutting episodes (unconformities) may note the longest droughts. In these considerations, the minor soils in the loess are less significant.

The observations were made chiefly in the loess-canyon areas, southeast of North Platte, in Lincoln County, Nebraska, and in the badlands of northwestern Nebraska and adjacent parts of South Dakota and Wyoming. These areas are strangely beautiful, and the loesses may be very thick.

It should have been evident from the data available even in 1944 that both the soil-forming and cutting episodes diminished in importance as one approaches the present. Also, we should have realized that each terrace-cycle was dominantly two-phased, but full recognition of both of these facts came slowly and somewhat later. If the erosion had always been of the same strength or intensity in the younger valley-fills, much or all of the preceding records would have been destroyed—just as the tides along the seashore remove much of the intertidal sediment.

Similarly, several other sets of observations came to play a part in our thinking and discussions and in conferences with colleagues, that were to lead progressively toward the development of a "model." Although documented in numerous publications (*see* References) that reflect some changes and even differences in interpretation, there was agreement on most points. The following discussion traces development of the most important considerations.

(1) An experiment was performed at the 1944 "Symposium on Loess," not mentioned in the published papers, that was profoundly to affect the "model." A block of "fresh" loess was placed in a flask filled with water, and in another flask also filled with water, a small block of soil that had been developed on loess was dropped. The "fresh" loess dissolved at once, like a piece of sugar, but it took many hours for the soil to break down. This experiment showed clearly that soil anchors the loess, holding it much as the lid on a tomb, but when this vegetative mat is destroyed, the loess erodes quickly, like the rapid destruction of the "mummy" exposed when a tomb is opened.

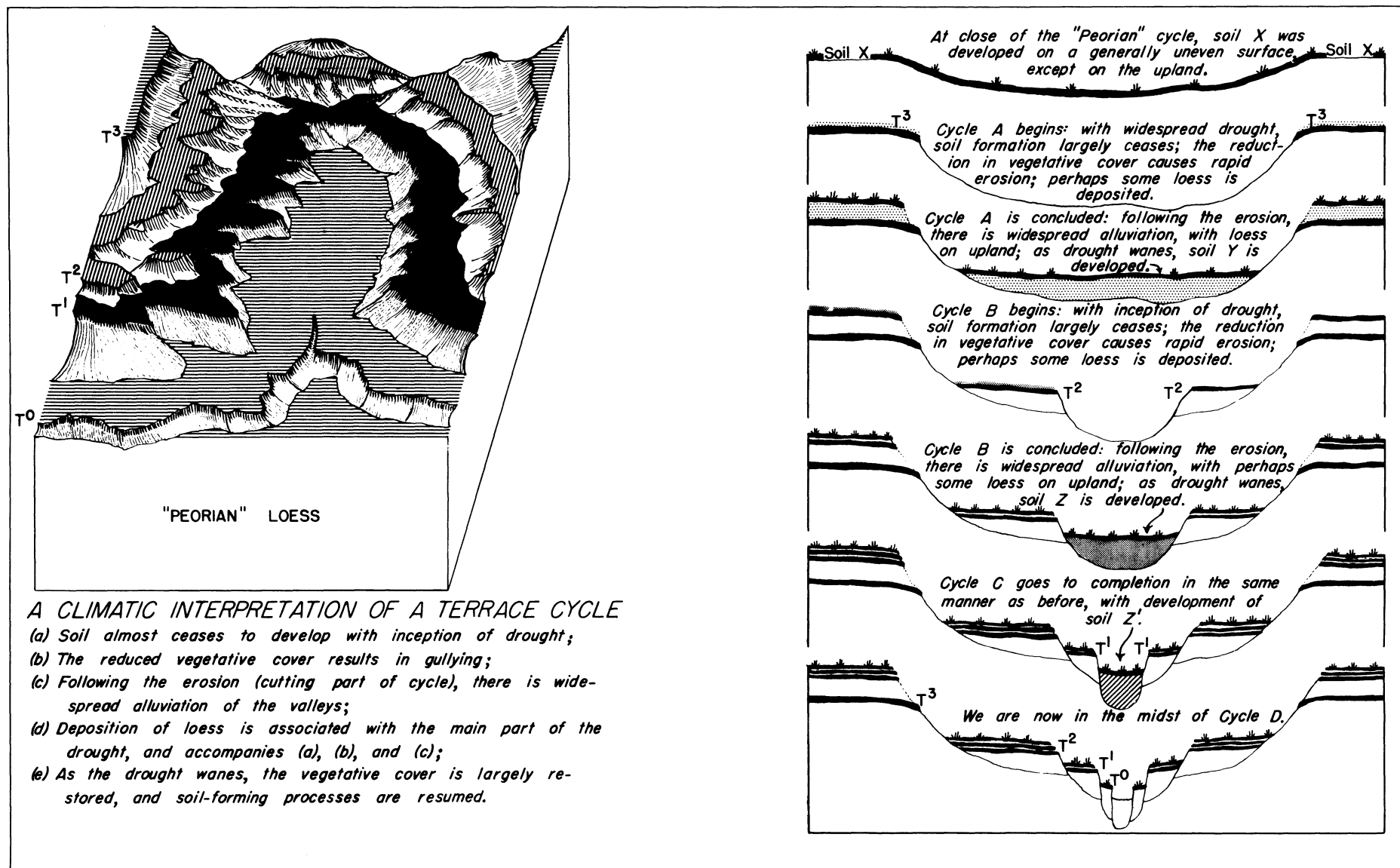


Figure 1. The sequence of events of younger (post-Peoria) terrace development in the loess-canyon area in Lincoln County, Nebraska, and the concept of a terrace-cycle. These terraces (valley-fills) are in the thickest loess region of North America.

(2) At the same symposium, Frank L. Duley (1945: 278) reported on the results of other experiments by the staffs of the Soil Conservation Service, United States Department of Agriculture, and of the Nebraska Agricultural Experiment Station, University of Nebraska. These stressed the importance of a plant or straw-mulch cover in reducing erosion and increasing intake from rain or snow:

Tests were made in both field and laboratory to determine the infiltration rate for loessial soils. The results indicated that when these soils are bare they seal over during rains and have their intake rate reduced in the same way as other soils. The intake rate can be greatly increased by covering the surface with a straw mulch. The effect of the mulch was much less on the raw, parent material of the Peorian loess, due to the fact that it had not developed as stable structure as has the surface soil. This absence of a well developed structure and shortage of binding material also leads to excessive erosion on this soil.

(3) Very early in these studies (by 1933), the erosional breaks (unconformities) in the younger valley-fills were recognized to coincide with the gaps or breaks in the cultural and faunal successions. This seems to have been confirmed by radiocarbon dates, as they have become available, even though some corrections of such dates may be necessary (Ralph and Michael, 1974; Rafter, 1975). The hiatus is rarely bridged.

(4) These same younger valley-fills, designated as terraces above the modern floodplain (T^0 , T^1 , T^2 , T^3), were studied regionally by us, partly because of the intriguing problems associated with dating both the coming of Man to North America and the extinction of many of the large mammals of the Great Ice Age. The apparent near coincidence of these events has led Paul Martin (1973) to the startling conclusion that when the First Americans arrived in North America (by way of the Bering Straits' Land Bridge probably at least some 11,000 to 12,000 years ago), they exterminated such spectacular mammals as the mammoths in perhaps a thousand years in their progress through North and South America to the tip of South America. But he has ignored the possible effects of drought and cold, for these seem to have been at least partly responsible in some earlier animal and plant extinctions, when Man could not possibly have been involved.

(5) Expressed in terms of the valley-fill sequence, this particular extinction occurred approximately in the middle of the second valley-fill above the floodplain (Terrace-2, T^2), where a significant erosional break (unconformity) occurs (Schultz, 1938; Schultz and Stout, 1945, 1948; Schultz, Lueninghoener, and Frankforter, 1948). This divides that valley-fill into older and younger parts, designated respectively as fills 2-B and 2-A. This would correspond to the "substratum" and "topstratum" (Fisk and McFarlan, 1955; Akers

and Holck, 1957) of the Lower Mississippi, as projected into the Central Great Plains (Stout, 1971, 1973; Stout and others, 1965, 1971).

(6) The relationship of this unconformity in the Terrace-2 (Kersey) valley-fill to conditions marginal to the great continental ice mass of that time is of considerable interest. It would seem that several times before the "extinction" of 11,000 to 12,000 years ago, and at least once after, we can picture the ice-cliff that marked the edge of the interior ice as stabilized along or near the present boundary of northeastern Nebraska and South Dakota (the Missouri River). In gravel pits of about that age range (say even as late as 7,500 years ago) near Yankton, South Dakota, the remains of caribou occur frequently, suggesting that tundra conditions may have been present at that time marginal to the ice. However, both musk-ox and caribou specimens are found commonly in many parts of Nebraska (but mostly assigned to earlier times in the Quaternary), so that we must visualize Nebraska as having been tundra-like many times during the Quaternary or Great Ice Age.

(7) Thus, we must conclude that long, hard winters and short summers were probably normal for glacial times, when the inland ice mass was covering parts of Nebraska and adjacent states. Likewise, conditions in interglacial and the even shorter interstadial times must have been more like the present, when we were far from the great ice masses. In both times of glaciation and interglaciation, however, Nebraska, at least formerly, must have had its climates dominated by the ice masses—for which the term *periglacial* is proper.

(8) Returning to our subject of droughts, it seems inescapable that these were also more severe at times in the past than even the drought of the mid-1930's. This is recorded by the major cutting-episodes (unconformities), but the drought of the 1930's allows us to understand the mechanism associated with such erosion.

DROUGHT AND RECOVERY

Figure 2 illustrates much of the previous discussion. We may consider that before the onset of a drought like that of the mid-1930's, there would have been a good vegetative cover over a unit plot. Many kinds of prairie grasses and other *native* prairie plants, some with very deep and intricate root systems, would have been present, and, supposedly, many individuals of each kind. With the reduction of moisture, this plant cover would have been reduced, so that gullies would have worked headward, cutting through the soil and into the loess. Some, or even most, of the plants would have been covered by dust (loess), but eventually colluviation and alluviation would have dominated. As the drought waned, the plant cover would have been restored.

For other types of vegetation, such as along well-wooded slopes and river valleys, the drought would also have taken its

DROUGHT AND RECOVERY

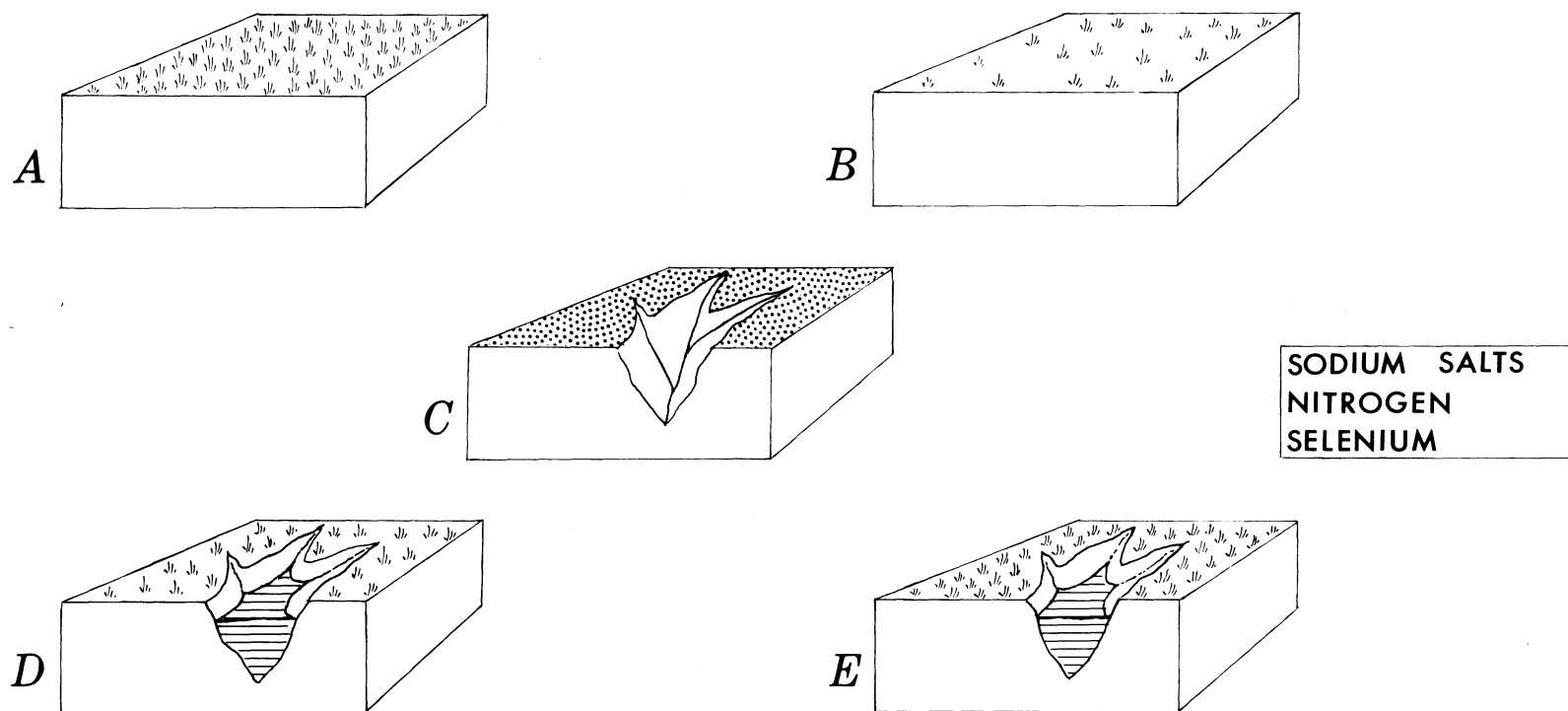


Figure 2. Drought and recovery. *A*, before drought; *B*, inception of drought; *C*, "gulying" and "dusting"; *D*, alluviation and colluviation; and *E*, recovery. For discussion of fixation of sodium salts, and selenium and nitrogen poisoning, see text.

toll in the reduced growth or even destruction of trees. And many of us can remember the great swarms of grasshoppers (Dick, 1975:191-215) and the dust storms of the 1930's.

