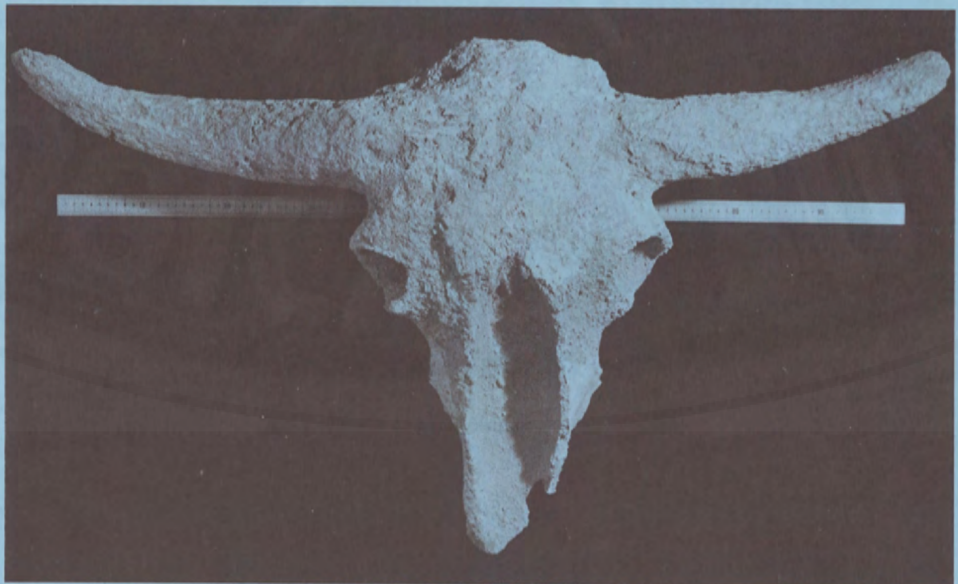
THE GEOLOGICAL SURVEY OF WYOMING

Daniel N. Miller, Jr., State Geologist

REPORT OF INVESTIGATIONS NO. 10

APPLIED GEOLOGY AND ARCHAEOLOGY: THE HOLOCENE HISTORY OF WYOMING

Michael Wilson, Editor



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APPLIED GEOLOGY AND ARCHAEOLOGY: THE HOLOCENE HISTORY OF WYOMING

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September 1974

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BACK COVER: *Distribution of some archaeological mammoth kills, early bison kills (large horn cores), and late bison kills (small horn cores) in Wyoming.*

INTRODUCTION

HOLOCENE STUDIES AND THE INTERDISCIPLINARY APPROACH

One of the most familiar words in the household of modern science is the word "interdisciplinary". Indeed, use of the word seems to be a prerequisite for recognition in many scientific circles. The fact is, we are beginning to become aware of the intense fragmentation that has gone on during the twentieth-century expansion of science. Some scientists are genuinely trying to counter the effects of such fragmentation -- with its jargons and myriad journals -- through the encouragement of boundary-spanning projects, programs, and symposia.

Regrettably, an even greater number of scientists are giving mere lip service to such efforts. Although members of interdisciplinary associations, they attempt to represent themselves to the association members as spokesmen for their own, more restricted disciplines. I sensed this very strongly at the 1974 meeting of the American Quaternary Association, held from July 30 to August 1, in Madison, Wisconsin. Few speakers addressed themselves directly to projects or problems spanning disciplines: most merely reported on their own progress as geologists, geographers, archaeologists, or hydrologists -- apparently in the hope that an interdisciplinary mood or spirit was all that was required.

But this misses the point of the American Quaternary Association by a considerable mark: a point which was fortunately brought home by Dr. Reid A. Bryson late in the conference[1]. There is no reason why individuals cannot be truly interdisciplinary in their approach to the Quaternary, particularly in view of the fact that the boundaries of disciplines (while assumed to exist) are almost impossible to discern. We can, and must, work together in the hope of producing predictive principles of social as well as scientific value.

It would be a challenging task for an enterprising young researcher to generate a project which was completely circumscribed within the bounds of one academic discipline. Rare is the history project devoid of any sociological significance; or the geology project independent of the fields of biology and physics. Indeed, in the realm of paleontological studies, for instance, there is reached a point at which it is impossible to say with any conviction whether a project is indeed geological or biological.

There is, of course, a way to sidestep the question: we may simply brand it as meaningless, and point out that the study is both geological <u>and</u> biological. But this does not satisfactorily describe the situation in a <u>practical</u> sense at many of our universities. The fact is, such a boundary-straddling project is not likely to be conducted from a theoretical position also straddling the boundary. Such a project is generally conducted from the perspective of one of the contributory disciplines -- but not both. It is nearly impossible to ignore the "boundary" and work simultaneously on both sides of the line.

It strikes me that the reason for this could be that academic departments at universities and other research facilities are not solely, or even primarily the reflection of natural boundaries in fields of study. They have developed in an increasingly ramose pattern through time because of the need for non-academic administrative structures in the enclosing institutions. Because departmental administrators tend to be academic practitioners doubling in their administrative roles, the administrative integrity of a department easily becomes translated into academic integrity. To get allocation of funds for geology departments, we stress the unitary nature of the field in a competitive setting -- as we compete with physicists, chemists, biologists, and others for money. We stress the past and potential contribution of <u>our</u> field, at the expense of others.

In broad historical perspective, it appears that the splitting of what used to be known (even in universities) as "Natural History" into an ever-increasing number of branches has coincided with the vast proliferation and enormous growth of post-

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[1]Bryson, Reid A. (1974) The lessons of the past: what Quaternary Studies will tell us about the environment and the future. Paper presented at Third Biennial Meeting of the American Quaternary Association, August 1, 1974.

secondary institutions in the Western world. I think that the competitive element is important here. Natural History departments tended to linger longest in museums, often in situations where private endowment reduced the necessity for aggressive competition for funds. In modern universities, competition for funds goes beyond the university superstructure to government-operated and private granting agencies; and the more intense, national (or even international) competition for such funds increases the need for "grantsmanship". Grantsmanship involves putting one's best foot forward, and of course, doing the same for one's discipline -- hopefully at the expense of other applicants.

The splitting of broad disciplines into component "fields", or "departments" (and now, "disciplines", all over again) has its own built-in positive feedback system. The abandonment of generalism in favor of particularism has resulted in a geometrically increasing flood of paperwork, and the rise of numerous scientific jargons -- often mutually unintelligible. Despite predictions that someday things will have to reach a plateau of sorts when the flood of information outstrips our ability to disseminate it, and interdepartmental communication becomes a physical impossibility, the flood tide continues to inundate our libraries and overwhelm our scholastic recruits, causing them for pragmatic reasons to limit their fields of interest. By limiting their fields of interest, they fit well into the modern split disciplines.

There are more serious consequences that go far beyond this simple feedback system. Kuhn[2] has observed that major breakthroughs at scientific frontiers are not usually the result of dogged application of the scientific method. The discoverers usually are using methods and theories not in the mainstream of their disciplines. Thus it is that their discoveries -- in vindication of their unorthodox procedures -- result in true scientific revolutions. Mainstream scientists, when studying suites of data, may try to analyze the clusters, in the hopes of producing laws of general applicability. Thus they will try to fit regression lines, or ellipses of equal probability, or other cluster-analytic devices to their data. Unorthodox scientists may ignore these clusters of data in favor of the one or two bits that <u>do not</u> fit the cluster. Such bits could be viewed as "contamination" of a cluster <u>due to</u> the interference of a second, previously undetected law or rule. Regularity in the orbital behavior of the planet Neptune allows us to describe in very elite terms where and when and how the planet will travel in its orbit. But <u>irregular</u> orbital behavior superimposed upon this regular, predictable base allowed the discovery of an additional planet, Pluto.

What is particularly important here is that as disciplines become narrower and narrower -- through the splitting, or "budding off" of subdisciplines to become full disciplines in their own right -- the impact of individual revolutionary discoveries becomes relatively larger. This increasing impact sponsored the recent (but already trite) term "quantum leap" as scientists cast about for some way to describe the situation. Magoroh Maruyama, in a 1963 paper describing The Second Cybernetics, provided us with an insight into what can happen when sudden change strikes a positive feedback system (such as we have described above).[3] A great many feedback systems are not equilibrating, or deviation-counteracting; but rather, <u>deviation-amplifying</u>:

> Such systems are ubiquitous: accumulation of capital in industry, evolution of living organisms, the rise of cultures of various types, interpersonal processes which produce mental illness, international conflicts, and the processes that are loosely termed as "vicious circles" and "compound interests"; in short, all processes of mutual causal relationships that amplify an insignificant or accidental initial kick, build up deviation and diverge from the initial condition.[4]

The effect of a revolutionary new <u>paradigm</u> can thus be marked. Kuhn describes a paradigm as an achievement that displays two essential characteristics:

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[2]Kuhn, T. S. (1970) <u>The Structure of Scientific Revolutions</u> (2nd Edition), University of Chicago Press, Chicago, Illinois. 210 p.

[3]Maruyama, Magoroh (1963) The Second Cybernetics: deviation-amplifying mutual causal processes. <u>American Scientist</u>, 51(2):164-179. Easton, Pennsylvania.

[4]<u>ibid</u>., p. 164.

1) the achievement is sufficiently unprecedented that it attracts an enduring group of adherents away from a competing mode of scientific activity; and
2) the achievement is sufficiently open-ended as to leave all sorts of problems for the redefined group of practitioners to resolve.[5]

The acquisition of a paradigm can transform a discipline:

> ... it is sometimes just its reception of a paradigm that transforms a group previously interested merely in the study of nature into a profession or, at least, a discipline. In the sciences (though not in fields like medicine, technology, and law, of which the principal raison d'être is an external social need), the formation of specialized journals, the foundation of specialists' societies, and the claim for a special place in the curriculum have usually been associated with a group's first reception of a single paradigm. At least this was the case between the time, a century and a half ago, when the institutional pattern of scientific specialization first developed and the very recent time when the paraphernalia of specialization acquired a prestige of their own.
>
> The more rigid definition of the scientific group has other consequences. When the individual scientist can take a paradigm for granted, he need no longer, in his major works, attempt to build his field anew, starting from first principles and justifying the use of each concept introduced. That can be left to the writer of textbooks. Given a textbook, however, the creative scientist can begin his research where it leaves off and thus concentrate exclusively upon the subtlest and most esoteric aspects of the natural phenomena that concern his group. And as he does this, his research communiques will begin to change in ways whose evolution has been too little studied but whose modern end products are obvious to all and oppressive to many. No longer will his researches usually be embodied in books addressed, like Franklin's Experiments... on Electricity or Darwin's Origin of Species, to anyone who might be interested in the subject matter of the field. Instead they will usually appear as brief articles addressed only to professional colleagues, the men whose knowledge of a shared paradigm can be assumed and who prove to be the only ones able to read the papers addressed to them.[6]

Since these mutual causal systems are deviation-amplifying, there can be no doubt that the acquisition of a major new paradigm today can result almost overnight in the development of a new academic discipline -- and department. The "initial kick" causes significant divergence from the original condition.