Now, let us consider some other factors, such as the fixation of sodium salts, and also the concentration of nitrogen or selenium in some of the plants that, at the height of the drought, would have been almost the only plants left available to the grazers. For example, in the mid-1930's we were collecting fossils in the Big Badlands, near Scenic, South Dakota, when thousands of cattle were driven into Scenic to be slaughtered because of the extreme selenium poisoning. The problem of selenium concentration ("Alkali Disease") has been discussed adequately for the Cretaceous (Pierre and Niobrara formations) of South Dakota by Moxon, Olson, and Searight (1939), and we have been told of the same problem having been encountered with respect to Cretaceous shales in Ireland. As regards concentration of sodium salts and nitrogen fixation, we can only refer to the literature (Lawrence, 1958; Kamen, 1953; and Delwiche *in* Hutchinson, 1970; Brill, 1977).

Such associated effects of drought, together with temperature, may be factors in earlier extinctions, such as the extinction of the dinosaurs. We have seen in southern France the great numbers of dinosaur eggs that have been preserved unhatched. These are found at several recurrent levels in the Cretaceous succession of that region, but most notably, at the end of the Cretaceous, when cold is now thought to have been responsible. Parenthetically, this was the time when there was also notable terrestrial plant extinction, as well as significant planktonic extinction, and also the disappearance of the last ammonites and certain marine reptiles, clams, rudistids, and other animals. Disturbances in the food-chain, possibly related to the nitrogen-cycle and temperature, may be inferred.

Similarly, the great extinctions of certain mammals in the Central Great Plains at the end of Ogallala (Pliocene), Hemingford (Late Miocene), Arikaree (Early Miocene), and White River (Oligocene) times lead us to suggest climatic changes as possible factors. Droughts and glaciations, thus, may be far more common in the geologic record than has been previously supposed. Perhaps droughts, as well as glaciations, are but a part of normal climatic rhythms, possibly to be associated with cyclic advances and retreats of the sea (glacio-eustasy) and, ultimately, with the solar mechanism.

DROUGHT, GLACIATION, AND SUNSPOTS

According to a recent summary (Damon and Kunen, 1976:452), global cooling trends in high northern latitudes of the Northern Hemisphere may be out of phase with a warming trend at high latitudes in the Southern Hemisphere. Even though the nature and prediction of climatic changes are not yet on a firm scientific basis (Mason, 1976), certain data suggest a linkage between sunspot number and glacial advances and retreats.

For example, the botanist Donald Lawrence (1950a-b; 1951; 1958) has been able to date the recessional moraines (stagnation periods) for certain Alaskan glaciers by use of tree-rings of certain large trees on the successive moraines. The moraines generally record stagnation or melting at about 11-year intervals, which Lawrence related to the sunspot cycles, possibly to sunspot minima. He even found in the pattern of moraines evidence of the period of reduced sunspots, the "Maunder Phenomenon" (Eddy, 1976). Similar minor morainic patterns have been described by Gwynne (1951) in association with the last retreat of the great ice mass from South Dakota and Minnesota.

Although earlier sunspot literature (Abbot, 1956; Lawrence, 1958) emphasized sunspot cycles of 22 3/4 years (273 months), the latest compendium (Gibson, 1973: Figs. 2-22, 2-23) on "The Quiet Sun" shows such regularity of 11-year cycles that reasonable prediction of sunspot minima and maxima can be made. It is of especial interest that Solar Cycle 20 began with a sunspot minimum in October, 1964 and was predicted to end in about October, 1975. It is not yet certain that our present drought has occurred in relation to the sunspot minimum, for there is always the possibility of lag effects, but the evidence is suggestive. It is often difficult to select important data from unimportant, but once in a while, biological phenomena also may reflect the sunspot cycle (J. Gribbin *in* Rosenberg and Runcorn, 1973:413-425). One extraordinary example is furnished by the late Frank Peabody (1958), who noted that the growth zones of a bullsnake recorded a Kansas drought.

We are on a somewhat firmer basis for relating glaciations and the up-and-down movements of the sea (transgressions and regressions), at least for the Quaternary, when the melting of the great ice masses caused the sea to rise (or to fall as the ice accumulated in such places as Antarctica). It seems that glacial maxima are recorded in the terrace-cycle (previously discussed) by erosional episodes, for the sand-and-gravel fillings in at least the basal portions of the valley-fills surely represent outwash deposits or their equivalents. But, as we have seen, it is the soils that must record the interglacial and interstadial episodes of the Quaternary.

Soils, likewise, are to be found in the pre-Quaternary rocks of the Central Great Plains at many horizons, even on the surface of the basement, beneath Late Cambrian marine sediments (Reed, 1954). In the Late Carboniferous and "Permian" successions, the soils are similar to those described in the Triassic of Germany (Gwinner, 1955; Ortlam, 1966) as "violet horizons" or red-beds, and these are also associated with cyclic sedimentation. Each of the eighteen, larger cycles (megacyclothems or stages) so far studied in these Carboniferous and "Permian" sediments of the Northern Midcontinent seems to be like the Quaternary, with six couplet-cyclothems, recording numerous episodes of regression and transgression that are probably glacio-eustatic. Since cyclic sedimentation is the *normal* sedimentation for the shallow epicontinental

(epeiric) seas of the past (Hölder, 1960:449), it is reasonable to postulate that the Quaternary "model" is widely, if not globally, applicable for much, if not all, of the geologic record.

SUMMARY: MODEL OF A TERRACE-CYCLE

In conclusion, it seems to us that this region, of which Nebraska is a part, has been characterized throughout much, or possibly all, of its presently-known geologic history—even from early in the Paleozoic—by alternations of climate. In earlier times, the sea often came in over the land and then retreated, the best explanation (especially for the Carboniferous and "Permian") being glacio-eustasy, when the expansion of ice sheets in remote regions may have caused the global ocean to fall, and with melting, to rise. In later times, we were here far from the sea, but seemingly always influenced by climate, probably in a cyclic pattern (stages) essentially like that of the Quaternary, but less prominently or dramatically effective.

ACKNOWLEDGMENTS

Many persons, including students, have contributed to the ideas here presented, and although we assume complete responsibility for them, we would like especially to express our indebtedness to many long-time colleagues: Lloyd G. Tanner, Gilbert C. Lueninghoener, Weldon Frankforter, Larry Martin, John Hillerud, Alfred J.J. Holck, R. George Corner, Duane Eversoll, Karen and Charles Messenger, and the late Alvin Lugin.

This paper was initially a contribution to the Bicentennial Symposium, "Our Changing Climate Since 1776," sponsored by the Institute for Tertiary-Quaternary Studies (TERQUA) of the Nebraska Academy of Sciences on April 23, 1976.

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1975 MAIBEN LECTURE

SHOULD WE KILL THE RATS OR IS BIOLOGICAL CONTROL PREFERABLE?

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These questions are becoming more controversial in recent debates which have emerged from new realizations of rodent impact on health, conservation, and economy. The controversy, coupled with widespread evidence of genetic resistance, bait aversion, and other modes of adaptive behavior and physiology displayed by rodent pests, represents a new appreciation for one of man's most persistent problems. Old World rodents live in commensal association with man and his domestic animals. These rodents include black rats (sometimes called roof rats), Norway rats (sometimes called brown rats, sewer rats, wharf rats), and Old World (house) mice. Of the three types of Old World rodents, the most feared and successful are Norway rats, which are eminently bound by the habits of man and which have been well provided for by man. An interesting and readable account of rat association with man (Zinsser's *Rats' Life and History*) relates the episode of disease and destruction which began when these pests adopted their commensal association with man and moved from Central Asia to all regions of the earth, except the Arctic, sub-Arctic, and Antarctic zones. Since about the time of the Crusades, man has made a considered effort to wage war against house mice, roof rats, and alley rats. Still, these species maintain healthy populations throughout the world, despite human efforts to eradicate them by trapping, release of predators, shooting, poison baiting, bacteriological warfare, and the use of poison gas. Thus far, only destruction of the harborage that provides housing for rats and the storing of food supplies in rat-proof containers have denied rats their cohabitation with man. Unfortunately, total elimination of rat harborage is rarely possible so that there are always large reservoir populations of the pests nearby. They invade and infest wide areas whenever conditions become favorable. Better sanitation, food and debris storage, and disposal and clean-up campaigns are essential to rat control. Yet, some situations cannot be corrected for economic reasons. Even in the United States we have the persistent problem of broken storm and sanitary sewers and a lack of rat-proof grain storage in many areas. In the United States there is probably at least one rat for every human being; in other parts of the world where grain storage and sanitation are not as sophisticated as ours, there may be 25 to 50 rats for every human being. Portions of Asia and Africa undoubtedly have huge reservoirs of rats; the most troublesome of these is the Norway

rat because of his aggressive and adaptive behavior.

Let us examine for a moment some of the public health problems that we face as a result of rat infestation. In the United States, about 14,000 rat bites per year are reported. Usually, such bites are inflicted in slum areas and afflict the young and the elderly, those who are helpless. Many more rat bites undoubtedly go unreported to Public Health authorities. Rats do not bite because they are enraged, but, rather, to consume. Although the case is cruel, it needs to be pointed out as a potential health hazard directly inflicted by these pests. In addition, rats are potential carriers of diseases; some diseases are borne by the ectoparasites carried on the animal's body. One such parasite—the Egyptian rat flea—spreads “pasteurella” organisms that cause bubonic plague. More common diseases borne by rats include leptospirosis, salmonellosis, typhus, hepatitis, tuleremia, hemorrhagic jaundice, poliomyelitis, trichinosis, and Lassa fever. The latter, appearing in African countries, is a particular variation of a lethal virus infection. Since rats can transmit these diseases via their urine and feces in food stores in which they have been feeding, huge stores of grain are destroyed on evidence of rat feces or fur in the grain. The economic cost of rat-borne disease in terms of medical attention required, drugs administered, and work lost is most difficult to estimate.

On the world scale, another public health problem results from grain and food consumption by rodent pests. There is an ever-growing awareness that the world grain used is presently at the limits of production so that because of political, logistical, and supply problems, much of the world's population has already begun to starve. It is noteworthy that in some portions of the world more than 50% of the grain crop (stored or planted) is consumed by rodent pests. Ten percent of the grain crop in the United States is presently lost to rats. Of the grain shipped and grown in other parts of the world, 40 to 90% goes to rats. The worst ravages are in countries like India, Bangladesh, and certain portions of Africa. Before one examines the present world food supplies, he must note that in our present situation much of the world population is below the 2000 calorie level on a per capita base. If we examine the impact of population in terms of tons of grain presently utilized and projected for 1985, we will

note that there will be some increase in food production, but it will barely keep pace, if not fall behind, the human reproductive rate. The present human cereal requirements (based on the World Health Organization estimate of 311 kg./capita base) is in the order of 1.38 billion tons. In 1985 we will require 1.63 billion tons. Conservative estimates of rodent waste (40%) are presently in the order of 0.5 billion tons of grain consumed or destroyed by rodents. By 1985, at the present rate of rodent destruction, we anticipate that 0.7 billion tons of grain will be wasted by rodent contamination and feeding. If we were to provide rodent control at 2% of the present world numbers, we would have a deficiency today, but by 1985 (with increased productivity brought about by new strains of grain and projected new land brought into production), we would be slightly above the world demand. In the United States alone, in the order of 25 million dollars worth of grain is eaten by rats; rat associated destruction is estimated to be in the order of 1 to 3 billion dollars a year. This economic impact is added to by loss of productivity and energy waste which result from a lack of conservation in food production as well as from the impact of chronic enteric disease on human populations and animal production.

In view of the drastic impact and a potential disaster which might be inflicted by rodent plagues, why is it that man has not been able to reduce rodent numbers below 35 billion? Rats are extremely intelligent and display unusual modes of physiological and behavioral adaptation. Interestingly enough, rat populations grow into just the carrying capacity of space and food available; approximately the animal's body weight in food is eaten on a weekly basis. This means that about 250-400 gms. of grain and of water per week are required to maintain an adult rat; the food requirements for these animals increase as pregnancy and lactation are added to female metabolic costs. Limitations in space or food tend to limit population. These limitations are probably brought on by density effects and intraspecific strife. A high degree of social order in rat colonies speaks to a regulation of reproductive rate under saturated density conditions which just meets the mortality losses. When animals are in saturated density conditions, two critical events tend to occur. The breeding members of the population are primarily restricted to a few dominant males and high-ranking females. This mode of behavioral regulation in breeding extends even to the physiology of the species in that juvenile emergence and high-density, stress-induced effects not only increase the mortality rate of the population, but actually interfere with reproductive development and cause regression of rat sex organs and accessories. At the same time, high densities affect reproduction and the ravages of disease are more pronounced so that a substantial attrition takes place in natural rat population during the year. This attrition varies from a mortality rate of 10 to 20% per month. Interestingly enough, when predators are introduced to rat populations, the effects of predation are not to control numbers but to reduce the number of diseased and socially subordinate animals. The ravages of extreme climate, too, affect mortality rates so that mortalities are higher in the

winter than in the summer in our region of the hemisphere.

The following illustrates some of our observations with reference to rat population growth in this region. Rat growth rate and rat food consumption rates are nearly equivalent. An expansion into the space provided occurs when food is provided in abundance; when a maximal population level is reached, it is maintained at essentially stable numerical levels. There is seasonal breeding in this portion of the hemisphere where winter cold and short photoperiod affect reproduction. A seasonal success rate with reference to colonization occurs; that is, new colonies can readily be formed in the wild during the spring and summer, but not so readily in the winter. There is a seasonal incidence of high fertility even in dense populations; a spring surge in reproduction is followed by a reproductive slump in the summer as the juveniles begin to assume adult pelage and to compete as mature, aggressive adults. There is a seasonal variation in endocrine function, particularly evidenced by adrenal secretion, sex hormone secretion, and reproductive tissue response. Moreover, as illustrated by renal pathologies, a seasonal variation in the severity and frequency of pathology occurs. With reference to daily activities, cold temperature modulates activity downward, but even in warmer times, there appears to be a distribution of forage habits so that preferred times of day are taken by the dominant animals, and less preferred times of day by subordinate animals. Reducing the population number by poisoning, trapping, shooting, or natural disaster tends to initiate the recruitment of breeders in the population so that reproductive rebound is a common phenomenon contributing to population recovery. This release of inhibition when densities are lowered may be effective in new colonization patterns as well.