As Kuhn points out, this process has been too little studied, considering its impact. I am not even certain that I should attempt to criticize the process (or its blind implementation). But I do wish to call attention to the fact that most so-called "academic" departments are in reality administrative departments that have arisen in response to the physical growth of institutions, the structure of granting institutions, and the physical problems of communication. Once set in motion, these departments, functioning as groups of scientists, develop the self-esteem necessary to keep themselves in motion.

A case in point is the situation in American anthropology. In 18th and 19th-century North America researchers of diverse sociopolitical and academic backgrounds conducted field ethnographic studies and excavated archaeological sites. Thomas Jefferson in 1784 excavated a burial mound in the enlightened spirit and with all the scientific accuracy of his time.[7] J. O. Dorsey and Alice Fletcher spent years among Indian groups such as the Omaha, recording their customs, material culture, and language.[8]

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[5]Kuhn, op. cit., p. 10.

[6]Kuhn, ibid., p. 19-20.

[7]Jennings, Jesse D. (1968) Prehistory of North America, McGraw-Hill Book Co., New York, p. 32.

[8]Fletcher, Alice C., and F. LaFlesche (1906) The Omaha Tribe, Annual Report of the Bureau of American Ethnology, 27:17-654. Washington, D.C.
Dorsey, J. O. (1892) Omaha dwellings, furniture, and implements, Annual Report of the Bureau of American Ethnology, 13:263-288. Washington, D.C.

Yet Franz Boas is often considered the "Father" of North American anthropology, because he occupied the first university Chair of Anthropology that resulted in the graduation of specialized anthropology students. Thus began the "laying on of hands" in a series of university-sanctioned official anthropologists, in a process that continues to this day.

Today, amateur researchers working without affiliation to learning institutions are very often scorned by official anthropologists, who doubt that such amateurs possess adequate resources with which to make meaningful contributions. As the new paradigm brings specialized societies and journals, it also brings a move to certify practitioners of the field -- practitioners who comply with "acceptable" academic standards. Even those who write books directed to the public at large (instead of their colleagues) are often the subject of derision -- especially if such a book raises public controversy (for instance, the controversy surrounding Morris' book, The Naked Ape).[9]

We thus see the emergence of new disciplines as a process inextricably intertwined with the growth of research and teaching institutions, the endowment of new "Chairs", the copious dissemination of research funds, and the establishment by eminent scholars of "schools" of students pursuing common sub-disciplines. We label groups of scholars if at all possible, in order to make it easier for us to understand the overall impact of their "common" philosophy. We set apart the "British School of Social Anthropology" from the "French School", and so on. We pretend that the functionalism of A. R. Radcliffe-Brown was really miles away from the functionalism of Bronislaw Malinowski -- even though G. Homans has quite clearly shown that these two worthies were talking past one another -- in ignorance of the closeness of their positions![10] It is much easier to dichotomize such entities than to enumerate their common features and demonstrate their historical identity.

It is difficult to find definite cause-and-effect in all of this process, though the correlation of events may be clear. Perhaps the rise of split disciplines in reality caused the growth of post-secondary institutions. As we have seen, these are mutual causal relationships, and as such, any small initial kick can set them in motion.

Here we face a problem similar to that encountered by J. Hoover Mackin[11] in his classic study of the graded river: do meanders "cause" the stream gradient to be what it is, or does the relationship of stream gradient to an ideal gradient "cause" the meanders to form? Is either answer really possible? Are both answers possible, as mutual causal processes, in a feedback system set in motion by some other, unmentioned initial kick?

Whatever the final opinion of the reader -- and that is all an answer really is -- we must come to grips with the problem of dealing with academic boundaries. Boundaries beget identification, and identification (through self-esteem, patriotism, chauvinism, and so on) leads boundaries to appear to be (or even to become) true discontinuities. It is the appearance of such discontinuities that we must combat, for they are the unwanted by-product of the administrative subdivision of academic disciplines.

We have only to think of academic departments (or disciplines) as facies of the overall field of Natural History -- or, beyond this, of Philosophy. When sand and silt are ideally dichotomized by a sedimentary geologist, there is no implied discontinuity in populations. In definition, sand grades right into silt. We can find grains of all sizes through this interval in nature, although differential transport and other environmental agencies may sort and localize certain populations. The sedimentary geologist needs to talk of certain grain size populations as indicators of specific sedimentary environments. Thus arbitrary boundaries are drawn, so that

[9]Morris, Desmond (1967) The Naked Ape, McGraw-Hill Book Co., New York. 252 p.

[10]See discussion of this bilateral monologue in Harris, Marvin (1968) The Rise of Anthropological Theory, T. Y. Crowell Co., New York, p. 545-556. See also Homans, G. (1941) Anxiety and ritual: the theories of Malinowski and Radcliffe-Brown, American Anthropologist, 43:164-172.

[11]Mackin, J. H. (1963) Rational and empirical methods of investigation in geology. In C. C. Albritton, Jr. (Ed.), The Fabric of Geology: 135-163. Addison-Wesley Publ. Co., Reading, Massachusetts.

grain size can be related to the boundaries, and communicable descriptions can be made. Geologists have tried to make these boundaries coincide with commonly observed boundaries in sorted deposits[12], but this does not imply the existence of such boundaries in the idealized natural continuum of grain sizes.

If academic boundaries are indeed simply facies, there are as many projects to be pursued at the boundaries as there are at the cores of the disciplines. It thus seems reasonable that universities should cater to this reality. While the boundaries must remain for pragmatic administrative purposes, students should be encouraged to incorporate methods, theories, and other assistance from both sides of such boundaries -- and thus they will not be discouraged from working at the periphery of a given discipline. No one is going to fall off the edge of the academic world -- flat as it may appear at times -- when he reaches the boundary of a discipline.

Many universities now allow students to receive cross-credit between departments during their pursuit of degrees. But a great many do not, and the latter group is unconsciously fostering the loss of communication between disciplines.

The insidious nature of this evolutionary process is indeed echoed in the work of those who today straddle the boundaries. As we have seen, many of these practitioners call themselves (or their projects) "interdisciplinary". But this very word presumes the definition of the disciplines, and through its use we renounce all intention to reconcile disciplines -- no matter how split they may be. The word itself tends to amplify the importance of the boundary being straddled; and as such, it is hardly a contribution to the improvement of communication. Indeed, it seems that today, interdisciplinary studies are rapidly becoming disciplines of their own -- witness the rise of "Geoarchaeology" and "Zooarchaeology".

I thus do not wish to call the present memoir an "interdisciplinary" approach to Holocene studies. I frankly do not care what discipline a scientist may wish to call his own. What is important is that a number of us are interested in the last several thousand years of earth history; and such history can be approached from a number of directions. If we are all able to communicate among ourselves -- despite our diverse backgrounds, I am overjoyed.

I sense that the present memoir does, however, contain a considerable amount of scientific terminology -- and, as such, it is not readily accessible at first reading to the layman. But I do not disparage the amateur in his quest for knowledge. Let us not talk down to the amateur; let us not be condescending in our approach to him. I heartily encourage amateur archaeologists and geologists -- and just plain amateurs not weighted down with the Albatross of academic tags -- to give the subject and this memoir a try. May we all benefit by it.

The Holocene period -- the last 15,000 years or so -- has indeed been studied in Wyoming prior to this attempt. That fact is evident from the bibliographies in this memoir. Our intent here is not to claim a "first" in the publication of a special memoir on the subject. Nor do we wish to claim that this memoir "brings together" all previous information in a summary volume. Far from it: our intent is merely to publish a contribution to the ongoing study of the Holocene epoch in Wyoming. As such, the papers range from descriptive studies to theoretical studies. The theoretical, or "methods" papers (such as those of Andrews and Webber, and Steidtmann) are presented because it is felt that they will be very helpful to future students of the Holocene in this area. I specifically invited these papers because I sensed the theoretical contribution of their authors to be considerable.

Some material is included here with the specific intent of eliciting interest among students or researchers seeking descriptive problems. The Casper terrace study (Albanese and Wilson) is extremely preliminary. Yet the potential along the North Platte river system for regional comparison of terrace sequences (especially, for instance, with the well-documented terraces of eastern Nebraska) leads us to believe that much descriptive work should be done here in Wyoming. We do not wish to lay claim to the project -- rather, we appeal to others to take advantage of the special opportunities for detailed study in the Casper area.

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[12] Pettijohn, F. J. (1957) Sedimentary Rocks (2nd Ed.), Harper and Row, New York, p. 15-21 and 49.

Archaeological and paleontological studies are still in their infancy here, although I am led to wonder what the term "infancy" really means. John Milton's observation that a sphere of light serves only to make perceptible the darkness surrounding it,[13] has rather chilling relevance to the growth of science. The more we know, the more we perceive that we do not know. In this sense, we are faced with the paradox that the more we progress, the greater is our perception that we are only in our infancy!

Within the last three decades, the emphasis in chronological studies at the Holocene time level has shifted from studies of archaeological and paleontological assemblages to radiometric dating. Some students of the Holocene now find themselves bound by a <u>need</u> for radiometric dates before they feel able to make confident statements. But <u>this</u> need not be the case. Although geologists make use of radiometric dates, suites of fossils are still used as indicators of time period -- be they Devonian, or Cretaceous, or even Pleistocene.

Leopold and Miller[14] "recalled" that several previous authors had been using geologic deposits -- such as those in terrace sequences -- to date archaeological materials. In fact, numerous such authors were doing just the reverse -- using archaeological materials to date geologic deposits! We can do the same today, although radiometric date addicts may pounce upon us at first. In fact, there <u>are</u> certain datable styles of artifacts. Once they are reasonably well controlled <u>in</u> a temporal sense in one area, they can themselves be used as temporal indicators at sites in the same area. This is a large part of the basis of Mulloy's (1958) classic historical outline for the Northwestern Plains. Archaeological remains are the index fossils of the Holocene.

ACKNOWLEDGEMENTS

The preparation of this volume has been far from a one-man show. The authors of papers presented here have been to a person most helpful in their preparation of textual and illustrative material, and in discussions of the Holocene epoch in its many facets. Dr. George C. Frison and Dr. Daniel N. Miller Jr. provided me with very welcome encouragement when it was needed most -- at the very inception of the project. Sally L. Petersen, as Wyoming Geological Survey editor, deserves almost sole credit for the stylistic continuity of the memoir, and without her assistance I would doubtless have drowned in a sea of editorial blue marks. Sue Baskett Harden, Colleen Kelly, and Linda Coffin undertook the typing of manuscripts onto masters. My wife and colleague, Diane J. Wilson, helped in many ways, overseeing the accuracy of radiocarbon dates, helping to prepare illustrations, and above all, putting up with occasional suppers at 2 a.m. My sincere gratitude is expressed to all.

Michael Wilson
Laramie, Wyoming
August 4, 1974

[13]Describing Hell in <u>Paradise Lost</u>, Milton observes

...one great furnace flamed, yet from those flames
No light, but rather darkness visible
Served only to discover sights of woe...

Milton, John (1961 edition) <u>Paradise Lost, Samson Agonistes, Lycidas</u>, Mentor Books, New York, p. 38.

[14]Leopold, Luna B., and John P. Miller (1954) A postglacial chronology for some alluvial valleys in Wyoming. <u>U. S. Geological Survey Water Supply Paper</u> 1251, p. 47.

GEOLOGIC HISTORY OF WYOMING LANDSCAPES

S. H. KNIGHT[1]

INTRODUCTION

The history of the Earth as recorded in rocks open to observation began some 3.5 billion years ago. The oldest dated rocks in Wyoming are more than 3.0 billion years old. The physical relief of the state as it now exists had its beginning some 70 million years ago. This review, therefore, treats the last small fraction of the geologic history of the state.

Wyoming landscapes include diverse landforms, with such major features as mountain ranges, intermontane basins, plains, and plateaus; and many lesser features such as canyons, valleys, mesas, buttes, hogbacks, flood plains, terraces, badlands, wind-eroded depressions, landslides, and sand dunes. These forms originated in response to the eternal conflict between two groups of forces.

The forces of one group operate within the earth's crust. They manifest themselves by periodic movements of the crust; and by the rise of liquid and gaseous rock-forming material (magma) into the crust, or to the surface as volcanic outpouring of lava, gases, and fragmental debris -- collectively referred to as ejecta. The second group of forces operates on the surface and includes running water, moving ice, waves, wind, and chemical action. The first group of forces builds highlands and the second group destroys them.

ROCKS AND HISTORY

The character and relative positions of rock masses play a significant role in the evolution of landscapes. For the purpose of this review the rocks common to the state are divided into three major groups. These are as follows:

1. <u>Basement complex rocks of Precambrian age (3.0 billion years to 600 million years B.P.[2])</u>: this complex is made up of assemblages of igneous rocks (for example, granite and basalt) and metamorphic rocks (for example, gneiss, schist, slate, and quartzite). These rocks are extensively exposed in the cores of the mountain ranges extending across the state from the southeast to the northwest (see Fig. 1 for structural areas); and in the Hartville uplift and the Black Hills.[3] The rocks of this complex are much more resistant to erosion than those of the two remaining groups.

2. <u>The older sedimentary rock succession of Paleozoic and Mesozoic age (600 million years to 65 million years B.P.)</u>: the rocks of this succession are exposed in the Wyoming and Salt River Ranges, the hogback zones flanking the major ranges, the cores of many minor upfolds such as the Rock Springs uplift, and on the floors of the intermontane basins. They are made up of conglomerates, sandstones, shales, limestones, and dolomites. The maximum aggregate thickness of this succession is more than 30,000 feet.

3. <u>The younger sedimentary succession of Tertiary and Quaternary age (65 million years B.P. to present)</u>: this succession is made up of rock debris derived from the erosion of mountains, and from the buildup of volcanic ejecta. Between 50 and 60 per cent of the surface area of the state is covered by rocks of this succession. Occurrences of these rocks vary in thickness from a few feet to a maximum of 20,000 feet.

HISTORICAL RECONSTRUCTION

In an attempt to summarize the main events which brought about great changes in the landscape during the last 70 million years, the writer has divided the history into a series of stages. The stages are of unequal duration and they reflect the major changes brought about by three factors.

1. <u>Periodic movements of the crust</u>: at times compressional forces folded the crust into large and small upfolds and downfolds. The large upfolds (anticlines) became mountains, and the large downfolds (synclines) became intermontane basins. Where folding was intense the rocks broke along low-angle shear zones and the upfolded segments were moved laterally over the adjacent downfolds through distances as much as several miles. Such situations are called "thrust faults". At other times, parts of the region were differentially uplifted without folding, with the development of high-angle tensional ("normal") faults.

2. <u>Erosion, transport, and deposition of vast amounts of rock debris</u>: thousands of feet of rock debris were eroded from the upper reaches of the mountain upfolds, and deposited in the developing intermontane basins or transported out of the region.

3. <u>Periodic volcanic activity, with the outpouring of volcanic ejecta</u>: volcanoes were intermittently active throughout part of the last 70 million years in the Yellowstone Park area and the adjacent Absaroka Range. Less extensive volcanism was also present at times in the Black Hills, the Rattlesnake Hills west of Casper, and the Leucite Hills northeast of Rock Springs.

---

[1]Professor Emeritus of Geology, University of Wyoming, Laramie, Wyoming 82071.

[2]B.P. stands for "Before Present".

[3]Editor's note: more detailed information of a survey nature relative to these named structural areas may be found in Blackstone (1971), cited at the end of this paper.

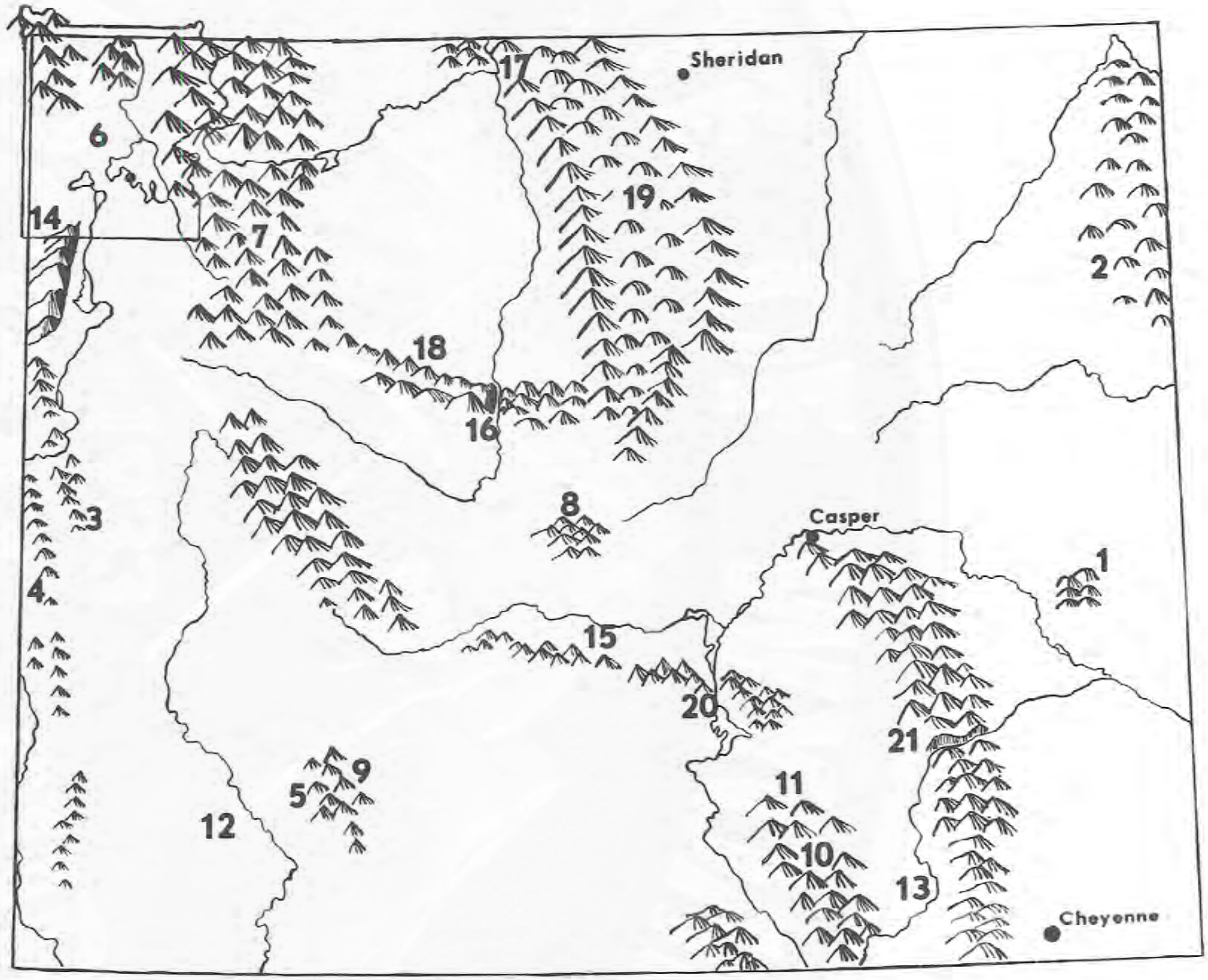


FIGURE 1. Outline relief map of Wyoming showing structural features discussed in the text. The numbered features are as follows:

1. Hartville uplift
2. Black Hills
3. Wyoming Range
4. Salt River Range
5. Rock Springs uplift
6. Yellowstone National Park
7. Absaroka Range
8. Rattlesnake Hills
9. Leucite Hills
10. Snowy Range
11. Medicine Bow Mountains
12. Green River basin
13. Laramie basin
14. Teton Range
15. Sweetwater upfold
16. Wind River Canyon
17. Bighorn Canyon
18. Owl Creek Mountains
19. Bighorn Mountains
20. North Platte Canyon
21. Laramie River Canyon

A PICTORIAL HISTORY

The following diagrams (Figs. 2 to 6) illustrate a portion of a representative intermontane basin with flanking mountain ranges, showing the relief as it existed at the end of each of five stages, as interpreted by the writer. Following each diagram is a brief description of the history of the stage.

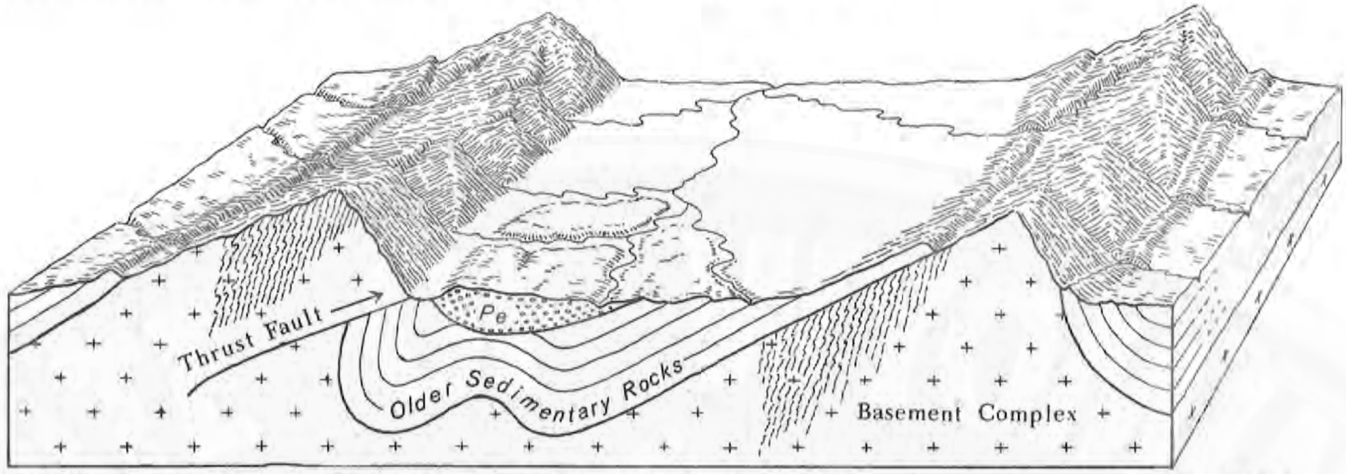


FIGURE 2. Reconstruction of Stage 1: Late Cretaceous and Paleocene (Pe in diagrams) to lower Eocene times; from 70 to 50 million years B.P.