In addition to the aforementioned behavioral and physiological capacity, some additional traits are noteworthy among rodents, particularly among Norway rats. These animals show additional kinds of adaptation; genetic adaptations have appeared with reference to resistance to the lethal effects of an anticoagulant (Warfarin). The development of Warfarin resistance in Europe has been known for some time, and Warfarin-resistant colonies of rats have been discovered by Jackson in various parts of the United States as well. Such Warfarin resistance results from genetic selection and could be overcome by using analogs of the dicumarol drugs. Owing largely to the delayed effects of the drug, Warfarin has been one of the more successful verminicides. The relative safety of Warfarin is attributed to its favorable toxic ratio, that is, rats generally are more susceptible to Warfarin poison than other species. A more immediate problem for rat control is the behavioral adaptation of rodents. The extreme intelligence of these animals speaks to an association of illness with the ingestion of foods that bear poison. It is believed that rats can associate illness with a poison bait and will not take that bait again. Although the evidence is somewhat controversial, generally speaking, in experimental trials where rats have associated illness with a particular bait, they will not take that bait even though the toxicant is not mixed with the bait

carrier. Some toxicants, on the other hand, have taste in themselves so that rats will not only avoid the bait which originally brought on illness, but will associate the flavor of the toxicant with illness, so that alternate bait forms cannot be used. If the toxicant and its flavor can be masked in baits, then bait substitution (as suggested by Chitty) is a workable device for getting a second take. Whether rats can be induced to retake baits by retraining toward a particular bait which is not carrying the toxicant is an open question. Certainly, there have been evidences that following sub-lethal poisonings with red squill, baits containing red squill would not be taken even a year later. This visceral learning of food preference with reference to bait toxicity is a poorly understood phenomenon. Wild rats do display a general level of central nervous system excitement and wariness not prominent among their domestic cousins so that such behavioral tests conducted in the laboratory may not be altogether representative of the sharpened sensory abilities of wild rats. In addition to the animals' intelligence which modifies their learning capabilities so that toxic circumstances are avoided, they must in some way also impart information to their cohorts. Aversions to toxic baits taken by the mother are also shown by offspring as well as by some other cohorts. Whether such aversions are learned via scent markings or result from changes in the mother's milk and behavior remain open questions.

Let us turn now to the chemical warfare which has been waged against rats. If we are to use toxicants to kill the rat, then we should be able to accomplish the kill with a single dose. While single-dose toxicants are effective in rat control, their action should be delayed somewhat so that association with toxicity is not as likely to be made when rats do not take the killing dose. The oldest of the toxicants used is arsenic. This substance is single-dose effective, is accepted fairly well but reaccepted very poorly. Like all of the inorganic toxicants, arsenic is a broad spectrum toxicant which has no target specificity. Arsenic can only be used in specialized situations which require special handling and special knowledge. Because arsenic does provide some taste, rats develop tolerance both on a physiological and on a behavioral level. Extremely toxic fluoracetates which are very effective in single doses are so toxic that only minute quantities need be taken. Of the organic toxicants, strychnine, red squill, chlorolose, and Warfarin have all been used. The mechanisms of action of these drugs are all quite different. The safest of these is Warfarin. Norbormide is also a relatively safe drug. Bait acceptance is best with Warfarin, re-acceptance is good, and there is a very good target specificity for rodents. The animals do, however, as we pointed out earlier, develop genetic resistance to this anticoagulant drug. Because of the extreme toxicity of some of these compounds, a series of risks needs to be tabulated. There is a very high risk with the use of arsenic (for example) in that the effective dose in rats (1 mg./kg.) is much higher than the lethal dose for humans. On the other hand, if we compare Warfarin, the effective dose for rats is several orders of magnitude lower than the lethal dose for humans. There is a moderate risk to desirable wildlife

and humans with the use of Warfarin in that accidental consumption only of large doses of this anticoagulant could cause death. Norbormide also seems to be moderately safe to use. The way in which red squill is made safe is to mix it with an emetic so that if pets or humans take the drug accidentally, they will vomit; rats do not have the vomiting reflex.

Biological warfare, too, has been tried by man as a rodent control measure. Of the early biologicals used, infections were most often introduced in the rat colonies. Rats now are reasonably resistant to typhus and carry the disease long enough to transmit it to man. Leptospirosis and salmonellosis also have been introduced in rat populations and have had immediate but transient effects on reducing rat numbers. Rats now chronically carry these diseases. Efforts to control rats by imposing bounties and by using weapons are very similar to efforts at introducing predators. The difference between bounty methods, shooting or trapping, and the predator method is that the predator which is introduced may opt for other prey. All these methods have a tendency to maintain low populations once the population has been brought down; but usually clean up only those members of the population disadvantaged by reason of age or social status or disease.

Several new approaches to rat control have recently been tried. Some of these approaches involve the design of new toxicants which rats are not genetically resistant to and which are single-dose effective. Microencapsulation of the drugs can prolong organ action until long after the meal is taken. Examples of such toxicants include new anticoagulants which are analogs of Warfarin and vitamins involved in the metabolism of vital organs. Vacore, a recently announced product, is an example of these. In addition, genetic sterilization by the introduction of lethal genes into the population appears to be a promising mode of control. Nonetheless, the social life of rats is such that foreign animals introduced into a population are very likely not to survive. An experiment done in Baltimore by Christian, Davis, Calhoun and Richter did involve introducing manually sterilized, vasectomized and ovariectomized rats into resident populations. Nonresidents were either driven off or killed. Therefore, the introduction of aggressive, sterile, lethal-gene-carrying rodents into populations has some major obstacles to overcome.

The promise of utilizing chemosterilant or birth control methods for controlling rodent populations remains. Human birth control agents (provera, mestranol) have been tried, but since these agents required constant doses to suppress estrus, and since they carry some undesirable taste, they have not been thought to be commercially feasible. Depoprovera, a broad spectrum reproductive suppressant which acts on females, may eventually be developed to some level of efficacy. The advantage in reproductive control stems from two features of rat populations: (1) The high mortality rate seen in natural populations would eliminate the population where reproduction not maintained at a fairly high level; (2) Toxi-

cants and killing methods, while they will reduce rat numbers, will release an inhibition caused by density factors and promote reproduction and recovery of the population if all animals are not killed.

Chemosterilant methods, similar to those used for control of insect populations, were suggested sometime back by Knippling and by Davis. Knippling's calculations represented on a theoretical basis the time it would require for a rebound to take place if a 70% kill were managed; recovery would occur within three generations. The same calculations indicated that sterilization of both sexes would reduce the number of the same population for twelve generations. Certainly, if there were any nonsterile members of the population present, we would anticipate some gradual recovery after reproductive inhibition. However, if killing *and* reproductive inhibition could be accomplished, the rebound effect would not be possible. Our own calculations based upon effective sterilization of various portions of the population are presented in the following illustration. Within the breeding periods evident in this portion of the United States, we can expect up to a 300% increase of population numbers within a six-month period. Where the breeding season is longer, we would anticipate an even greater increase as theoretically possible if space and food were not limiting factors. The growth rate of partially sterilized populations is much lower. On the basis of these calculations and on some preliminary trials in Calhoun pens, we began to implement field studies which tested a new chemosterilant, U-5897. This drug is simple chlorhydrin and had been used as an antihypertensive agent. Ericsson discovered, serendipitously, its sterilant effect on the Norway rat. The drug does show transient antifertility effects in several species but shows permanent sterilization effects in the Norway rat. These effects are accomplished by caput epididymal lesions and are specific to the Norway rat. The drug is effective in a single oral dose and has a permanent lesioning capability. It does not, however, interfere with androgen production, so important to a social status integration of dominant male rats in natural populations. With a single oral dose, the population in an isolated quarry was reduced first by the toxic effects of the drug; the rats took more of the drug than we had anticipated. Second, the drug prevented reproductive rebound. Repeated trapping yielded no pregnant females, no juveniles, but lesioned males. About 90% of the population was rendered sterile with the initial dose.

Several of the other dump trials provided similar successes, but because immigration was possible, these dump settings require a second dose of drug to be given at least once a year (preferably twice a year) during the breeding spurts that we mentioned earlier. We attempted the use of this drug in the sewer system in Ralston, Nebraska. Cooperation of the City Council and citizens of the City of Ralston made these trials possible. The Ralston community had a dramatic rat episode during the summer of 1973. In 1974, after we had reduced the neighborhood hazard by major clean-up cam-

paigns and some poison, we began to treat the sewer system in the older portion of this city. These sewers have breaks in them which provide ideal harborage for reservoir populations of the rats. Our census indicated that approximately 700 rats were in the system. Following a treatment with U-5897, we again had both lethal and antifertility effects. The rate of reinfestation of the city (by the pattern of census) was confined to the immigrants from the outside, rather than as the result of population increase from reproduction. Several field trials have consistently lowered and maintained low populations of the rats for more than six months. Such an effect dramatically illustrates that reproductive rebound was overcome with the use of this particular drug.

While U-5897 is only a beginning to antifertility control of problem rat infestation, and while antifertility methods have to be applied on an area-wide basis to be effective, we believe that our field trials show that use of such methods is a practicable matter. We are hoping that with the cooperation of the Upjohn Company and the World Health Organization these trials can be implemented on a wider scale throughout the world. U-5897 represents one additional approach to rat control. It complements a limited arsenal of methods which employ chemical and biological techniques for rat eradication. Since the rat is such a wily and intelligent creature, it is unlikely that populations will be totally eradicated. Nonetheless, if rats could be managed at 2% of the present level, enough food conservation could be achieved to feed the increasing hungry mouths of humans in the world.

We believe that careful attention to sanitation, to food storage, and to general neighborhood and yard cleanliness is the best answer to rat control. In situations where pests crop out and emerge in plague proportions, in situations where it is economically difficult to achieve ideal storage and sanitation conditions, we believe the methods we have begun to develop will be helpful. At a time when conservation of resources is not just a matter of aesthetic desirability but of essential survival, we believe that better, more diversified and efficacious methods of rodent control need to be sought. These methods collectively can be used to treat a social disease—human carelessness. Since man's provisions are necessary for the survival of the rat, we must attempt to curb man's carelessness. Yet, undoing all of man's bad habits is unlikely for economic and social reasons; therefore, we believe that in regulating rodent population members at lower levels we must employ techniques similar to those used by the rodents themselves. Such methods have the advantage of stemming off immigration from the outside and of protecting the public from the economic, food, and health hazards of pest proliferation.

Like most other studies, this one began as a result of serendipity. The study's progress has been the result of patient observation, hard work, and a conviction that new information would be valuable to our understanding of rodent populations in general and would be applicable to rodent control specifi-

cally. We, like Richter, were reluctant rat catchers. But, we have learned from this intelligent, fastidious little animal about the management of its social affairs and even its physiological economies. We have only begun to understand the biology of this animal and the impact that chemical and biological warfare can have in its management. We believe that a deeper understanding of the habits and physiology of this little beast would be invaluable to the protection of resources so needed by the human population.

ACKNOWLEDGMENTS

I would be most remiss were I not to acknowledge the help of my collaborators, especially Dr. Robert Belknap; my colleague and my students and assistants, Kathleen Ryan, Ed Keenan, Ed Christenson, Megan Kline, Lynne Farr, John Southard, Ron Strohbehn; and many others. I, too, am grateful for the support provided us in the initiation of our studies by the Bureau of Environmental and Community Health Management, by the National Science Foundation, and by Upjohn Company. We believe that the funds invested have produced not only academic manuscripts and basic understanding, but also an insight and potential for solving an important human problem. The proper and appropriate management of rat species, like any other pest management, can contribute not only to human welfare, but also provide a healthier ecology. Pest species are ecologically destructive, and their management provides for more desirable forms of wildlife.

1976 MAIBEN LECTURE

A REVIEW OF THE EVIDENCE FOR ABORIGINAL AGRICULTURE WITH SPECIAL REFERENCE TO THE NEBRASKA AREA

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Many of us, particularly in this bicentennial time, hear many references to pioneers, civilization, and farmers, often with such references directed in the Plains area to people who have inhabited the area for a period of less than two hundred years.

I'm sure that we are all aware that there were earlier Indian pioneers, at least ten thousand years ago. "Civilization" and "culture" are both somewhat vague terms, meaning different things to different people. There can be little doubt that the American Indian possessed the ability to adapt readily to the Plains environment, just as the later white settler had to adapt to survive. In historic times, such tribes as the Dakota Sioux and the Cheyenne, in moving west to the Plains, greatly changed their lifestyles.

The area that I would like to review in somewhat greater detail is that of agriculture, or more specifically horticulture. Every school child is aware that our ancestors received many of our present plant products from Indian sources. Such a list is long and diversified and ranges from tobacco to corn.

At the dawn of Nebraska's written history of the early 1800's, there are considerable data on the various tribes who came into contact with representatives of the U.S. government. Among these representatives were members of the Lewis and Clark expedition of 1804-1806, the Lieutenant Zebulon Pike party of 1806, and the Major Stephen H. Long expedition of 1819-1820. Some of this information relates to horticultural products and processes and is relatively well documented. Common to their references of native crops are maize, beans, pumpkins, and squash.

Although maize was important in the subsistence of all tribes, it held a very special significance to the Pawnee. Corn was their mother; it was important in their rituals and in their mythology, even more so than the buffalo. Two ears of corn went into the sacred bundles of the tribe and were renewed annually (Dorsey, 1904:20). Some of the most important ceremonies—including the sacrifice of a maiden to the Morning Star by the Skidi—were directed as much toward securing a bountiful corn crop as toward success on the bison hunt.

It may be appropriate to comment briefly on the methods used by the Pawnee and other historic tribes in gardening activities. The cultivated fields were small, seldom more than an acre. They were usually in the flood plain at the mouth of a ravine, where the soil was fertile with increased moisture. The field work was, for the most part, carried on by the women, with the men providing some guard service as needed. The corn was planted in hills, with the primary garden tool being a hoe, fashioned from a shoulder blade of a buffalo. I have found no references to artificial fertilizers. Historic records indicating irrigation are also lacking for the Nebraska area. There is evidence, however, of an irrigation system being developed by Pueblo tribes in a Scott County site of western Kansas, believed to date circa 1700 (Wedel, 1959:437-438). Such development, however, may be considered a result of direct influence from the Southwest. All Nebraska tribes, particularly those of a nomadic way of life, also depended rather heavily on wild plants.

The most intensive studies on the ethnobotany of Nebraska tribes were carried out by Melvin R. Gilmore (1868-1940), who made particular reference to the Omaha tribe (Gilmore, 1913:314-357). From 1911 to 1916, Gilmore served as a staff member of the Nebraska State Historical Society, with his field and research interests directed toward the Indians and their subsistence (Erickson, 1971). Much of Gilmore's discussion relates to the utilization of wild plants by the Omaha, but he does provide details on such cultivated plants as tobacco, corn, pumpkins, and melons.

Studies by George F. Will and George E. Hyde (*Corn Among the Indians of the Upper Missouri*, 1917, reprint 1964) provide information based, in part, on the work of Gilmore. The corn varieties collected from sources at that time are generally divided into flint dent and flour, with the latter being more common in the Nebraska area. The dent variety generally occurred over the southern area of the United States, while the flint was more common north of Nebraska. The studies also indicated that the Indians were aware that different varieties of corn could become mixed; care was taken in planting to prevent such action. The Mandan tribe, for example, is credited with the cultivation of some

twelve varieties, including both flint and flour corn. Sunflowers were usually planted in rows between the corn.

Native corn proved an important contribution to settlement in the Upper Missouri country. One of the earliest uses was by troops at Fort Atkinson, now in Washington County, Nebraska. General Henry Atkinson's fond hope was to make Fort Atkinson, with the exception of a "few hundred grown hogs and a moderate supply of beef cattle," wholly self sufficient after the year 1821. Some 512 acres of land were placed under cultivation. Private gardens, as well as regimental and company gardens, were laid out, and root cellars were dug to store the produce. After retreat, the officer of the day sent out patrols to protect the cabbages, beets, radishes, parsnips, carrots, and other vegetables. The crops occasionally required the labor of sixty to eighty soldiers. Among the supplies suggested for the post, prior to its establishment, was a supply of "Mandan Corn" which would be adaptable to the climate. Archeological excavations carried out at the site in 1956 revealed charred corn cobs up to four inches in length. The success of the experiment in farming west of the Missouri was confirmed by the corn harvest in 1822. Almost nineteen thousand bushels of corn were husked for the post, if we may rely on the reports. To house all of the grain reaped, it was necessary to construct a new barn. Additions were made to the hogs and cattle herds which were on feed. The best riflemen were posted as guards to protect the livestock from wolves. A civilian, Ashael Savery, was employed to superintend the care of the cattle and to manage a dairy, where butter and cheese were made.

The efficient operation of the fort as an agricultural-experimental farm served to hasten the downfall of such operations. Inspector George Croghan was less than complimentary following his inspection of 1822. He reported that the men devoted so much time to their agricultural pursuits that military training was entirely neglected. The post commander, Colonel Woolley, had earlier posted this notice: "Farming hereafter is to be subordinate to military instructions and habits and is not to be made an excuse for neglect of duties, strictly military." Mandan "squaw corn" of several varieties were utilized by the later white settlers eventually to end up as hog food. In some cases, the varieties of Indian corn were improved to provide corn for the marginal areas of the corn belt.

We have briefly reviewed the records for plant cultivation during the historic period for both Indians and whites. Present archeological evidence, however, would indicate that Indians occupied the Nebraska area for more than 10,000 years prior to the coming of the whites. Yet, the data for this period are more limited and are dependent largely on carbonized specimens recovered from archeological excavations.

Thus far, such remains in reference to cultivated crops coincide with pottery-making cultures dating after 1 A.D. and probably closer to 600 A.D. In Nebraska, the earliest

pottery groups have been generally assigned to the Woodland Culture. Their villages or camps were usually small, of a semi-permanent nature, and may represent family or clan groups numbering less than fifty people. Their habitation structures may have been comparable in design to the wigwam: a bark, mat, or hide-covered oval structure not to be confused with the later teepee. A limited number of storage pits, often less than 3 feet in depth, are usually found in the village sites. The later bison shoulder-blade hoe is lacking, and it seems likely that the digging stick or other such tools were of a perishable nature. One such site was excavated in 1941 by the Society in Platte County, Nebraska. From a trash-filled pit at the site came various charred wood fragments and six small charred seeds that were tentatively identified in the field as corn. These were submitted to the late George Will, who identified them as "an early flint or popcorn judging by the size of the kernels." The sample was also made available to Dr. Paul Mangelsdorf of the Botanical Museum, Harvard University, who did not have the benefit of the identification by Will. He commented, "I have examined these with interest and find that two of them are undoubtedly corn and furthermore, their size and shape is such to indicate they are not too different from the primitive popcorn from Bat Cave, [New Mexico] dated at about 1500 to 2000 B.C." This does not mean, of course, that this particular corn was grown at such an early date, but there is no doubt that it represents a relatively primitive type of corn (Kivett, 1952:57-58). This find has been documented in some detail since presently it seems to represent the earliest known occurrence of such remains for the Nebraska area and to fix the earliest Nebraska "Corn-husker" at the reasonable date of 600 A.D. It should, perhaps, be noted that whereas there was random evidence of post holes, they lacked the pattern for goal posts; and definite evidence for the game of football is lacking. The late Woodland Walker Gilmore Site of eastern Cass County has yielded remains of squash and gourd, but evidence for corn is lacking.

It should be noted that the early occupants of the Nebraska area were subject to adverse climatic conditions, particularly droughts. The archeological evidence would suggest that the native people may have been forced to relocate to more favorable areas during extreme conditions. Whether such droughts were totally responsible for the lack of continuity in cultural sequence cannot be determined. There is no doubt, however, that they were an important factor and seem to coincide, in the dendrochronology studies, with a change in culture (Champe, 1946).

Thus, following the Woodland period, which may have extended to 800 A.D., we have not identified groups living in this immediate area until about 1000 A.D. In the Nebraska-Kansas region, these include the Upper Republican and Nebraska Culture remains in the form of rectangular earthlodge village sites, suggesting an increased population. The remains from this period are commonly found near most of the stream valleys east of the 100th meridian and, less commonly, 200

miles or more farther west. Their period of occupancy may have lasted until 1400 A.D., and there is some evidence they were, in part, the ancestors of such historic tribes as the Pawnee. These groups, in addition to hunting and fishing, practiced a fairly intensive corn and bean horticulture. Storage pits increase in size, and agricultural tools become more varied. Such tools include the buffalo shoulder-blade hoe, as well as hoe blades fashioned from stone and shell. Their only domesticated animal was the dog.

Of particular interest in the crop inventory is the evidence of sunflowers as a cultivated crop, and there is some evidence to suggest that the sunflower may have rivaled corn as an important food source. Excavations carried out at the Medicine Creek Reservoir in Frontier County in 1948 yielded large quantities of charred sunflower seeds in the storage pits. Among the historic tribes, it is reported that sunflowers were the first to be planted in the spring, with several varieties being planted.

Whereas to date the earlier Woodland Culture sites have not yielded corn cobs, they have been recovered from sites of the Middle Ceramic or Upper Republican period. Such cobs are of the eight- and ten-rowed varieties up to three—rarely four—inches in length. It should be noted, however, that several varieties may be present, suggesting considerable advance from the earlier Woodland period.

Most Plains' Indian corn grown at the time of contact with Europeans is reported to have belonged to the Northern Flint race, a straight-eared, usually eight-rowed corn which had flint, flour, and probably sweet variants in a wide range of colors. Will and Hyde (1917:155, 306) describe and illustrate ten kinds of corn grown by the Pawnee. Excavations by the Nebraska State Historical Society at the Crow Creek site north of Chamberlain, South Dakota, have yielded charred seeds which have been recently identified by Hugh Cutler of the Missouri Botanical Gardens, St. Louis, Missouri. It is of interest to note that specimens were recovered from a habitation level of approximately 1000 A.D. and from a second of 1400 A.D. From the latter zone came popcorn of a fourteen-rowed form, while others of the same time period ran eight, ten, and twelve rows and seem to represent both Northern Flints and flour corns. The limited collection from the level of 1000 A.D. contained only remains of ten and twelve rows of grain, which have been compared to forms from the Southwest. The samples are small, and few valid conclusions are possible as to the origin of corn in the Nebraska and Central Plains area.

On the basis of the present evidence, it would appear that the cultivation of crops by native groups in Nebraska has extended over a period of at least a thousand years and perhaps considerably longer. Of the various cultivated crops, corn has been produced in the greatest variety and has provided the greatest assistance in the settlement of Nebraska and the Plains by white settlers.

THE HISTORY OF AGRICULTURE IN THE UNITED STATES BEGINNING WITH THE SEVENTEENTH CENTURY

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INTRODUCTION

The purpose of this paper is to summarize important historical developments in agriculture in what is now the United States, from the earliest colonial times to the present. In terms of the length of time of human history on this world, this period is so short as to seem almost insignificant. However, in terms of progress, the situation is the opposite—more has been accomplished in agriculture in this fraction of a millenium than in all previous history combined.

Agriculture, under immigrant settlers in what is now the United States, had its beginnings in the seventeenth century. The thirteen original colonies were settled predominantly by the English, but also by the Dutch, Germans, Swedes, Irish and Welsh, and by African slaves. Meanwhile, the Spanish and French, and to a lesser extent the English, also established colonies in the southeastern part of the United States, and the Spanish also in the southwest. All of these settlements had agricultural involvements.

Although not all, most of the major crops and livestock species being produced in the United States today were being produced in colonial times. An exception was soybeans. Alfalfa, though not grown on a farm scale, was being tried. Some crops like indigo, common in colonial times, have since disappeared—in fact after invention of the cotton gin, cotton completely replaced indigo. Most power was provided by man and draft animals. At that time, the simple tillage tools were made of wood, but, increasingly, iron was being utilized. Harvesting was done by hand, with a sickle or scythe. Crops were threshed with the flail, hand winnowing, and sieving.

Farmers provided a much higher proportion of farming requirements than they do today. Except for the sun, there was little source of external energy. Energy consisted principally of human labor and animal power, the latter being sustained with feeds grown on the farm. Primarily by means of farm manures, soil fertility was added. Chemical fertilizers and pesticides were almost unknown. Farmers produced, processed, and stored most of the vegetables, fruits, flour and meal, meat, and dairy products that they needed for domestic consumption. They fished and hunted game, depended heavily on furs, hides, wool, and cotton for domestic needs, spun yarn to make clothing, constructed buildings and fences from local

stone or wood, and used wood for heating and cooking.

Agricultural exports were vital to the well-being of the colonial farmer. Increasing distances from seaports and cities, combined with poor transportation facilities, often resulted in low profits and limited the choices of what the farmer could produce. Land speculation was common, and farmers struggled hard to gain title to the land they farmed. By the close of the Revolutionary War, most slaves in the northern colonies had been freed.

Now that we have very briefly examined agriculture as it existed in colonial times, let us review the accomplishments in the United States that have taken place in the past 200 years. The labor force in farming has gone from 90% of the total in 1776, to 20% in 1935, to 4% at the present time. In 1870, one farm worker produced enough products for five people—today he produces enough for 55. The maximum number of farms in the U.S. was reached in 1935, when there were 6.8 million—today there are 2.8 million farms. Yet, total farm output has nearly tripled since the beginning of the twentieth century, doubled since the thirties, increased by 50% since 1950, and by 25% since 1960.

On a per-acre basis, wheat yields have tripled during these 200 years, with one-half of the increase having occurred since 1950. Cotton yields have quadrupled, with one-half of the total increase coming since 1950. Corn yields have also quadrupled, with almost 80% of the increase having occurred since 1950.

How has all of this progress been possible? The answer is complex—it has resulted from a combination and interaction of a fairly large number of factors. We shall attempt to identify the most important of these and elaborate briefly on each of them. They will be considered from the following standpoints: mechanical, technological, and socio/economic.

IMPORTANT MECHANICAL IMPROVEMENTS

Well into the eighteenth century, agriculture remained rather primitive—it was not too different from that practiced in biblical times. To the end of the colonial period, farmers possessed only simple tools and implements, made principally of wood, supplemented with a minimum of iron. Important

agricultural tools were the hoe, sickle, and flail. Animal power was used in plowing, transporting, and, to a lesser extent, in threshing.

1. Plowing

- (a) The cast iron plow was patented in 1793. By 1840 it was replacing the wooden plow.
- (b) John Deere developed the moldboard plow in 1837. It was about this time that improved technology in the production of steel made it economically available for equipment manufacture.
- (c) Maintaining a maximum of crop residues on the surface to conserve soil moisture and to reduce soil and water erosion has been on the increase, starting with the 1930's. Special types of equipment—for example, sweeps—have been developed for subsurface tillage. There have even been modifications made in the moldboard plow to leave more trash on the surface.

2. Harrowing

Prior to 1820, harrows were of two basic types: (1) brush drag—made from the crotches of untrimmed trees; and (2) straight tooth—the wooden teeth were replaced with steel teeth in the 1830's. The spring-tooth harrow was patented in 1869, and the disc harrow came into use in the 1870's.

3. Planting

In colonial times, planting of small grains, rice, and forage crops was done by scattering seeds by hand and covering with hand rakes. Later, broadcast seeders were used—first operated by hand and later supplanted by endgate and horse-drawn broadcast seeders. These persisted well into the present century. In fact, seeding by plane, being used increasingly today, is a form of broadcast seeding.

Grain drills were first used in England in the eighteenth century. In the U.S., the manufacture of drills began in 1841. By the 1890's many farmers with good land (but not all) were using drills. More recently, there have been developed specialized drills for planting small-seeded grasses and legumes. Drills are now also equipped with fertilizer attachments.

Large-seeded crops like corn and cotton were also hand planted earlier, but in a somewhat different manner. Openings were made in the soil, one or a few seeds were dropped in each hole, and then they were covered with soil. To a very limited extent, the method has persisted and is still used today by home gardeners

and in some experimental plantings. In the 1850's, hollow canes were used to place the corn seed in the ground. A horse-drawn corn planter was patented by George W. Brown in 1853. In about 1865, a tripping mechanism appeared that ran on wires with knots placed across the field so that corn could be "check" planted. Thus, the corn could be cultivated, first, in one direction and, then, crosswise. Check planting of corn was practiced well into the present century. Cotton planters were developed about the same time as corn planters.

The hard-ground lister, especially useful in drier areas, made its appearance about 1880.

Today's corn planter is a highly engineered, precision machine, planting up to twelve rows at one time. There are attachments for applying fertilizers, herbicides, and insecticides.

4. Cultivating

Historically, weed control in crops has been effected by hand pulling, by hoeing, and by cutting. Specialized cultivators were first used about 1820, supplanting plows which had previously been used to some extent to cultivate crops. The expanding cultivator appeared in 1830. The sulky (riding) cultivator came into use in the 1840's, but the writer, from first-hand experience, can attest to the fact that the single-row, walking cultivator was still used in the 1920's. It persisted because it enabled the operator to do a better job and because it was less burdensome for the horses.

The tendency in recent years has been to cultivate with sweeps—to avoid root damage to crops, to preserve soil moisture, and to retain crop residues on the surface in order to reduce erosion. With the availability of ever-more efficient herbicides, the need for cultivation lessens. Minimum tillage is generally accepted, and no tillage is becoming a reality.

5. Harvesting small grain

Harvesting of small grain has an interesting history. We have already made reference to the system followed in colonial times. The major improvements since that time have been as follows:

- (a) The cradle and the fanning mill made their appearance between 1776 and 1797.
- (b) McCormick invented the grain reaper in 1809 but did not patent it until 1834—he did not apply for a patent until he had a serviceable machine.