Stage 1: Late Cretaceous, Paleocene, and early Eocene (70 to 50 million years B.P.) (Fig. 2). Compressional forces operating intermittently throughout this stage folded the crust into large and small anticlines and synclines, resulting in a series of linear mountain ranges and intermontane basins. It was during this time of folding that the basic pattern of the physical geography of the state came into being. Periods of folding were followed by long periods of relative crustal stability. As the mountains rose they were attacked by erosion and vast quantities of rock debris were transported from their higher reaches and deposited in the intermontane basins and lowlands beyond.

If one had journeyed into the region following the last compressional movements in early Eocene time (Fig. 2), he would have found the basins flanked by spectacular mountains, the crests of which stood several thousand feet higher with respect to the basin floors than they do today. He would also have found that the basin floors, which now stand at elevations from 4,000 to 8,000 feet, were not more than a few hundred feet above sea level. Drainage from the basins escaped through their open ends. A semi-tropical climate prevailed and luxurious coal-forming forests grew on the basin floors.

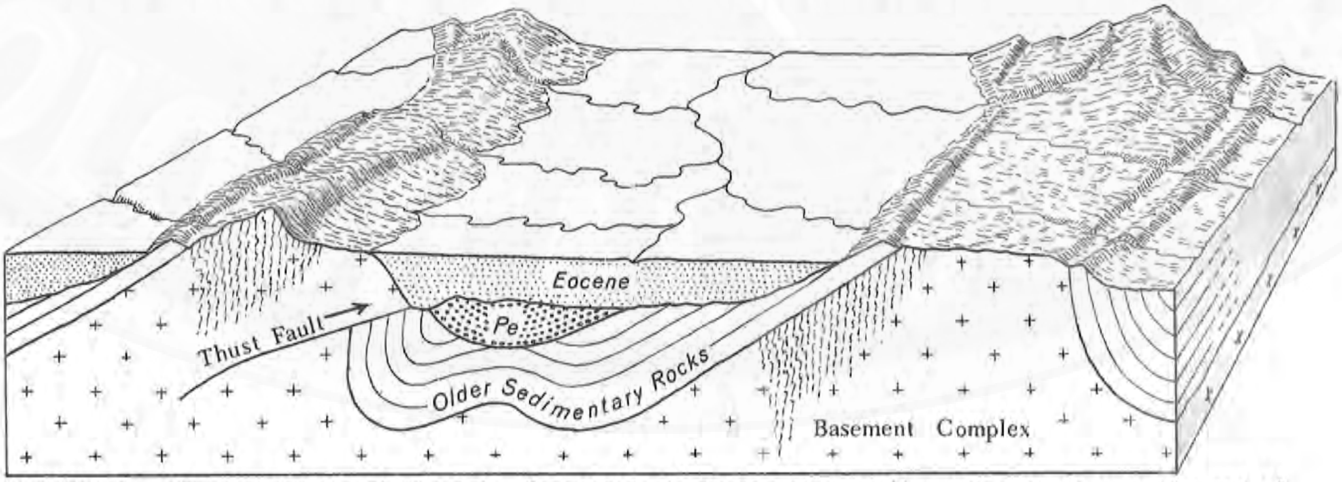


FIGURE 3. Reconstruction of Stage 2: from early in Eocene time until a point at or near the end of middle Eocene time; from 53 million to 47 million years B.P.

Stage 2: early Eocene to middle Eocene (53 to 47 million years B.P.) (Fig. 3). During this stage the crust remained relatively stable and erosion greatly reduced the upper reaches of the mountains. The resulting rock debris was deposited in the basins.

If one had visited the region at the

end of this stage, the only conspicuous relief would have been erosional remnants of the pre-existing mountains. These remnants rose above an erosional surface of moderate relief and were more commanding than they are today. A representative modern example of such a remnant is the Snowy Range in the Medicine Bow Mountains which owes its existence to the exceptional durability of the rock (Medicine Peak Quartzite) of which it is composed.

With the exception of the conspicuous erosional remnants, the region consisted in part of an erosional surface of moderate relief cut in the resistant core rocks of the mountains; and in part, of a depositional surface over the basins and the buried flanks of the mountains. Often during the filling of the basins the drainage was impounded in lakes. One of the larger, if not the largest, of these lakes during its maximum extent covered several thousand square miles on the floor of the Green River Basin. In time, such lakes were filled with sediments. Throughout this stage, the basin floors remained relatively low with respect to sea level.

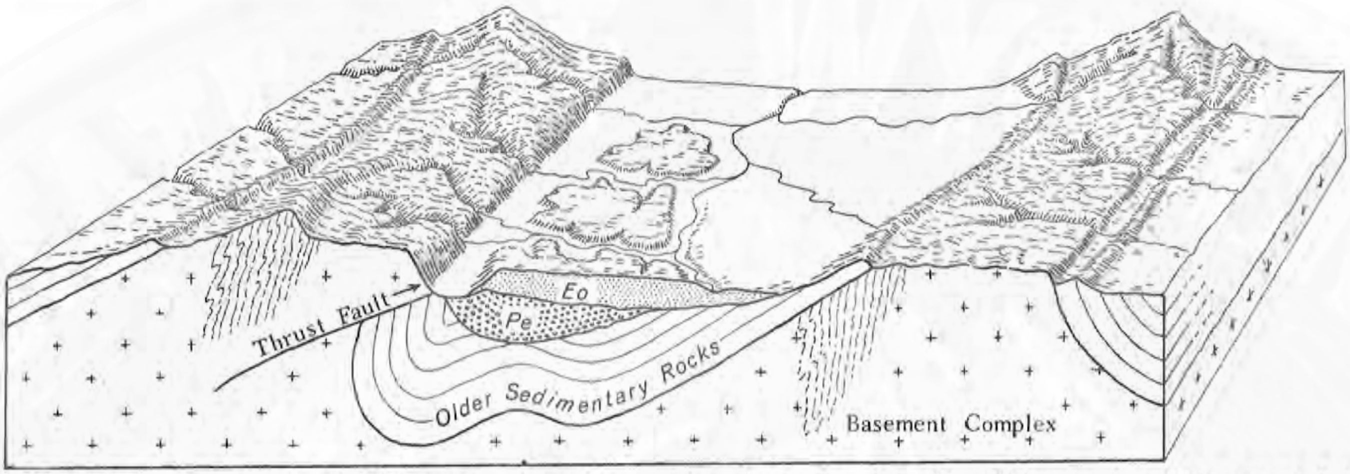


FIGURE 4. Reconstruction of Stage 3: late Eocene time, from more than 47 million to 37 million years B.P.

<u>Stage 3: late Eocene (47 or more to 37 million years B.P.)</u> (Fig. 4). At the end of middle Eocene time or early in late Eocene time the region was uplifted differentially without folding. This uplift brought on a new cycle of erosion during which much of the existing Tertiary sediments were removed from the higher basins, such as the Laramie Basin. This debris was deposited in the lower basins or transported out of the region. As the higher basins were emptied, the mountain flanks were exposed and streams excavated canyons in the resistant basement complex rocks of the mountain cores.

If one had visited the region at the end of this stage, he would have found a landscape quite similar in its major aspects to that which exists today. The flanking mountains stood at about the same relative height above the basin floors, which were lower with respect to sea level than they are today. The canyons excavated in the basement complex of the mountain cores were near their present depths.

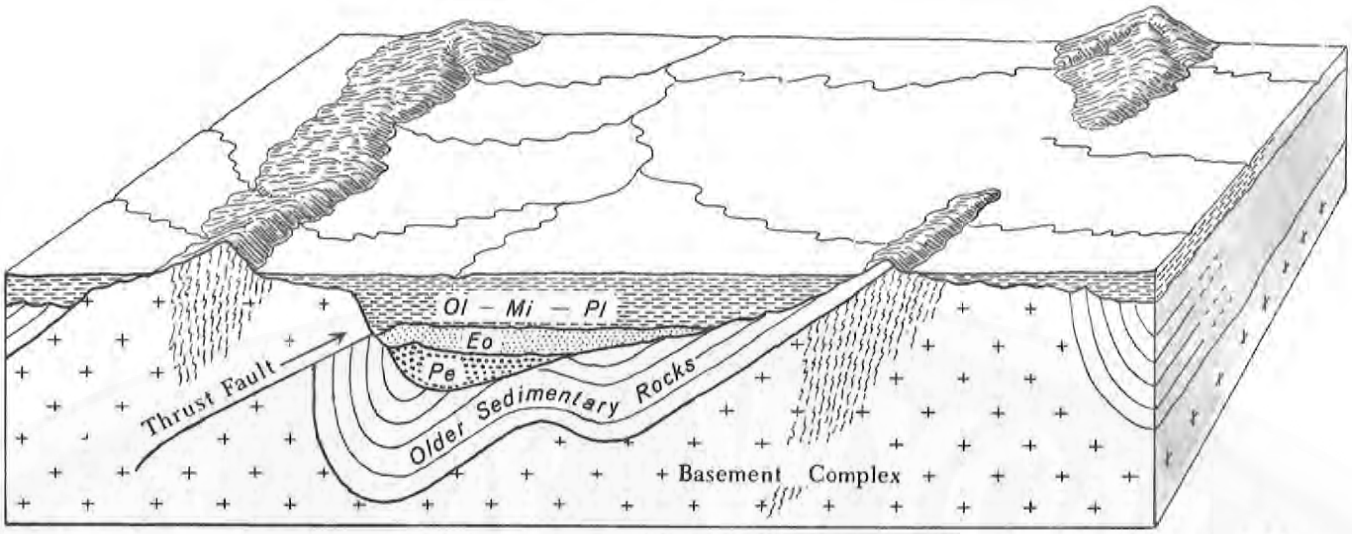


FIGURE 5. Reconstruction of Stage 4: Oligocene (Ol), Miocene (Mi), and Pliocene (Pl) times; from 37 million to more than 2 million years B.P.

Stage 4: Oligocene, Miocene, and Pliocene (37 to more than 2 million years B.P.) (Fig. 5). The fourth stage in our story was a prolonged one during which the basins and all but the higher portions of the mountains were buried under sediments. These were derived in part from volcanic ash falls, and in part from debris from the adjacent highlands. During this stage, and especially early in its history, vast amounts of volcanic ash were deposited over the region. Volcanic ash is made up of minute rock particles ejected from explosive volcanoes and may be transported great distances in the atmosphere. Numerous volcanoes throughout the Rocky Mountain region and farther west were active during this stage. Some of these must have exploded from time to time on a grand scale, to have produced the enormous amounts of ash which fell on the region. Today, erosional remnants of these deposits occur at elevations up to 10,000 feet. On the basis of such occurrences it is concluded that at the end of this stage most of the region lay buried under these sediments, which had filled the basins and overflowed low places on the mountain divides.

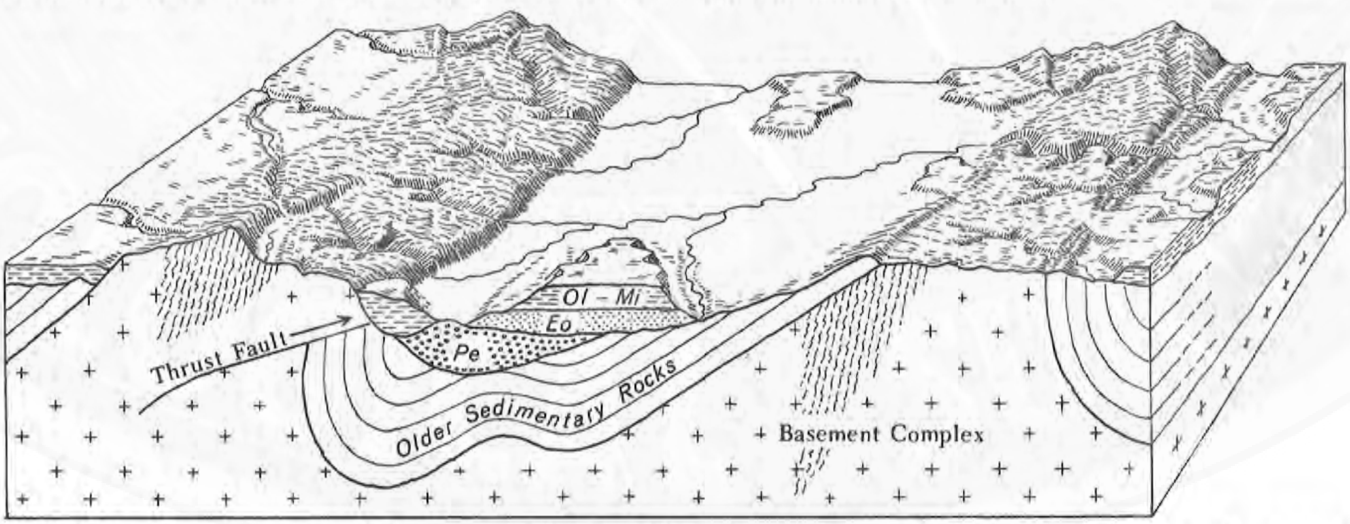


FIGURE 6. Reconstruction of Stage 5: Quaternary time; from more than 2 million years B.P. to the present.

Stage 5: Quaternary (More than 2 million years B.P. to the present) (Fig. 6). At or near the end of Pliocene time, more than 2 million years ago, the region was again differentially uplifted and the present cycle of erosion came into being. It was during this period of uplift that the region attained its relatively great altitude. Wyoming is the second highest state in the United States, with a mean elevation of 6,700 feet above sea level. The uplifted Quaternary surface was warped and broken in places by normal faults. It was on this uplifted, warped, and faulted surface that the present drainage pattern of the master streams was established. Normal faulting along high-angle shear zones gave rise to such outstanding features as the Teton

Range, the collapse of the core of the Sweetwater upfold, and many less conspicuous features. Since the beginning of this stage the basins have been re-excavated to varying degrees.

RELIEF AND RIVERS

Today an interesting relationship exists between the relief and the drainage pattern of the master rivers, in that the rivers seem not to respect the mountains as they now exist. It is a novel experience to travel down a river flowing on the floor of an intermontane basin and suddenly enter a precipitous canyon from one to three thousand feet deep, excavated by the river <u>through</u> a flanking mountain range. Going down a river into and through a mountain range is indeed contrary to expectation, making this the most striking feature of the physical geography of the region.

To understand the lack of adjustment of the master rivers to existing relief one must go back to a time early in the Quaternary stage when the master rivers established their courses on the uplifted depositional surface of late Tertiary sediments (Fig. 5). The reader will recall that such sediments had buried low places on the mountain divides. The rivers followed the gradient of this surface and escaped from higher to lower basins where the surface extended over the buried mountains. As the basins were re-excavated, the Late Tertiary sediments were stripped from the buried mountain divides and canyons were excavated in the more resistant underlying rocks. In other words, the rivers were <u>superimposed</u> on the relief buried beneath the Late Tertiary sediments. The spectacular Wind River and Bighorn Canyons were excavated largely in the older sedimentary rock succession where these rocks arch over the Owl Creek and Bighorn Mountains, respectively. The superimposed canyons of the North Platte and Laramie Rivers were excavated in the more resistant basement complex rocks.

Numerous familiar land forms occur on the floors of the basins, as a result of Quaternary erosion and deposition. These features include mesas, buttes, pediment surfaces (benches), hogbacks, river flood plains (both existing and abandoned), terraces, wind-blown depressions, badlands, and sand dunes.

GLACIAL LAND FORMS[4]

The great ice sheets which covered much of the northern portion of the continent during the Pleistocene epoch, or Ice Age, did not reach Wyoming. However, extensive local icecaps formed on the higher reaches of the major mountain ranges, and glaciers descended from them down the existing valleys to the basin floors. The erosive and transportive power of moving ice sculptured the pre-existing landscape into distinctive land forms. Figures 7 and 8 are diagrams of the same area illustrating the relief of the area as it existed prior to glaciation (Fig. 7) and as it exists today, following glaciation (Fig. 8). The various land forms shown in Fig. 8 are as follows:

1. alpine peak
2. U-shaped glacial trough
3. remnant of a glacier
4. cirque, the expanded headwall of a glacial trough
5. hanging valley
6. unglaciated upland
7. terminal moraine impounding a lake
8. mountain front

CONCLUSION

Intermontane basins and mountain

[4]Editor's note: an excellent brief, non-technical summary of Wyoming's alpine glacial land forms, along with excellent photographs, is to be found in Mears (1972).

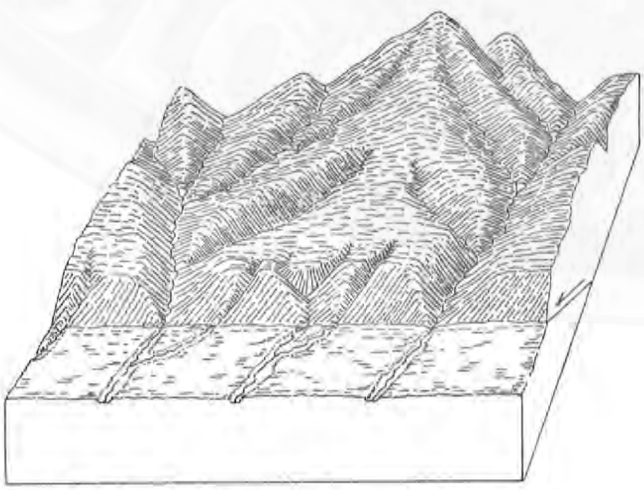


FIGURE 7. A hypothetical mountainous area before glaciation.

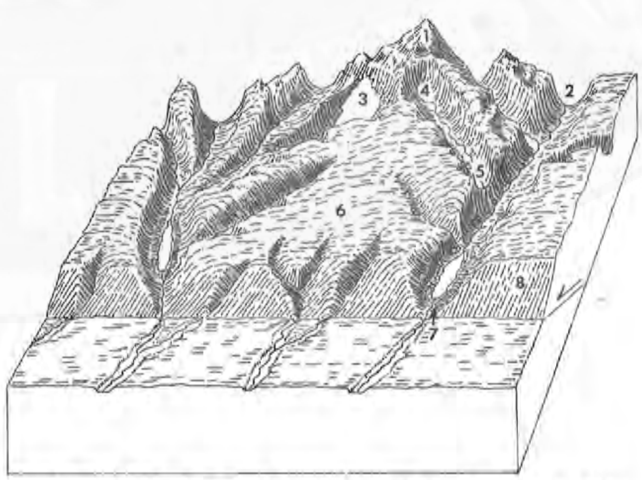


FIGURE 8. The same landscape after mountain glaciation. For key to numbered features, see text.

ranges vary greatly in size, configuration, degree and complexity of folding and faulting, and modification of relief by erosion and deposition of sediments. However, they have imprinted upon them in varying degrees features which reflect periodic movements of the crust, volcanic activity, and erosion and deposition of rock debris since they first came into being some 70 million years ago. Geomorphologists, geographers, archaeologists, and others must keep this background in mind if the interrelationships of modern features are to be understood. In particular, a thorough knowledge of the genesis of the modern landscape will aid the researcher in predicting where features of interest are likely to occur. Through knowledge of the genesis of features of the earth, geology is moving from a purely descriptive science to a predictive science, surely to the benefit of all related disciplines, be they applied or theoretical.

EDITOR'S REFERENCES

Blackstone, D. L., Jr.
1971 Traveler's guide to the geology of Wyoming. The Geological Survey of Wyoming Bulletin, 55:1-90. Laramie, Wyoming.

Mears, Brainerd, Jr.
1972 Wyoming's glaciers, past and present. Wyoming Wildlife, 36(4):26-34. Cheyenne, Wyoming.

PRELIMINARY DESCRIPTION OF THE TERRACES OF THE NORTH PLATTE RIVER AT CASPER, WYOMING

JOHN P. ALBANESE[1] AND MICHAEL WILSON[2]

INTRODUCTION

On its way eastward from the uplands of south-central Wyoming, the North Platte River flows through the city of Casper, Wyoming. Here, it displays in its valley a series of well developed Pleistocene and Holocene alluvial terraces. Such terraces are of considerable interest and importance to the Holocene stratigrapher, inasmuch as their proper recognition can be a guide to the chronology of a river valley. In addition, it is expected that future Holocene stratigraphic work and archaeological excavations in the vicinity of Casper will allow the association of archaeological materials with particular terrace deposits.

The North Platte River valley at Casper is up to 2.5 miles in width, and 140 feet deep. The valley is incised into the Upper Cretaceous Steele Shale, which is exposed in steep river cuts, some tributary valleys, and in man-made excavations such as the large pits at the Casper city dump.

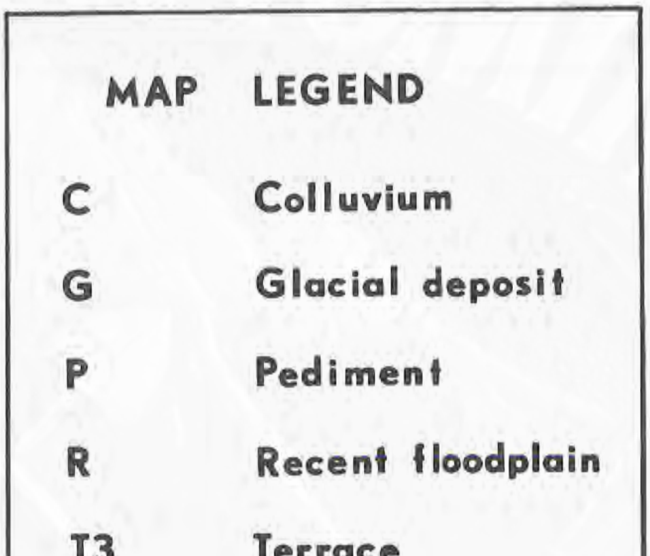
At Casper there is a system of five terraces, two of them of Holocene age, and the remaining three of Pleistocene age. North of Casper the Pleistocene terraces are widely obscured by sand dune fields[3], for the most part made up of stabilized parabolic dunes. South of the river valley, a complex series of pediments is present along the north face of Casper Mountain. The pediment sequence is older than the river terraces and has not yet been investigated.