- (c) In 1836 the Pitts brothers patented a machine that combined threshing and winnowing. It was powered by horses and required three men for operation.
- (d) The development of the horse-drawn, self-raking, binding reaper and horse-powered threshing machines took place largely during the 1840's and 1850's. J.I. Case developed the thresher in 1844.
- (e) 1880 witnessed the first combines, which were horse-drawn. However, the binder and stationary thresher constituted the principal small grain harvesting machines until about 1945. More recently, we have seen the development of the self-propelled combine, used for harvesting soybeans and corn as well as for small grains.

6. Harvesting of corn

Corn was harvested by hand until well into the present century. Hand shelling gave way to very simple mechanical shellers which made their appearance in the eighteenth century. In time, the shellers were enlarged, powered by horses, and, finally, by engines. Custom shelling became common by the 1860's.

Placing entire corn plants in shocks in the field was practiced in this country for three centuries.

Some mechanical corn pickers were being marketed by 1909. The picker-sheller made its appearance in the 1930's. Artificial drying was essential for general adoption of the picker-sheller. The portable corn drier was starting to be used about 1949. Today, most corn harvested for grain is picker-shelled. Husking by hand has become virtually a lost art. The hand cornhusking contest and the husking bee, so popular in yesteryear, are gone forever.

7. Forage harvesting

The horse-drawn rake began to be used in New York in 1812. Cyrus Wheeler patented the mower in 1856. Hay loaders appeared in 1866. Today, there is equipment available which obviates the use of any hand labor in stacking and feeding loose hay. The "perpetual press" hay baler made its appearance in 1872. The field pickup baler was in use by 1932. More recent improvements have been a machine making a small bale and throwing it into a wagon pulled behind the baler, and still more recently, machines making jumbo bales (up to 1500 lbs. in size) which are handled entirely by machines.

The first cutter-loaders used for making silage

appeared in 1876. The first field forage chopper appeared in 1915 but did not become widely used until after 1928. By 1960, 90% of the silage was harvested with field choppers.

8. Harvesting cotton

A very significant step in the history of American agriculture was the discovery of the cotton gin by Eli Whitney in 1793. This machine made economically possible the separation of seed from lint of upland cotton, a task that had previously been done very tediously by hand.

The second revolutionary step in cotton production was the beginning of manufacture of the spindle cotton picker in 1942 on a commercial scale by the International Harvester Co. By 1970, cotton harvesting was almost completely mechanized.

9. The evolution of power

Human beings supplied most of the farm power in early colonial times. From human power, we shifted, in part, to oxen, to horses, to the steam engine, and, finally, to the internal combustion engine and electricity, the latter being generated in a variety of ways.

The change from oxen to horses represented progress. An ox moves very slowly; probably the only draft animal which is still slower is the water buffalo.

The next step in progress was the coming of the steam engine. Steam engines were used to process sugarcane in Louisiana as early as 1833. The first steam engines used to power threshing machines were produced in the United States as early as 1849. Five thousand steam tractors were being manufactured annually in this country by 1900. They were somewhat too heavy for plowing. They were used to a limited extent for pulling combines prior to 1912, but their use for this purpose was limited because of the danger of starting fires from sparks.

Probably no other single development has had as much effect on American agriculture as the discovery in 1876 of the internal-combustion engine by the German, Nicholas Otto. In this our bicentennial year, we should pay tribute to him on the 100th year of that discovery. Much of the advancement in farm machinery has been made possible by the coming of the internal combustion engine.

By the 1890's stationary, internal-combustion engines were being manufactured in the U.S. These found important uses on farms, as they still do today. Then in 1892, John Froelich of Iowa, mounted a sta-

tionary, gasoline engine on a wooden and steel frame—i.e., he built the first internal-combustion tractor. This opened up tractor manufacturing on an industrial scale. Improvements after World War I, such as adding power take-off and putting the tractors on rubber—which contributes dramatically to the power, efficiency, and ease and flexibility of operation—have added immeasurably to the value of the tractor in providing power for the farm.

In summary, we can say that the internal-combustion tractor has all but replaced the steam engine, horses, and mules for farm power purposes. It, along with electricity, has also replaced most human energy in farming. Professor William Splinter of the University of Nebraska has stated that in a ten-hour day one man working by hand contributes 2.8 cents worth of energy as measured by the amount of equivalent energy provided by diesel fuel used in a tractor.

10. Livestock and poultry

Livestock production has also been mechanized to a considerable extent. Whereas in colonial times most of the processing of livestock and livestock products was done on the farm, most of it is now done commercially. Refrigeration, improved processing methods such as freezing, improved transportation, and other progress in technology have made this possible.

Dairying has successively seen the coming of the butter churn, the cream separator, and the milking machine (1905). Significant, too, was Babcock's announcement in 1890 of his test for butterfat in milk and cream. We have witnessed the shift from farmers selling fluid milk, cream, cheese, and butter ready for consumption, to bulk handling of milk—the milk going by pipeline from the milking machine to a storage tank, to the tank truck, and, finally, to the central processing plant. In order to have it pasteurized, the dairy farmer of today typically buys milk for home consumption. The cream separator, the home butter churn, and even the milk can have largely gone the way of the horse and buggy.

Chicken production, both broilers and eggs, has become almost completely confined, mechanized, and automated. It is a factory operation. Increasingly, hog production is moving in the same direction. Except to some extent in ranching, horses and mules have almost ceased to be a factor in production. Beef cow and calf operations still require a good deal of labor. Fattening of cattle has been mechanized to a considerable extent, with respect both to feeding and waste removal. In the larger operations, there is also a good deal of automation. The situation with respect to sheep is similar to that for beef cattle, but we are less aware of this because

of the continuously sharp decrease in the number of sheep in the United States.

Today, except for vertically integrated operations, the farmer markets live animals, directly or indirectly, to the processing plant. Virtually no home slaughtering and processing remain. The smoke house has disappeared from the farm.

TECHNOLOGICAL PROGRESS

For the purpose of this paper, a distinction has been made between mechanization (and all of the improvements in machines and equipment that are implied) and technological progress. The latter has to do principally with management and with the biology of the crop or livestock species and/or with biological enemies, such as weeds, diseases, insect pests and parasites.

In this country we are fortunate to have started with comparatively good crop varieties (obtained chiefly from Europe and the American Indians) and with good breeds of livestock. Witness such crop varieties as Turkey wheat and Lincoln brome grass, and livestock breeds such as Holstein-Friesian cattle. The gene base was a good one on which to build. The virgin soils were largely non-eroded and generally high in inherent fertility. Pest problems were far less serious than they became later, following years of farming and increased intensification. My father grew 40 bu. per acre of wheat 65 years ago, a yield which we find it difficult to average on the same farm today. Also in earlier times, farmers produced fruit of reasonably good quality in their farm orchards, with no attention given to the crop except for harvesting. Trying to grow full-season apples in a backyard in Lincoln today without a minimum of about nine sprays is likely to be an exercise in futility. In general, we do have much higher crop and livestock yields today, but we would have had to apply a considerable quantity of improved technology over the years just to stay even.

Technological improvements have been made principally through genetics (breeding), fertilizers, pest control, better livestock nutrition, irrigation and drainage, and improved farm practice and management.

1. Genetics

Improvement in plant varieties and animal breeds received a great impetus with the discovery of the laws of heredity by Gregor Mendel in 1865. It was not until we understood the principles of genetics that we could do really effective plant and animal breeding. The discovery of the phenomenon of hybrid vigor in corn by Shull and East early in this century, followed by the discovery of the double cross hybrid by East and Jones, and other scientific knowledge, have led to the development of commercially superior, hybrid corn. Hybrid

seed corn began to be used in earnest by farmers in the 1930's. Today, open-pollinated corn is almost unknown in the United States.

The hybrid principle of corn production has spread to a number of other crops. Concomitantly, plant breeders have continued to use other improvement methods and with very marked success. The result is that for most crops today, we are using planting stocks of hybrids or improved varieties. Not only is yield enhanced significantly thereby, but there are improvements in quality, and resistance to pests and to stress. More uniform maturity and other desirable growth characteristics have contributed materially to mechanical harvesting. All of this is much to the benefit of the consumer ("Hard Tomatoes and Hard Times" notwithstanding).

Livestockmen were slower in adopting a scientific basis for animal breeding than were crop specialists. But today, they are making every possible application of genetic knowledge. This is very much in evidence, for example, at the USDA Meat Animal Research Center at Clay Center, the world's largest livestock research facility in terms of total animal units. The utilization of hybrid vigor through cross breeding explains the variegated cattle that are seen there and elsewhere over the state—a phenomenon which not too many years ago would have been considered the mark of a farmer too backward to utilize modern breeds. Numerous so-called exotic cattle breeds have been introduced into the crossing programs, especially in the past decade, in order to broaden the gene base. The hybrid principle is also being extensively utilized in poultry and swine improvement.

2. Fertilizers

The value of fertilizers was recognized in colonial times. In those early days fertilizers, like most other inputs, were largely farm produced. Animal wastes were the principal means of improving soil fertility. Legumes were used to add nitrogen to the soil. Lime and guano were among the early commercial additives and fertilizers used. Some buffalo bones were collected, ground, and shipped east for use as fertilizer following the slaughter in the west in the 1870's.

Today, the lion's share of fertility is added to the land through commercial fertilizers. In North America, the consumption of commercial fertilizers in millions of metric tons of plant nutrients went from 11.8 in 1966, to 25 in 1975, and will reach an estimated 35 to 40 by 1980. Of the nitrogen available to crops in the United States, one part comes from animal wastes, two parts from legumes, and nine parts from chemical fertilizers. Truly, the U.S. farmer has a high stake in what happens

to the oil reserves in the Middle East.

In the U.S. in 1974, the following percentages of crops grown were fertilized: corn 94%; cotton 79%; soybeans 30%; and wheat 66%.

3. Pest Control

In all likelihood, pests, including weeds, diseases, insects, and parasites, have been a problem throughout history. They have sometimes reached destructive proportions and resulted in famines. This was the case, for example, when the potato crop was virtually destroyed by late potato blight in Ireland in the 1840's.

(a) *Plant and animal diseases.*—Louis Pasteur, the founder of the science of bacteriology, played a role in disease control equivalent to that of Mendel in genetics. From him we learned that we had to control microorganisms which were causal agents in diseases. One of the first recognized plant diseases of serious proportions was black-stem rust. It was first noted in 1660. It became so serious that commercial wheat production was virtually dropped in New England until after the Revolutionary War. Partial control of this disease has since been effected through the destruction of the alternate host, the common barberry, and through development of resistant varieties.

The use of chemicals for plant disease control has been taking place over a considerable period of time. The well-known Bordeaux mixture was developed in 1890. Many other chemicals have been utilized over the years, including the introduction in recent years of systemics. Controlling vectors, destroying alternate hosts and hosts for vectors, management practices, and breeding for resistant or tolerant varieties—all have played an important role in plant disease control.

There have also been many important developments in animal disease control, starting with the latter part of the nineteenth century, and based principally on immunization. For example, Marion Dorset developed the hog cholera vaccine in 1903. A test for bovine tuberculosis, which can spread to human beings through milk, was developed by Koch in 1890. Through a federal program, the United States was virtually free of bovine tuberculosis by 1942. Pasteurization of milk has contributed to human health, especially in preventing undulant fever.

A modern breakthrough in animal disease control came with the use of sulfa drugs beginning in 1935. These were followed rapidly by anti-

biotics, the first of which was penicillin. It had been discovered by Fleming in 1928, re-studied by Florey and Chain ten years later, and the supply was made available on a large scale by the end of World War II.

The antibiotics were found to stimulate animal gains as well as to help control disease and, as a result, have come to be very widely used as feed additives.

Most advances in the use of systemic poisons to control internal parasites have occurred in the period starting with the 1940's. Much progress has been made in the use of metallic arsenates and a host of other poisons.

Control of animal diseases and parasites has closely paralleled human medical developments. Preventative disease control, based on good management, is becoming increasingly important.

- (b) *Insects*.—Insects have been a problem for man, animals, and plants since long before the first colonies were established in the U.S. In Exodus (10:15) we read "And they [locusts] covered the whole face of the earth. . . . And there remained not anything that was green . . . in all Egypt."

Insecticides have been used over a long period of time, but the problem has been one of selectivity—that which was toxic to insects was often also toxic to plants and/or animals. The real breakthrough came with DDT, the first synthetic compound used as an insecticide. Patented in Switzerland in 1939, it became available in the U.S. in 1943. A series of other chlorinated hydrocarbons followed. Then came other synthetic compounds, viz., the organic phosphates like malathion, and carbamates like sevin.

Problems arose with respect to the development of insect resistance and with residues in plants and animals which were toxic to man. Some of the compounds were found to have carcinogenic properties. Over recent years, the Pure Food and Drug Administration has been ordering removal of some of the insecticides previously offered for sale in this country.

The use of biological controls is very appealing from an economic, health-related, and environmental standpoint. Some advances have been made, especially with use of resistant varieties. Autocidal control has been successful with the screwworm, through the use of releasing large numbers of males sterilized by treatment with

radioactive materials. Diseases, parasites, and predators of insects have been used with some success. Effective sex attractants have been synthesized.

Today, chief control is through use of insecticides. All the unfavorable publicity notwithstanding, the world food supply today would be critically short without the synthetic compounds. We are using an integrated system of control, but leaning heavily toward the use of insecticides.

- (c) *Weed Control*.—Up until World War II, about the only herbicides available were inorganics such as sodium chlorate. They were used only to a limited extent because of cost and residual effect. Then came significant breakthroughs with the synthesis of 2,4-D by Pokorny in 1941, the suggestion by Kraus in the same year that hormones might be good weed killers, and in June, 1944 the recommendation by Mitchell and Hamner of 2,4-D as a herbicide. The use of 2,4-D became widespread. Even today it is still the number one herbicide in terms of volume used.

The middle-to-later 1940's was characterized by the development of growth-regulating hormones for herbicide use; the mid-50's, by compounds which blocked photosynthesis, such as the triazines and the substituted ureas, like diuron and the uraciles; the early 60's, by compounds which blocked cell division, such as lasso and treflan; and the early 70's, by the use of a simple amino acid like roundup that blocks amino acid production.

The use of herbicides is very widespread. For example, in the United States in 1964, we grew 30 million acres of soybeans, of which 10% were treated with herbicides; in 1974, we grew 58 million acres, of which 90% were treated with herbicides.

Presently, farmers commonly use a combination of herbicides and cultivation for weed control. However, the use of herbicides is increasing, and the amount of cultivation is decreasing. Fairly extensive acreages of row crops now receive no cultivation whatsoever.