METHOD OF INVESTIGATION

The present paper is the outgrowth of two independent mapping exercises, one based upon ground survey (by Albanese), and the other based upon high-altitude color aerial photographs[4] (by Wilson). Results of the two exercises were found to be quite similar, indicating that the use of such photographs has validity as an initial research tool. One major drawback of the photographic method was that the terraces were for the most part obscured in heavily built-over areas, even though ground relief in fact still remained. In most areas south of the North Platte River at Casper, ground mapping was required.

The accompanying maps (Figs. 1-3) are the result of the merger of the two mapping exercises, with rechecking in cases of notable discrepancy. Discrepancies resulted almost solely from situations where photographs were indistinct and ambiguous results were obtained. These were resolved easily through the addition of ground data.

It should be pointed out that the maps presented here are very preliminary in nature. At this stage of analysis, multi-colored maps (while easier to interpret) are not warranted, and thus the boundaries are in some cases difficult to discern. Since our intent is to show in a general fashion where the terraces -- rather than the detailed boundaries -- lie, the maps will suffice for the present. Addition of data



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[3]See John P. Albanese, this volume, p. 46-50.

[4]NASA Mission 213, lines 18 and 19.

FIGURE 1. Map of Holocene and Pleistocene terrace distribution along the North Platte River in the vicinity of Red Buttes and Paradise Valley, west of Casper, Wyoming.

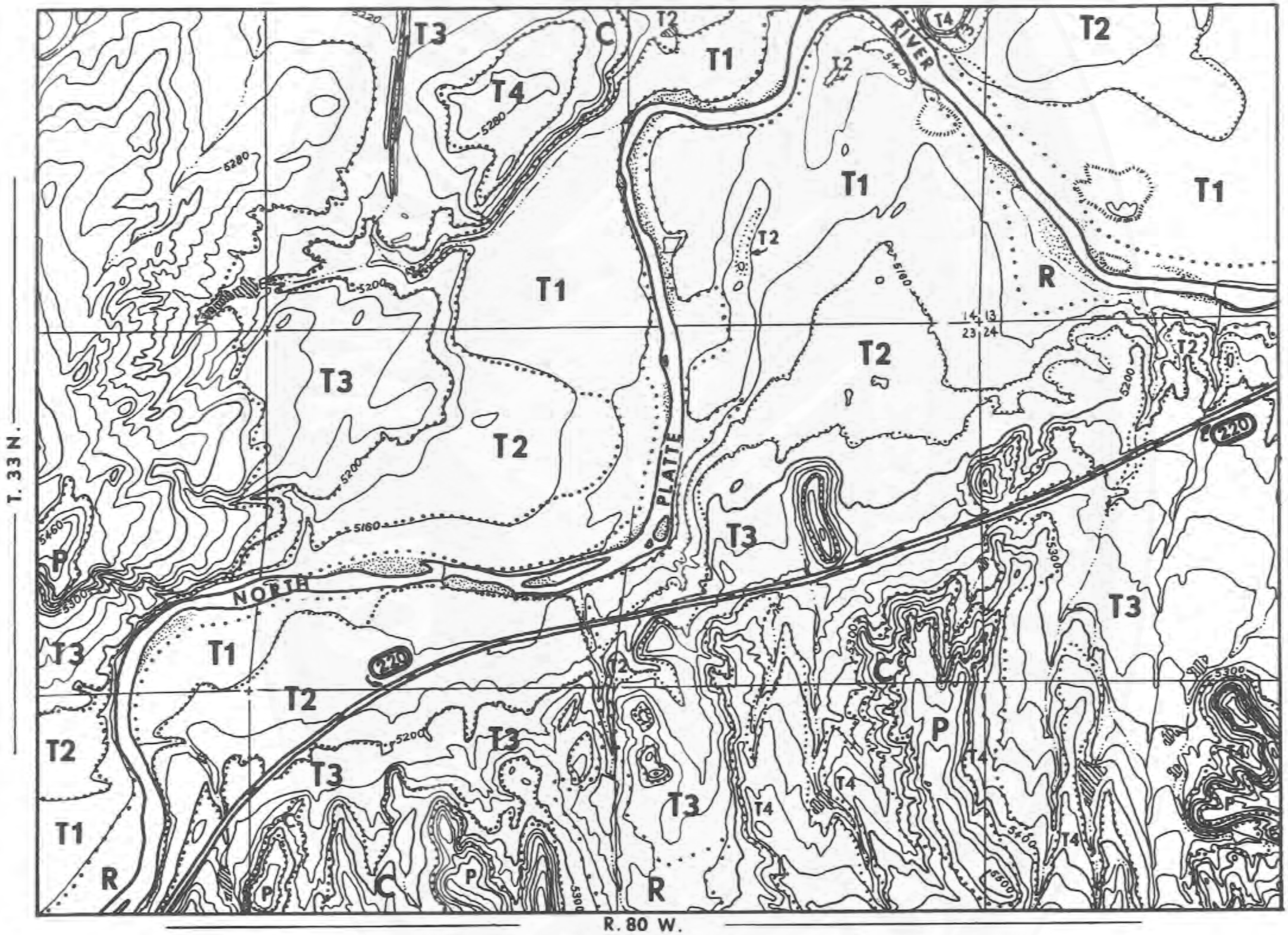
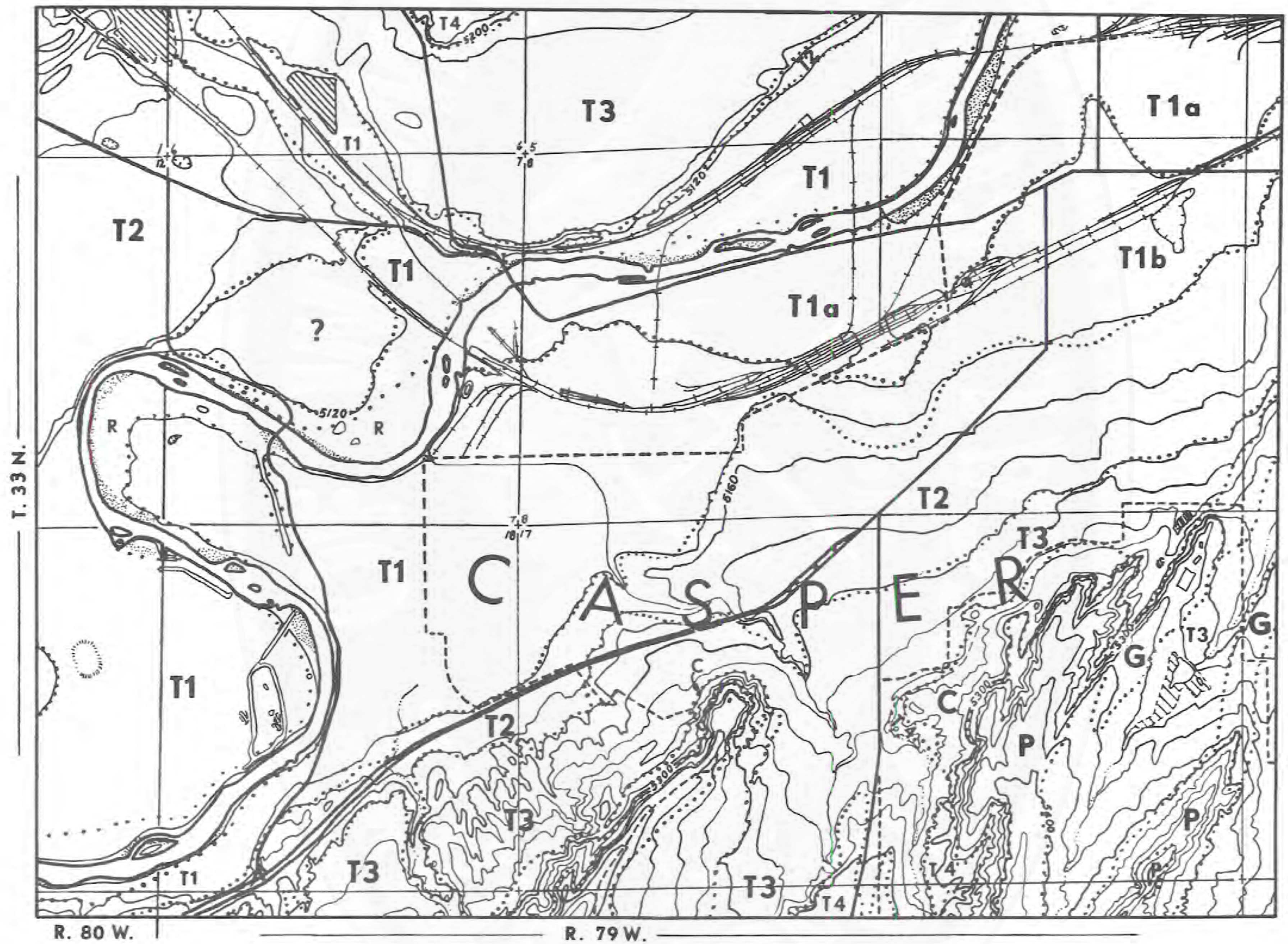


FIGURE 2. Map of Holocene and Pleistocene terrace distribution along the North Platte River in the western portion of Casper, Wyoming.