4. Better livestock nutrition

The value of legumes to provide proteins in animal rations has been recognized for a long time, along with the need for carbohydrate concentrates. The discovery of vitamins by Funk in 1911 and vitamins A and B by McCollum in 1915 opened the field of using vitamins in

in livestock feeds.

Antibiotics stimulate animal growth and are used as feed additives. Early in the 1950's manufacturers began the addition of synthetic amino acids to feeds; also about this time was seen the addition of antioxidants to preserve fat-soluble vitamins and fats. Urea began to be substituted for a part of the protein in feed rations. The synthetic hormone, diethylstilbestrol, was found by Wise Burroughs about 1951 to increase gains in livestock. It became very popular among livestock producers, but its use has been curtailed more recently by rulings of the Pure Food and Drug Administration. The February 6, 1976, issue of *Science* (p. 453) discusses three possible substitutes.

In general, there has been much advancement in livestock nutrition, including the use of improved forages. In no other type of livestock has the efficiency of feed equalled that of poultry.

5. Irrigation and drainage

Irrigation and drainage have been practiced for numerous centuries. Drainage is done to improve or reclaim wet lands for farming and must also accompany irrigation for good water management.

There was a large increase in the use of irrigation following World War II. The development of bulldozers and earth-moving equipment greatly simplified and lowered the cost of clearing and leveling land. The substitution of gated, aluminum pipes for canals and ditches to convey water constituted a big improvement. Although dams on streams are still an important source of irrigation water, the use of wells to tap underground water has been growing rapidly in both actual and relative importance. Sprinklers, chiefly center pivot systems, are becoming rather commonplace. They obviate the necessity of most land leveling, can be used on rolling land, sandy land, and they save labor. In Nebraska, especially, land being placed under irrigation is increasing very rapidly.

6. Improved farm practice and management

Farm practice has improved markedly since colonial times. Mechanization, improved technology, and increasing the size of operations have necessitated ever-higher levels of management. Farmers, with the help of research findings and education, have learned how to better handle livestock, manage crop production, conserve soil and water, irrigate, fertilize, apply pesticides, summer fallow, harvest and store crops, and market farm products. Good farming is both a science and an art and requires business acumen. Farming is extremely complex, and success does not come easily—a fact some-

times not fully appreciated by non-agriculturists. Few other professions require the breadth of mechanical capability, technical knowledge, and business-management judgment that are necessary in farming.

SOCIO-ECONOMIC DEVELOPMENTS

The socio/economic changes that take place off the farm have a great influence on the welfare of the farmer. To a considerable degree, the well-being of the farmer moves upwards as socio/economic advances are made in the nation as a whole. True, there may be a lag of farm income as contrasted to non-farm income, but, in general, the correlation between the two is fairly high. Without attempting to answer the conundrum of whether in the U.S. industry has made such fantastic advances because of a highly successful agriculture or vice versa, we can safely say that both are the envy of much of the rest of the world.

Agriculture in a developing country can reach a level such as that in the U.S. only when adequate economic, industrial, and educational developments also take place. We often see in developing countries inadequacies in the following: advancement with respect to port facilities, storage, transportation, marketing, quality control and grading standards, purchased production inputs (e.g., parts for repairing tractors), farm credit, skilled workers to provide the farmer with necessary inputs and to handle the products he sells to the point that they reach the consumer in good condition, educational and research facilities, and others. Too often the worker on the farm and in agri-business is illiterate. Even if one placed our best Nebraska farmers into an underdeveloped country on good land with adequate equipment and with plenty of irrigation water, most, if not all, would fail without the above developments also taking place.

Now, let us examine some of the socio/economic developments in the U.S. which have helped make our agriculture superb.

1. Education

Perhaps in No. 1 place is education. In the U.S., we have always placed much emphasis on children going to school. Not only have we virtually eliminated illiteracy, but there has been a continuous increase in the average level of education, both on and off the farm.

2. Land—free or, at least, very cheap land

In spite of the fact that most of the early settlers in the Jamestown Colony were indentured servants, it soon became apparent there and elsewhere that individual land ownership constituted the basis for maximum farm production. So, the policy of making land available to settlers without cost or at a low cost evolved, European law and economic theory notwithstanding.

Following colonial times, there have been numerous laws passed by Congress to dispose of federal lands, not only to individuals, but also to the states, to railroads, and to land-grant colleges. It was easy to give land away because of the westward-moving frontier over so much of our history—especially since we largely disregarded the interests of the previous owners and long-time occupants. Here in Nebraska we are especially familiar with the Homestead Act of 1862 as a means of securing free land.

Over much of our history, free or cheap land—combined with the fact that one would start farming with simple, inexpensive equipment—enabled the young man with little or no capital to enter the profession. Rather suddenly, and largely since World War II, all of this has changed. The cost of land, equipment, and livestock necessary to start a farming unit with a reasonable chance of success is now in excess of two or three hundred thousand dollars. It is no longer easy to enter farming without extensive capital.

3. Processing of food and fiber

Moving the processing of farm products off the farm was necessary in order to develop the technology, mechanization, automation, and general industrialization of the processes which have taken place. We dry, smoke, can, refrigerate, freeze, dry-freeze, season, fortify, pasteurize, irradiate, roast, ferment, culture, bleach, and/or purify raw agricultural products in order to provide the consumer with maximum quality at a reasonable price. Can you imagine where we would be in the food world today if processing had remained on the farm as it was in colonial times?

4. Marketing

To move farm products from the farmer to the consumer in the United States and into export channels has, of necessity, resulted in the establishment of a complex market system. This included the establishment of commodity exchanges such as the New Orleans' cotton exchange established prior to 1837 and the Chicago Board of Trade in 1848, the New York Produce Exchange in 1862, and many more since. Livestock marketing was gradually centralized and, more recently, again decentralized to a considerable extent.

There are numerous regulations to protect the producer and buyers, including consumers. To a reasonable extent, the market system operates on a free-economy basis. It is far from perfect but has served the farmer fairly well. The consumer, too, has a fair deal when he goes to his supermarket to purchase his groceries.

5. Transportation

The improvements in transportation have been great, indeed. In ocean transport, we have gone from wooden sailing vessels to iron and, ultimately, to steel ships powered by engines. There has been continuous improvement in internal transport systems, including river navigation; the building of canals; constantly improved roads; and the coming of the automobile and truck; steamboats (Fulton's invention of 1807); boats powered by internal-combustion engines; railroads, including, more recently, rail shipping combined with truck shipments through the "piggyback" arrangement; and, finally, air transport. Refrigeration has played a major role in transporting perishable foods. Without good transportation, it would be impossible to carry on the heavy exports of agriculture products which are essential to the farmer and, equally important, necessary for the balance of payments of our country.

6. Federal and state support for agriculture

There have been a series of laws passed and appropriations made by the federal government and by the fifty states to help farmers and, in turn, consumers. These have proven to be most valuable. Important among these have been the following:

- (1) The establishment of the U.S. Department of Agriculture in 1861—a federal agency providing agricultural research, educational, regulatory, and service functions of inestimable value to farmers and consumers alike.
- (2) The Morrill Act of 1862, providing support for land-grant universities, including a great impetus for the establishment and support of agricultural colleges.
- (3) The passage of the Hatch Act in 1887 and legislative action by the fifty states which have resulted in establishment of, and in continuously increased support for, state agricultural experiment stations.
- (4) Passage of the Smith-Lever Act in 1914, providing for the establishment and continuing growth of the co-operative extension services in the fifty states and in the federal government.
- (5) The Smith-Hughes Act of 1917, providing federal support for teaching agriculture in high schools.
- (6) The Agricultural Adjustment Act of 1933 and its successors (today, the Agricultural Stabilization and Conservation Service) which, through the Commodity Credit Corporation, provided support prices through non-recourse loans for farm products; assisted in the adjustment of crop acreages; and provided incentives through the Soil Bank and

other means to conserve the soil. This much-maligned agency has served American agriculture very well. It helped preserve and advance farming, especially during those years when surpluses constituted a major problem. The wisdom of supporting agriculture during those years should be apparent to almost everyone today when we need all of the food farmers can produce. It would have been a sad mistake, indeed to have permitted the agricultural plant to deteriorate during the period of surpluses.

- (7) The creation by Congress of the Soil Conservation Service in 1935. This agency has contributed and continues today to contribute greatly to the conservation and wise use of our natural resources.
- (8) The establishment early in the New Deal days of what is now the Farmers' Home Administration. It has enabled many individuals with inadequate resources to enter and/or remain in farming.
- (9) The various federal acts and subsequent amendments which have resulted in the present Agricultural Marketing Service, Agricultural Research Service, Economic Research Service, Statistical Reporting Service, Foreign Agricultural Service, Forest Service, Farmer Co-operative Service, Bureau of Land Management, Bureau of Reclamation, Farm Credit Administration, Rural Electrification Administration, Tennessee Valley Authority, and others.
- (10) The ever-increasing financial support by the states for agricultural research, regulatory services and education, through both state agricultural colleges and state departments of agriculture.

7. Farm organizations

There are today four major, general, farm organizations in the United States. The oldest is the Grange, which was begun in 1867. Then followed the Farmers' Union, the Farm Bureau Federation, and, finally, in 1954 the National Farmers' Organization. All attempt to speak for the farmer, but over the years there has been considerable variation in the policies enunciated by these organizations.

Farmer co-operatives had their beginning over 100 years ago. Many sad experiences have since followed. But today farmers utilize co-operatives extensively and successfully. These involve both buying and selling, and they operate on local, regional, and national levels. Examples of very successful co-operatives are the farm credit banks.

8. Miscellaneous

In a paper of this length, it is impossible to cover all aspects of agricultural history. There have been some recent breakthroughs which have not yet been fully developed; for example, EROS for getting unbelievably detailed information on the earth's resources, and microbial nitrogen fixation on grasses.

A few additional organizations and developments are worthy of mention. The private foundations—such as Rockefeller, Ford, Kellogg—and the Farm Foundation have made significant contributions. The private sector has been the backbone of much of our progress. Private industry has built the machines, provided the farmer with most of the purchased inputs, and done much of the processing, transporting, and marketing of food and fiber. Increasingly, private industry has entered into research, education, and service to the farmer. Today, for example, the private sector devotes far greater resources to developing improved corn hybrids than do the USDA and state experiment stations combined. We have a good, stable government which always has and still does today provide an excellent environment for agricultural progress.

And, finally, we have good people doing the farming. Like our colonial forefathers, they have a high respect for integrity and for hard work. They are educated, intelligent, resourceful, and ambitious. They constitute an example of excellence in our economy. We can take just pride in our American agriculture wherever we travel in the world.

ACKNOWLEDGMENTS

Presented as a part of the Maiben Memorial Lectures, a bicentennial symposium. The Nebraska Academy of Sciences and Affiliated Societies Program of the eighty-sixth annual meeting, April 23, 1976. Although the writer made use of all of the subsequent references, as well as drawing on his own knowledge and experiences, Schlebecker's excellent book was the most important source of information.

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COLLEGIATE SECTION

PRELIMINARY POST-CRANIAL METRIC ANALYSIS OF MAMMOTHS FROM THE HOT SPRINGS MAMMOTH SITE, SOUTH DAKOTA

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Salvage investigations of a Karst depression containing more than nine Late Pleistocene mammoth were conducted during approximately twenty field days in the summers of 1974 and 1975. The deposit contains a local death assemblage of a mammoth population. A post-cranial metric analysis has been conducted on the fossil elephant remains.

† † †

INTRODUCTION

Construction work on a housing development on the southern edge of Hot Springs, South Dakota during the summer of 1974 uncovered teeth, tusks, skulls, and a variety of post-cranial skeletal remains of mammoth. The mammoth bones as exposed were concentrated in two separate areas (Areas A and B) of a sediment-filled, Karst depression (Fig. 1), currently a hilltop. The faunal remains seem to lie peripheral to the entire edge of the deposit. The depression, roughly circular in shape, was developed in the Spearfish Formation (a red shale of Triassic age) as a result of dissolution in the underlying Minnekahta Limestone of Permian age. The collapsed sinkhole was later filled with sand, silt, and clay of Late Pleistocene age. Bank caving is noted in the eastern portion of this area, with blocks of Spearfish material compressing and contorting the sand. These were apparently capable of fluid movement, suggestive of subaqueous conditions. The model proposes a Karst depression containing a standing body of water which received sediments and served as a watering location for Late Pleistocene fauna (Agenbroad and Jones, 1975). If the mammoth did come into the sinkhole for water, they probably could not scale the slippery Spearfish shale to get out.

Here we have a local death assemblage (thanatocenosis) of mammoth and associated fauna. The associated animals consist of peccary (*Platygonus*), bear (*Ursus arctos*), coyote (*Canis latrans*), camel (*Camelops*), rodents and an unidentified raptorial bird. An estimated age of +20,000 years has been postulated on geologic evidence for the site. A collagen sample has been submitted to the laboratory for a radiocarbon date,

but is not currently available.

METHODOLOGY

Excavation of the site followed standard archaeological and paleontological techniques as applied at the following sites: Murray Springs, Lehner Ranch, Boney Springs, and Hudson-Meng. Bones were mapped *in situ*, both vertically and horizontally, as encountered in the fill. Horizontal provenience was done with a string grid and transferred to metric graph paper. A vertical datum gave levels on individual bones. A level was taken on the central portion of the bone except when abnormally inclined.

Excavation centered in Area B, the edge of the proposed alleyway, in the approximately 20 days of field work during the two seasons. Remains from this area were mapped, field numbered, removed, and taken to the laboratory for further stabilization, reconstruction, and identification. The remains from Area A were left *in situ* after excavation, for subsequent development of the site.