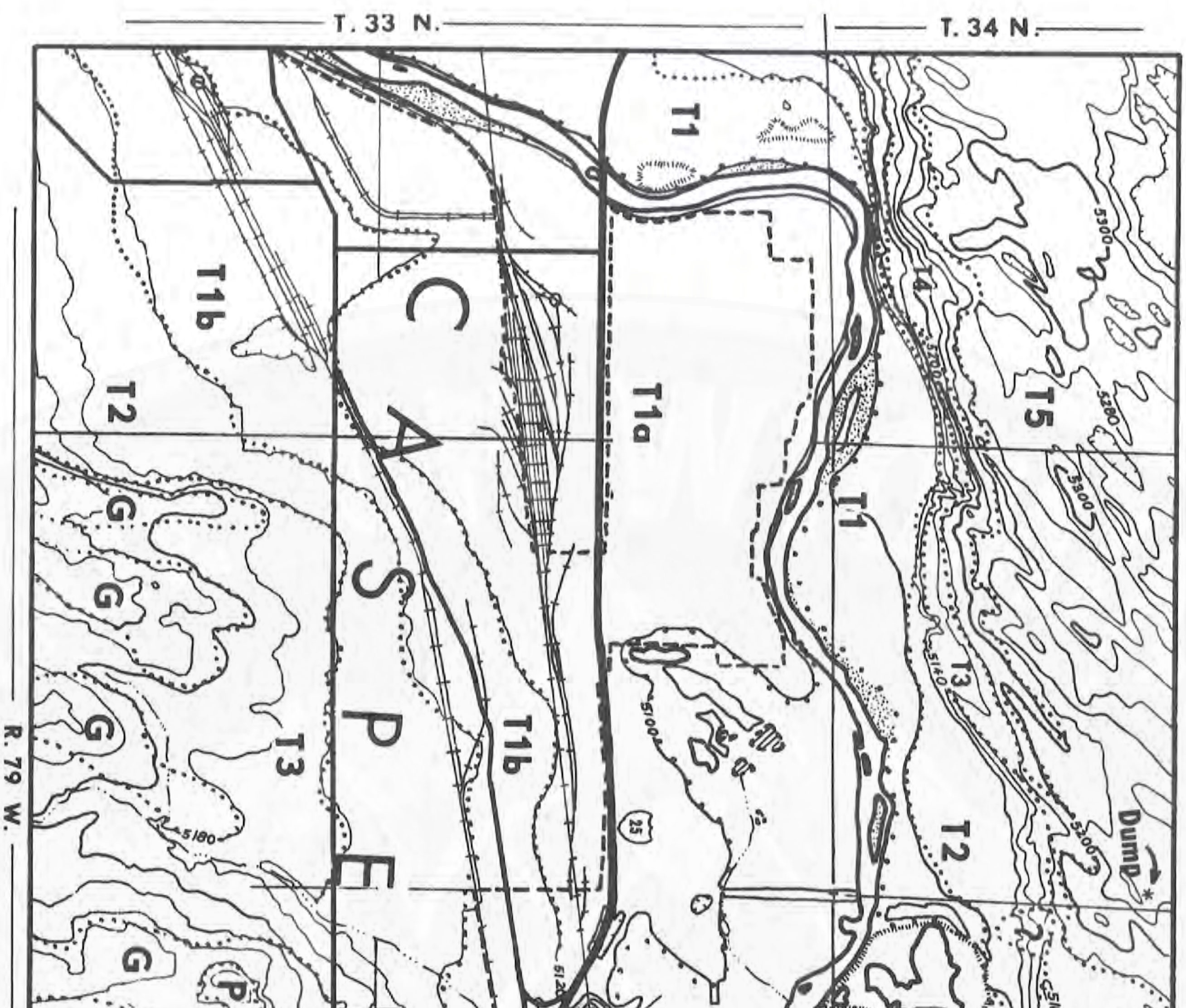


FIGURE 3. Map of Holocene and Pleistocene terrace distribution along the North Platte River in the eastern portion of Casper, Wyoming.

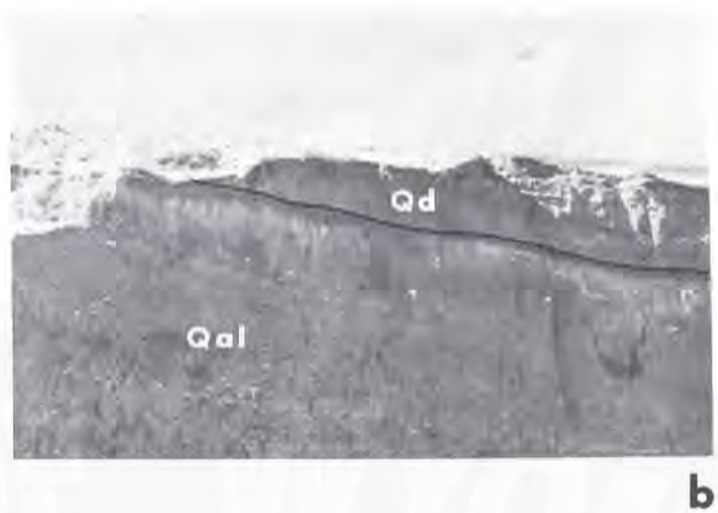


FIGURE 4. Deposits of T5 at the Casper city dump: a) view looking northward along west wall of large pit. Steele Shale (Ks) is exposed in bottom of pit and is overlain by alluvium of T5 (Qal), the latter being draped with later (Holocene) dune deposits (Qd). Arrow indicates position of recovered cubitus of camel, Camelops sp. b) view of alluvium in north wall of large pit, showing contact with overlying dune deposits. Soil atop the alluvium is visible; particularly the whitish calichified B horizon.

allowing revision and improvement of these preliminary maps would be welcomed.

THE MAPS

Three maps are published here, covering the area from the village of Red Buttes eastward to the eastern boundary of the city of Casper. The maps are based upon U. S. Geological Survey topographic sheets 4769 IV SE (Casper) and 4769 IV SW (Goose Egg), of the 7.5 minute series. It is useful to have these maps available for comparison with the maps published here.

The terraces are at their widest in the second map (Fig. 2), which covers the western portion of Casper. The broad terraces appear to be of Holocene age, although the youngest Pleistocene terrace (T3) is locally also extensive.

A locally small slope break or "terrace riser" at 5,120 feet crosses what we have designated T1, of late Holocene age. The break is not as marked as those which delineate older terraces, and at the present it is not viewed as a major discontinuity . Portions of T1 divided by this minor rise are labelled "T1 a" (younger) and "T1 b" (older) in our maps.

AGE OF THE CASPER TERRACES

Pleistocene Terraces

At the Casper city dump, in the E½ of Sec. 34, T. 34 N., R. 79 W. (Fig. 3), extensive excavations are being conducted in sands and gravels of T5, the third Pleistocene terrace. At this site, as many as twenty-five feet of alluvial deposits overlie the Upper Cretaceous Steele Shale. The alluvial deposits of T5 are in turn overlain by Holocene dune deposits. A prominent soil with a dark humic horizon and a whitish calichified B horizon is present at the top of the terrace deposits (Fig. 4, b) on the north wall of the pit. A photo mosaic of a portion of the north wall (Fig. 5) shows the stratified and faciated nature of the T5 deposit.

At a point about halfway up in the alluvial deposits (approximately seven feet above the contact with the Steele Shale; Fig. 4, a) a fragmentary camel cubitus (radius and ulna) was found by amateur collectors, who turned it over to the University of Wyoming for analysis. The junior author is particularly grateful to Mr. James J. Stewart of Casper for his efforts in obtaining the specimen and in guiding him to the locality.

The right radius and ulna (Fig. 6) are referable to a species of the genus Camelops. Only the proximal portion of the fused elements is preserved, the diaphysis being truncated distal to the bicipital rugosity by an old break. The break itself is interesting, as it quite closely resembles the butchering cuts observed on fossil bison at many archaeological sites. However, no firm statement can be made in this regard, the cut or broken surface being eroded by at least short-distance transport.

The width of the proximal articular surface is 86.5 mm., smaller than the range given for C. hesternus by Webb (1965:52; C. hesternus, 92-99 mm.). In comparison with C. hesternus the Casper specimen shows an anconal process even more massive, broad,

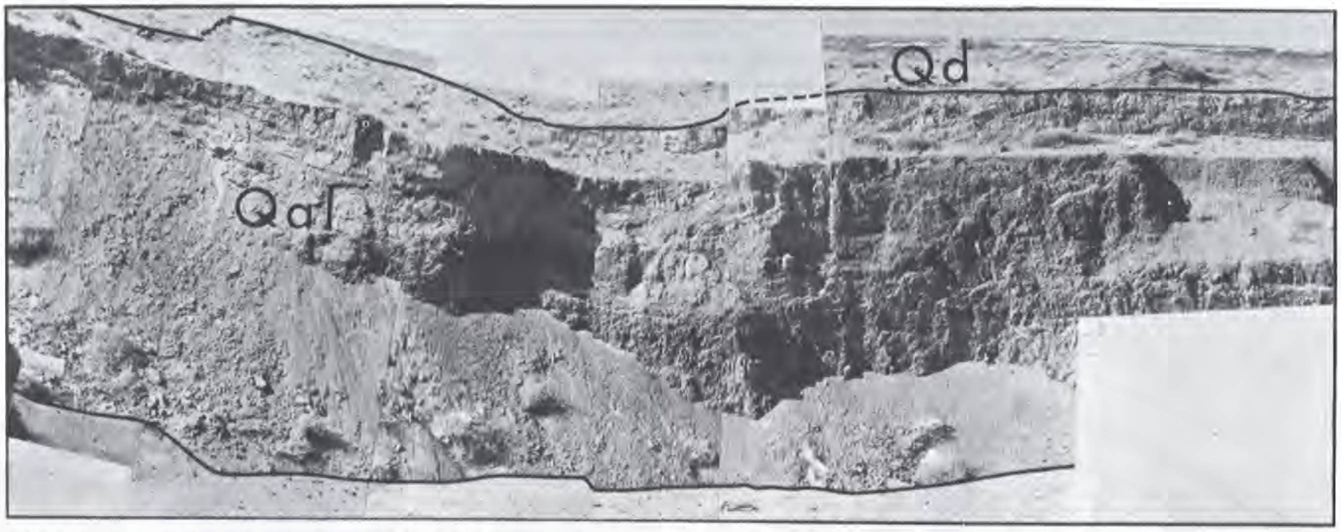


FIGURE 5. Photo-mosaic view of a portion of the north wall of the large pit of the Casper city dump, showing T5 alluvium. The stratified and faciated nature of the deposit is easily seen. Section here includes Cretaceous Steele Shale (Ks), T5 alluvium (Qal), and Holocene dunes (Qd). Depth of Qal at center of photo is approximately 15 feet.

and produced anteriad: a good generic character for Camelops. The lateral tuberosity of the Casper specimen is slightly less well developed than in C. hesternus as described by Webb (ibid.:20-21). It is thus impossible to refer the species to C. hesternus. Other species of Camelops, such as C. kansanus, are not yet well described in terms of postcranial material.

At present the camel bone tells us little concerning the age of T5. Camels of the genus Camelops survived through the Wisconsin glacial stage and succumbed to climatic change and human predation during the late Pleistocene extinctions. The decline of the camel was a relatively early event: few camel remains have been reported even from early archaeological sites in North America (Hester, 1967:180). Nevertheless, a few camels lingered on: Hester (ibid.:183) cites a terminal date of 8,240 years B.P. for Camelops (A-184c, Whitewater Draw, Arizona). Camel bones referable to this genus were recovered from a terrace gravel at Calgary, Alberta, in association with crania of Bison bison antiquus. One of the latter was dated to 8,145 ± 320 years B.P. (GX-2104; Brian O. K. Reeves, personal communication, 1972; Wilson, 1974a), and the date may well apply to the camel remains, as the bones exhibit little abrasion or other evidence of redeposition.

One major archaeological excavation has been conducted near Casper, and material from this site, the Casper Site (48NA 304) provides us with a minimum date for the terrace upon which the materials were superposed. The site itself lies with dune deposits atop the terrace.[5]

The Casper Site sits atop North Platte terrace T4, the second Pleistocene terrace up from the river. At the site, the terrace is represented by five feet of poorly sorted sandy arkosic gravel lying atop the Upper Cretaceous Steele Shale. Charcoal from the Casper Site was dated to 9,830 ± 350 years B.P. (7,880 B.C., RL-125; Frison, 1974), and a sample of bison bone was dated to 10,060 ±170 years B.P. (8,110 B.C., RL-208; ibid.). Despite this age and the presence of an extinct subspecies of bison[6], the Casper Site yielded a local fauna (the Casper Local Fauna) of decidedly modern aspect (Wilson, 1974b), as tabulated in Table I. On the basis of the age of the Casper Site, we can apply to T4 a minimum age of more than 10,000 years; of course,

[5] See John P. Albanese, this volume, p. 46-50.