PURPOSE

Due to the value of post-cranial metric studies on bison at the Hudson-Meng site (Agenbroad, 1977), Casper site (Frison, 1974) and others, we felt a similar analysis would aid future studies in comparisons of mammoth populations. A search of the literature (Saunders, 1970; Maglio, 1973; Osborn, 1942; Falconer, 1863; Barbour, 1925) revealed few measurements taken on post-cranial material, and no standardized measurements for an extensive study of post-cranial metrics have been published. Other than Osborn's (1942) figure of Standardized Skeletal measurements—which is minimal—no other data have diagrams specifying the measurements taken for mammoth have been found. Collections at the Smithsonian Institution and the American Museum of Natural History also fail to yield any comparative data published on the post-cranial metrics of mammoth. We felt our

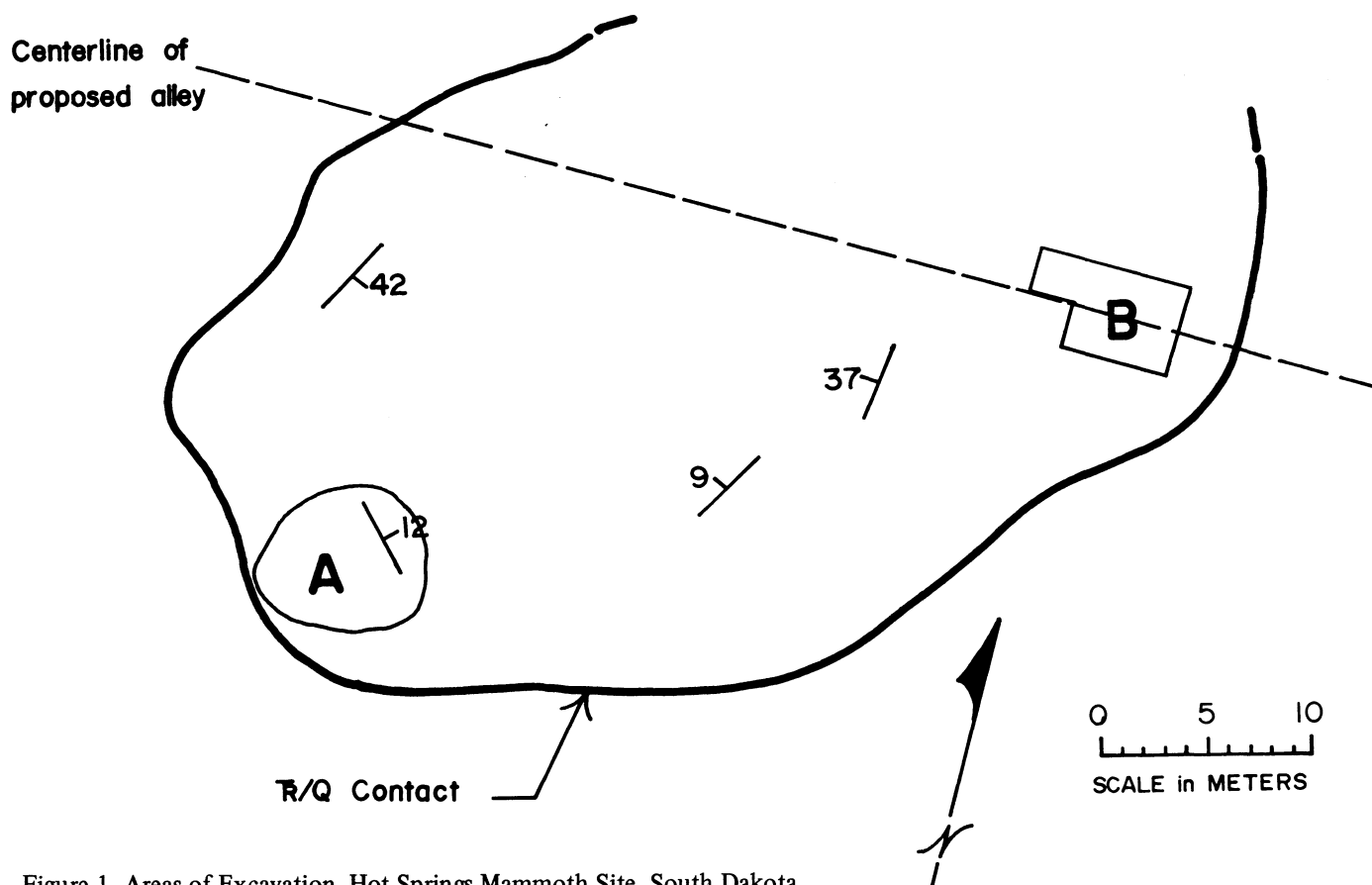


Figure 1. Areas of Excavation, Hot Springs Mammoth Site, South Dakota.

contribution from a thanatocenosis of mammoth would aid the paleontologist and archaeologist in comparative studies when encountering mammoth remains in the field. With additional work, this area may also be of use when determining species when remains are absent of crania or teeth.

RESULTS

Speciation was a primary concern of this study. Much of the published data concerning speciation provided measurements for the skull only. Since none of the four skulls taken from the site was useable for speciation—one remains *in situ*, the discovery skull was demolished by a bulldozer, one was fragmentary, and one is currently in a field cast—speciation was done using teeth, which are the next most frequently described element. Cooke (1960) devised a graph relating the Index of Hyposodonty (100 Ht./Wd.) to the Length-Lamella ratio. Saunders (1970) applied these data to second and third molars from Arizona mammoth, as I did with the first molars, which are most prevalent from our site (Fig. 2). Plotting these values, we arrived at the species *Mammuthus columbi*, coinciding with our first estimation. Further verification of species will result when a skull is made available. Because of the many discrepancies pointed out by Morrison-Scott (1947), ridge-plate formulas were not used in determination of the species.

Using the method devised by Laws (1966), further

study of the teeth resulted in approximating the age of the mammoth at the time of their death. According to their age groupings, we may have one kinship unit, which came to water at this locality and died, the bones of which then became incorporated into the sediments. If not a kinship group, at least we have a thanatocenosis representing a local mammoth population.

To date, we have 267 specimens representing at least nine mammoth. Vertebrae are the most abundant, excluding ribs. The vertebrae consist of 6 incomplete cervicals, including one partial axis; 14 incomplete and complete thoracic; 23 lumbar, incomplete and complete; 2 incomplete sacra; and 5 incomplete and complete caudals. Other specimens include: 4 incomplete and complete crania; 1 incomplete hyoid; 9 complete and incomplete mandibles, 3 broken ascending rami and condyles; 23 teeth, including 9 in crania, 8 in mandibles, and 6 isolated; 19 incomplete and complete ribs; 1 distal end of a humerus, broken about midshaft; 2 incomplete radii, 1 proximal end broken about midshaft, and 1 complete except for the distal, unfused epiphysis; 1 fragmentary ulnae; 8 incomplete pelves; 7 femora, 1 complete shaft with both epiphyses unfused, 3 unfused femur heads, 2 distal epiphyses, 1 proximal end with unfused epiphyses broken about midshaft; 3 complete patellae; 1 fragmentary fibula; 1 complete calcaneum; 1 complete astragalus; 3 incomplete and complete metapodials; 12 phalanges; plus numerous foot bones, includ-

ing 1 complete trapezium, 1 complete lunar, 1 partial scapoid, 2 complete uniforms, and 2 complete cuniforms. Also in the collection are 34 unidentifiable fragments. Identification was from Olsen's (1972) work on mammoths and mastodons.

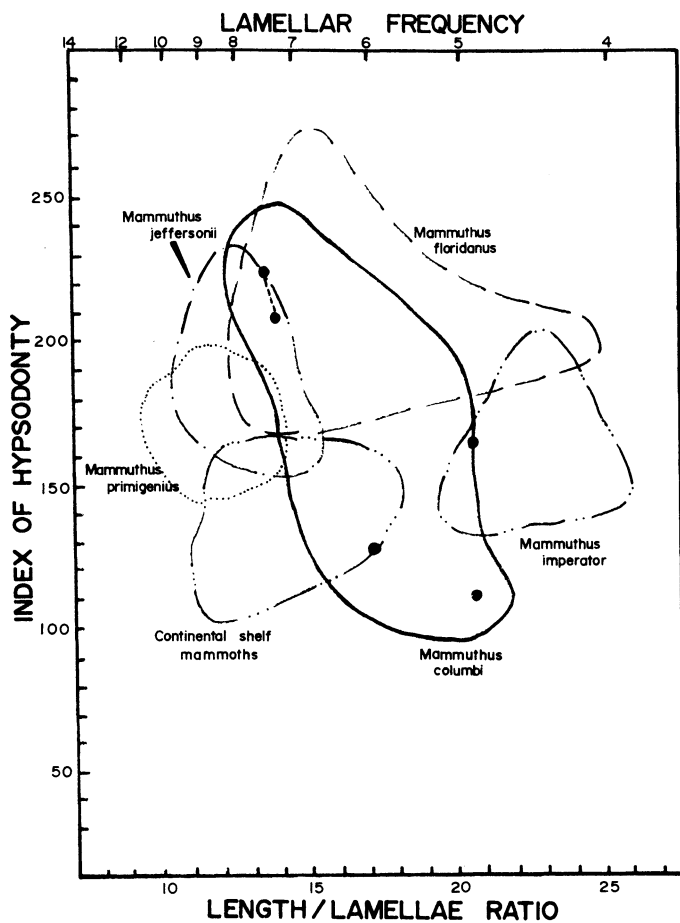


Figure 2. Variation in Hyposodnty and Lamellae Compression of first molars referred to as *Mammothus columbi* from Hot Springs Mammoth Site, South Dakota (after Cooke, 1960, and in Whitmore *et al.*, 1967, and Saunders, 1970).

The elements from the "articulated" mammoth in Area A are not included in these statistics, as the additional 39 specimens remain *in situ*. Included in this study are specimens from the upper portion of Area B with a total known thickness of over 16 feet of thinly laminated fill.

As stated previously, searching the literature provided no standardized post-cranial measurements for mammoth. An attempt was then made to locate the most diagnostic measurements of each bone. After defining what I felt to be the most valuable, I noted what Jeffrey J. Saunders (personal communication, 1976) uses for the mastodon. Combining this with Maccagno's (1962) measurements for the mastodon and my own, I derived what I felt to be the diagnostic measure-

ments for the mammoth. In an attempt to standardize the measurements, selected diagrams are included showing the measurements taken (Figs. 3 and 4).

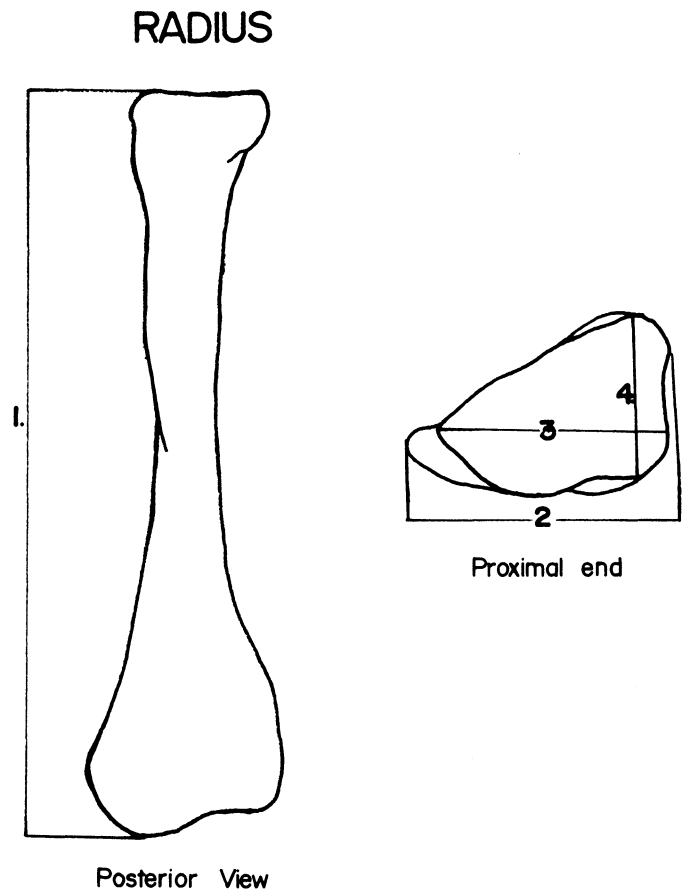


Figure 3. Measurements for the Radius: 1. Max. art. length, 2. Max. trans. dia. prox. end, 3. Max. trans. dia. art. surface (prox. end), 4. Ant. post. dia. art. surface (prox. end), 5. Breadth of carpal extremity.

Published comparative data are nearly non-existent with the exception of Osborn's (1942) data for *Parelephas jeffersoni* and a few *M. columbi* measurements. The other published data are those of Saunders' (1970) on Arizona Columbian mammoth. From his 78 specimens recorded, only 10 were post-cranial remains. Barbour (1925) has the only published data on *Elephas columbi* from Nebraska. These comparative results must be considered with caution, as there is no indication as to the age of the individual. Measurements do reflect the age and maturity of the individuals. If ratios are used, more valid comparisons could be made (Table I).

SUMMARY AND CONCLUSIONS

I would like to stress that this is a preliminary paper and should be considered as a working report. Comparative data are nearly non-existent for post-cranial elements of the

Table I:
Comparative Measurements of *Mammuthus columbi*

Specimen	<i>E. columbi</i> Nb. St. Mus.	<i>P. columbi</i> Amherst Mus. 25-1	<i>M. columbi</i> Arizona	<i>M. columbi</i> So. Dakota
ATLAS				
Max. height	240	-----	185-246	-----
Wd. across trans. proc.	-----	-----	323-420	-----
Ht. neural canal	110	-----	90-142	-----
Wd. neural canal	97	-----	60-94	-----
AXIS				
Trans. dia. centrum	180-280	-----	215	191
Max. ht.	336	-----	202	-----
Ht. neural canal	75	-----	62	-----
Wd. neural canal	84	-----	70	-----
CERVICAL				
Trans. dia. centrum	192	-----	154	203
Max. height	-----	-----	210	-----
Ht. neural canal	58-70	-----	64	70
Wd. neural canal	109-122	-----	70	56
LUMBAR				
Trans. dia. centrum	135	-----	-----	126-160
THORACIC				
Trans. dia. centrum	144-156	-----	-----	131-153
SCAPULA				
Ht. supra-scap. border to glenoid	1257	1037	-----	850-876
Lgt. of glenoid cavity	330	-----	188-263	235-254
Wd. md. pt. length	-----	-----	113	468-594
HUMERUS				
Art. length	1226	1030	-----	-----
RADIUS				
Art. length	----	952	-----	(709)
ULNA				
Art. length	1080	1060	-----	-----
FEMUR				
Art. length	-----	1340	1300	(1008)
Mid. dia. trans.	157	-----	-----	161
Max. dia. head	-----	-----	180	141
TIBIA				
Art. length	-----	825	730	-----

Columbian mammoth. With the coming field season, we hope to increase greatly our inventory of faunal remains and comparative data.

This should result in a complete representative sample of a local mammoth population and may give us an age structure as well as a statistical sample. The purpose of this paper is to standardize measurements of post-cranial elements of mammoth and to make the methodology known and available.

LUMBAR VERTEBRA

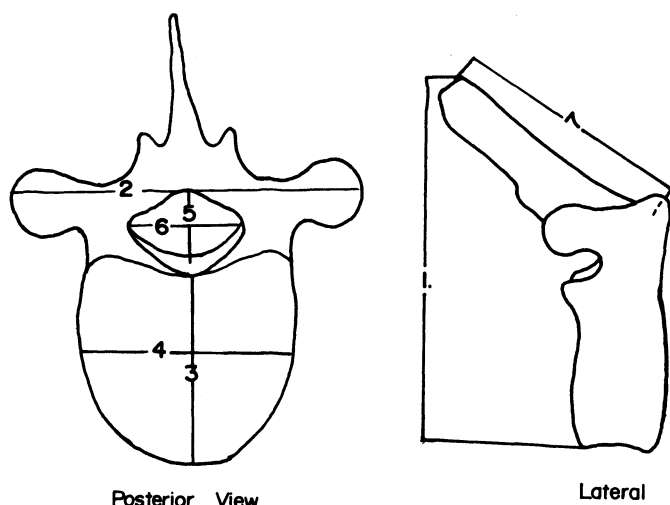


Figure 4. Measurements for the Lumbar Vertebra: 1. Max. height, 2. Max. width, 3. Max. height of centrum, 4. Max. width of centrum, 5. Max. height of neural canal, 6. Max. width of neural canal, 7. Height of spinous process.

ACKNOWLEDGMENTS

I would like to acknowledge Dr. Larry Agenbroad of Chadron State College for allowing me the opportunity to do this research and for all his advice, encouragement, and information. Also, I would especially like to thank Dr. Jeffrey Saunders of the Illinois State Museum for his valuable assistance in this regard and his giving information so freely. Field work in 1975 was made possible by a small grant from the Geological Society of America. The Chadron State College-Research Institute provided a transportation grant.

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SOME ASPECTS OF LITHIFICATION IN CHALK

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Chalk is affected by different diagenetic processes in comparison with other carbonate rocks. Commonly observed lithification processes are pressure-solution and reprecipitation and neomorphism. The first process is divisible into: (a) spot-welding or welding; (b) overgrowth; (c) stylolitization and cementation. Further, pressure-solution and reprecipitation is dependent on (a) geostatic pressure and (b) the ratio of Mg/Ca in the pore fluid. Overgrowth of calcite cement is controlled by the size and shape of the biogenic crystals. Neomorphism is also important in diagenesis. Neomorphic process dominates when pressure-solution process is ineffective. Organic and insoluble residue content dictate neomorphism. In conclusion, pressure-solution or neomorphism or a combination of both accounts for various modes of lithification observed in chalk.

† † †

The initial reports of the deep sea drilling project (JOIDES) have yielded new data and new impetus to studies of pelagic and deep water carbonate sediments. A further aid to the understanding of depositional and diagenetic environments of the pelagic sediments has been given by the recent discoveries of oil fields under the North Sea where the Cretaceous chalk is a major petroleum reservoir. Further, detailed observations with the scanning electron microscope have disclosed different processes of lithification, such as dissolution and precipitation. Application of these new ideas to the study of chalk has been an interesting revelation to many petrographers.

Chalk is a pelagic sediment of biogenic origin. The *Glossary of Geology* (1973:117) defines chalk as "soft, pure, earthy, fine-textured, usually white to light gray or buff limestone of marine origin, consisting almost wholly (90-99%) of calcite, formed mainly by shallow-water accumulation of calcareous tests of floating micro-organisms (chiefly foraminifers) and of comminuted remains of calcareous algae (such as coccoliths and rhabdoliths) set in a structureless matrix of very finely crystalline calcite (some of which may have been chemically precipitated) and marked by a porous, somewhat friable, and unindurated or slightly coherent character."

At the present time, pelagic sedimentation is virtually confined to ocean basins. In the Mesozoic era, on the other hand, pelagic deposits, including chalk, were laid down on the continental basement. In Late Cretaceous time there were widespread continental seaways, and practically every continent was affected by this world-wide marine transgression.

The best known and most widely distributed deposits of these seaways are chalks of the Cenomanian-Maastrichtian age. The chalks of western Europe are of particular interest here because of their economic importance and their contribution to progress in chalk petrography.

Lithification includes all diagenetic processes which serve to convert unconsolidated sediment to coherent rock. The diagenetic alteration of chalk has long been a subject of controversy in petrography. For example, the lithification of the Irish Chalk has been variously attributed to the presence of aragonite in the original sediment and to metamorphism by overlying basalts (Bathurst, 1975:401-408). Similarly, major hypotheses offered to explain radical differences in hardness of Cretaceous chalk in Great Britain all appear inadequate (Scholle, 1974:178). In this paper, an attempt is made to summarize the new data and examine the mechanisms proposed by various authors to explain patterns of chalk diagenesis.

Unlike most regions of shallow water carbonate deposition where the major carbonate component is aragonite (e.g., the Arabian Gulf), the bulk of chalk mud is totally biogenic in origin, consisting mostly of stable, low-Mg calcite. Consequently, the mechanisms of chalk diagenesis have to be explained by processes other than simple compaction, leaching, solution (fresh-water influx), and cementation. Common and widely observed processes are pressure-solution and reprecipitation and neomorphism. The mechanism of pressure-solution and reprecipitation is divisible into: (a) spot-welding or welding; (b) selective overgrowth on some calcite grains; and (c) stylolitization and cementation. The process of reprecipitation is usually local and occurs as calcite cement. Solution-precipitation is dependent on two factors: the depth of burial and pore-water chemistry.

Schlanger (1974) concludes that lithification generally increases with age and the depth of burial. The history of compaction starts with dewatering and is followed by increased packing, spot-welding, subsequently by dissolution-precipitation (selective overgrowth cement) and stylolitization and extensive cementation. Interesting advances in theoretical understanding of pressure-solution have come about with Neugebauer's (1974) analysis of the solution in the chalk. His main thesis is that chalk remains soft and uncemented because Mg-rich pore fluids, which are supersaturated

with respect to low-Mg calcite, inhibit pressure-solution and reprecipitation until considerable overloads are reached. When this inhibiting factor (supersaturation) is removed, pressure-solution and cementation can proceed at an accelerated pace. During diagenesis, the Mg/Ca ratio of the pore-fluid generally decreases considerably (Neugebauer, 1974:156), which, along with the inevitable rise in geostatic pressure, leads to extensive pressure-solution and culminates in stylolitization and cementation. Neugebauer constructed a model, illustrating the relationship among such factors as overburden, dissolution of nannofossils and cement fabric, and the ratio of Mg/Ca in the pore solution. His results compared well with deep-sea drilling data, and he concluded that an overburden of at least 2000-4000 m is required for the complete lithification of the chalk by pressure-solution.

It is very interesting to note where the precipitation of cement in chalks takes place. Cement in a typical chalk occurs as pore-filling, sparry calcite and also as overgrowths on nannofossils. Neugebauer (1974:168) observed that different group of fossils (coccoliths, foraminifera, *Inoceramus*, etc.) are coated with different amounts of overgrowth cement. He noted that size and geometrical shape of the host grain control the form of calcite overgrowths. Foraminifera acquire smaller overgrowths than macrofossils but larger overgrowths than coccoliths. Neugebauer (1974:172) points out further that coccolithic elements, unlike other biogenic crystals of the same size, are somewhat protected from dissolution because of their stable form. Adelseck (1975:969-970) demonstrates that dissolution is further dependent on the thickness of the coccolith plates and that within the foraminifera, the individual species resistance is dependent on the pore size and pore density of the test.

Wise and Kelt (1972) demonstrated the cementation of an Oligocene, South Atlantic chalk by calcite overgrowths on coccoliths and discoasters. Scholle (1974) attributed cementation of English chalk to overgrowth on coccoliths, while Mapstone (1975) believed that the cement in the Danian and Maastrichtian chalk from the Tor Field (North Sea) was derived from pressure-solution of calcite grains (mostly individual coccolithophorids). Similarly, Jørgensen (1975) favored the consolidation of the soft sediment to white chalk in the Danish region over pressure-solution.

Scholle (1976:719) states that small variations in initial grain size, faunal composition, or clay content can lead to significant stratum-to-stratum variations in lithification. Jørgensen (1975:312) noted in Danish chalk that, though argillaceous chalk and pure chalk were subjected to the same lithostatic pressure, the lack of lithification in argillaceous chalk was due to the fact that very little cement was produced at the clay/carbonate grain contact. The *hard grounds* that are seen in the Cretaceous chalk of Europe and in the chalk and shaly chalk strata of the Greenhorn Formation (Upper Cretaceous) in the western interior U.S. are examples of this type of cementation. *Hard grounds* are layers of hard,

well cemented chalk in a sequence of porous, poorly cemented, soft-chalk strata; they are believed to be the remnants of hardened sea floors.

Neomorphism plays a key role in hardening a loose, noncoherent, carbonate mud to chalk wherein pressure-solution processes are subordinate. Neomorphism as used by Folk (1965:20-21) includes all transformations between one mineral and its polymorph. The newly formed crystals can be of differing sizes. The growth of carbonate mud to sparry calcite is controlled by insoluble residue and organic content. The Upper Cretaceous Greenhorn chalk is a good example of lithification by the growth of calcite grains (Kirumakki, 1976:47; Hattin, 1976:83-86).

The conclusion is inescapable: Variations in the character of chalks are related to different diagenetic histories. The occurrence of spot-welding at point contacts of calcite grains, the presence of extensive overgrowth cement, and the abundance of stylolites all testify to the idea that pressure-solution is a possible mechanism of cementation. The various modes of lithification found in chalks can, to a large extent, be attributed to: (1) cementation by pressure-solution, and (2) independent neomorphism, or (3) some combination of the above processes.

ACKNOWLEDGMENTS

Professors P.R. Krutak and D.G. Kersey gave many helpful suggestions and comments for improvement. Professor R. Smith critically reviewed the manuscript. My thanks to them for their help and time.

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NEBRASKA ACADEMY OF SCIENCES, INC.
PREPARATION OF MANUSCRIPTS FOR PUBLICATION IN THE *TRANSACTIONS*

The following suggestions are presented in order to minimize revisions and editorial corrections. Uniformity of style and format necessitates attention to detail by authors. More information is available from the Nebraska Academy of Sciences, 306 Morrill Hall, University of Nebraska, Lincoln, Nebraska 68588.

STYLE. Recent issues of the *Transactions* should be examined so that authors become familiar with its general style. The page size of the *Transactions* will be 8.5 x 11 inches, and the text will be printed in double columns. Manuscripts should be neatly type-written on 8.5 x 11 inch paper with wide margins and *double-spacing throughout*. Pages should be numbered consecutively. Extensive quotations in the text should be typed with slightly narrower margins, and should be single-spaced. Words and numerals to appear in italics should be underlined in the typed copy. Acceptable symbols should be used for units of measurement; e.g., see *Style Manual For Biological Journals*, compiled by the Conference of Biological Editors of the American Institute of Biological Sciences, 2000 P Street, N.W. Washington D.C. 20036.

Title is to be typed in capital letters. Scientific names of organisms in the title should be underlined. The author's name should be typed in capital letters below the title. The address of the department, institution, city and state which are to be credited with supporting the author and his work should be typed (caps and lower case) below the author's name and underlined. If more than one institution is to be credited, their names should appear in the order corresponding with the author's names.

TABLES. Tables are to be typed, double-spaced, on separate sheets of paper, one table to a page, numbered consecutively, and placed in a group at the end of the manuscript. Keep the number of tables at a minimum; numerous small tables especially should be avoided. When the headings for a number of tables are similar, an attempt should be made to combine the tabular data. Use a double horizontal line immediately below the title of the table and a single horizontal line below the column headings and at the bottom of the table. *Do not use horizontal lines in the interior of the table and use no vertical lines.* Tables should be planned and prepared with proper spacing so that such lines are not necessary.

Footnotes to tabular data should be noted by asterisks, daggers, or other signs to avoid confusion with numerals in the table or elsewhere. The general style desired in tables can be seen by examining recent issues of the *Transactions*.

ILLUSTRATIONS. All illustrations are referred to as "figures" and must be numbered consecutively. They may be photographs or line drawings in black ink. Illustrations should be grouped and mounted close together on heavy white cardboard for reproduction as a single cut as grouping is more economical. Each figure or collection of figures in a plate should be identified along the bottom edge with *author's name, figure number, and size after reproduction*, and on the back with *author's name and title of manuscript*. Use of illustrations not original with the author must bear permission for use and credit to the originator.

The size and proportions of each group of illustrations should be made suitable for reduction to the width of the printed page (7.25 inches double column) or (3.5 inches single column) not more than 8.5 inches in length. Care should be taken to insure that a figure does not occupy any more space than necessary. Excessive white space should be eliminated. Line drawings for reproduction are often made too large. As a general rule, the dimensions should be no greater than 9 x 11 inches. If carefully drawn they need be no more than 50 percent larger than the size desired when in print. Special care should be taken to insure that all lettering is large enough to be read after reduction. A graphic scale should be drawn on each figure to indicate automatically the size of the original regardless of reduction. Original drawings should be submitted for making engravings. In addition to the original illustrations, two photographic copies of each (no larger than 8.5 x 11 inches) must accompany the manuscript, to avoid delay in review.

Figure captions should be typed, double-spaced, in a list on a separate sheet of paper with the heading **FIGURE CAPTIONS**. Line drawings and photographs cannot be combined in a single engraving.

FOOTNOTES. Footnotes to tables are permissible as described above. Reference to the literature is not permitted as footnotes but must be handled as described below. Acknowledgments are incorporated in the regular text at the end of the summary, just before *References Cited*.

Text footnotes are to be avoided; only two kinds are permissible. A footnote on the title may be used to state "Department publication No. . . ." "Supported by a grant from. . ." or "Part of a dissertation submitted in partial fulfillment. . ." A footnote on the author's name may be used to state "Present address. . ." or "Fellow of the . . ."

REFERENCES. References to scientific literature should be in a list, arranged alphabetically by author's last name, and typed, single-spaced, on a separate sheet of paper at the end of the text. They should not be numbered. The page should be entitled **REFERENCES CITED**, typed in caps and centered. Examine recent issues of the *Transactions* for the detailed form. References are referred to in the text as Anderson (1976) or (Anderson, 1976). In case of more than two authors, Bishop, *et al.* may be used in the text, but all coauthors must be listed in the reference section. Total number of pages should be given for books or other publications.

ABSTRACTS. The abstract should be a concise summary of the significant facts contained in the paper. It should be sufficient within itself, presenting the main conclusions of the paper, any new compound, species, or mineral, etc. described, and any new methods of procedures critical to the results presented in the paper. It should be brief and concise, not over 250 words. Complete sentences should be used to promote comprehension and clarity and to avoid ambiguity. Words such as "are presented" or "as explained" should be avoided. Abstracts are not to contain illustrations, tables, references, or footnotes.