[6] See Michael Wilson, this volume, p. 91-99.

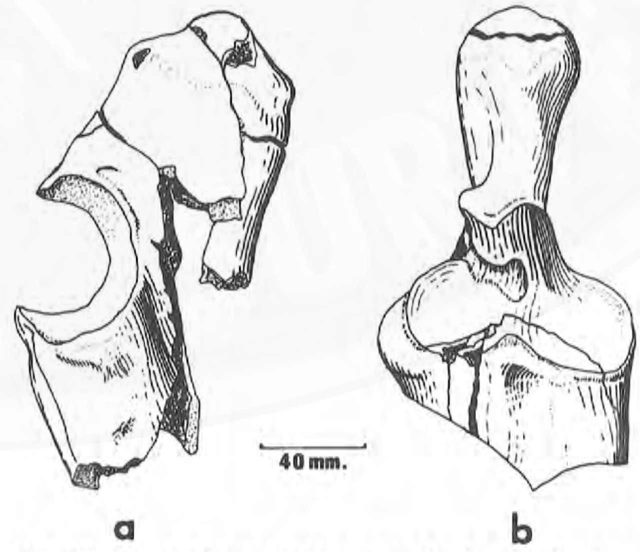


FIGURE 6. Cubitus (radius and ulna) of a Pleistocene camel, Camelops sp., recovered from T5 alluvium at the Casper city dump. The sharp distal truncation is rather suggestive of butchering by man, but is somewhat eroded by transport.

TABLE I. LIST OF THE CASPER LOCAL FAUNA, FROM THE EARLY HOLOCENE CASPER ARCHAEOLOGICAL SITE (after Wilson, 1974b)

Mollusca

Succinea sp., cf. *S. stretchiana* or *S. grosvenori*

Aves

woodpecker, cf. *Sphyrapicus* sp. or *Dendrocopos* sp.

Mammalia

Homo sapiens (indirect evidence -- artifacts)
Lepus townsendii
Spermophilus sp., cf. *S. richardsoni*
Spermophilus sp., cf. *S. tridecemlineatus*
Thomomys sp., cf. *T. talpoides*
Canis latrans
Vulpes sp., cf. *V. vulpes*
Lynx sp., cf. *L. rufus*
Antilocapra americana
Bison bison antiquus

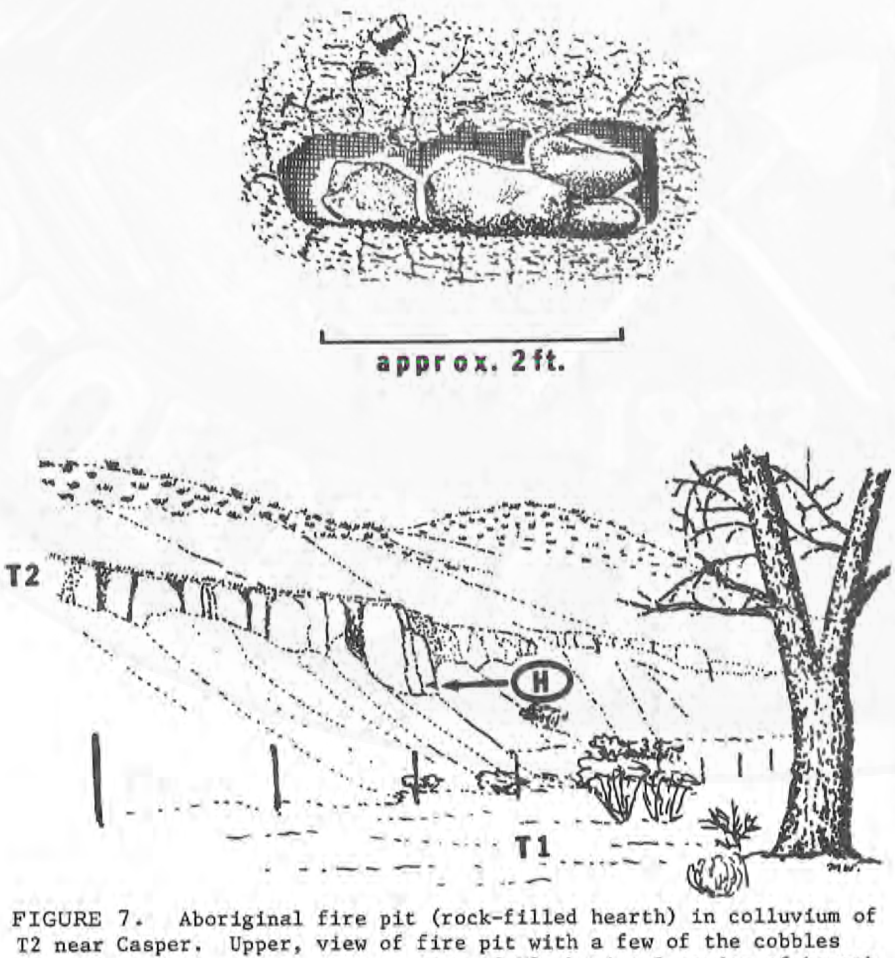


FIGURE 7. Aboriginal fire pit (rock-filled hearth) in colluvium of T2 near Casper. Upper, view of fire pit with a few of the cobbles removed to show cavity. Lower, view of T2 showing location of hearth. After photographs by Mr. Carleton Belz.

the true age is probably considerably in excess of this.

In addition, on the basis of geomorphic setting, the minimum date of T4, and the presence of a Pleistocene genus, we can say at present that T5 must date within the Pleistocene and considerably in excess of 10,000 years B.P. Quite possibly T5 was deposited during the Wisconsin glacial stage, but it may be even older than this.

A further piece of information bearing upon the chronology of the Pleistocene terraces at Casper comes from the Sweetwater River, a tributary of the North Platte west of Casper. Here, during construction a few years back, a mammoth (*Mammuthus* sp.) was recovered from deposits of T4, the second Pleistocene terrace. The mammoth was retained by the contractor and has not been studied.

Bone fragments collected in a sand blowout of T3 (first Pleistocene terrace) near the Casper Site display a considerable thickness of cortical tissue. This is strongly suggestive of a large Pleistocene mammal, but the critical evidence is so far lacking.

In the SW¼ SE¼ of Sec. 33, T. 34 N., R. 79 W., T3 is a strath terrace cut into weathered Steele Shale. The weathered shale zone varies from 5 to 10 feet in thickness and contains contorted lenticular sand lenses and features suggestive of ice wedges. This suggests former permafrost conditions and Pleistocene age.

Holocene Terraces

Terrace T2 lies at an average height of 30 feet above the water level of the North Platte River. In the NE¼ SW¼ of Sec. 33, T. 34 N., R. 79 W., T2 contains an aboriginal hearth or firepit located 5 feet below the terrace surface. The hearth (Fig. 7) was discovered by Mr. Carleton Belz in 1961 and is now nearly eroded away. The hearth contained large cobbles. Nothing definite can be said with regard to a possible date for the fire hearth; although it can be noted that in this area, rock-lined hearths are most abundant through the Middle Prehistoric Period (Mulloy, 1958: 210). This is at best a very rough index; but we can say that the terrace is clearly of Holocene age.

The terrace fill in the vicinity of the hearth consists of 12 feet of colluvium composed of poorly sorted sand, Steele Shale fragments, and cobbles. The colluvium rests upon the Steele Shale.

In the center of the city of Casper, building foundation excavations dug into T2 invariably reveal a sequence of fluvial sands and gravels with sedimentary structures typical of medium flow regimes. The thickest deposit observed by the senior author was 25 feet thick.

Terrace T1 lies approximately 5 feet above the summer level of the North Platte River. Gravel pits adjacent to the river and dug into T1 contain fluvial sands and gravels similar to those underlying T2.

At Glenrock, 25 miles east of Casper, the lowest terrace on the North Platte River has been correlated with the Lightning Terrace, described by Leopold and Miller (1954) (see Albanese, 1970). Archaeological evidence and radiocarbon dates indicate that the Lightning Terrace is 600 to 700 years old or less (see final section of this report). It is probable that this is also the age of terrace T1 at Casper.

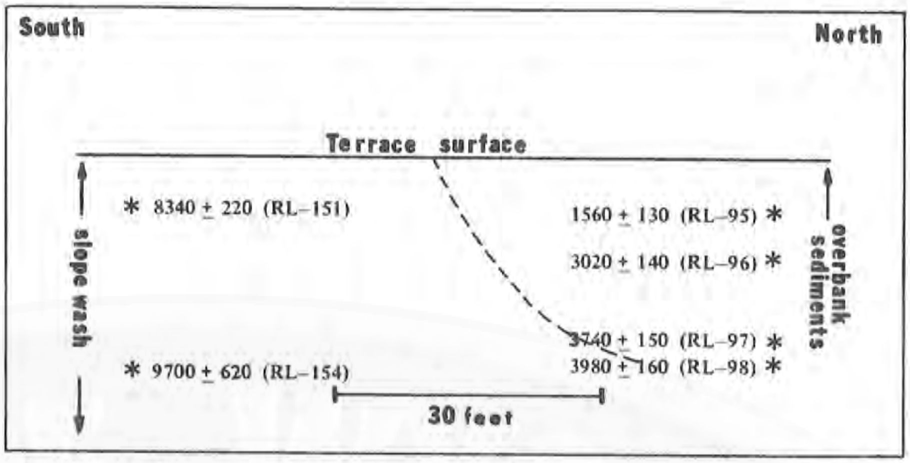


FIGURE 8. Diagrammatic cross-section of deposits along the west bank of Medicine Lodge Creek Site, near Hyattville, Wyoming. Asterisks show sample proveniences, and a marked lateral discontinuity is clear.

SOME COMMENTS CONCERNING
HOLOCENE TERRACES IN WYOMING

In a comprehensive and pioneering study of eastern and central Wyoming alluvial terraces, Leopold and Miller (1954) recognized a widespread system of three postglacial terraces in the Powder River, Bighorn, Belle Fourche, and Cheyenne River drainage basins. They were named, from oldest to youngest, the Kaycee Terrace, the Moorcroft Terrace, and the Lightning Terrace. The Kaycee Terrace surface is underlain by early post-Altithermal sediments estimated to have been deposited between 4,000 and 2,500 years B.C. The Moorcroft Terrace is described as "a terrace cut on Kaycee alluvium" (<u>ibid</u>.), estimated to have formed between 2,500 and 1,000 years ago.

There is some ambiguity concerning Leopold and Miller's definition of the Moorcroft Terrace. In the text and on cross-sections the Moorcroft Terrace is described as an erosional feature. However, on pages 58 and 59, a correlation chart indicates that the "Moorcroft" is also a depositional unit that correlates with alluvial units in the southwestern United States, even though a stratigraphic unit named "Moorcroft" is not mentioned in the text.

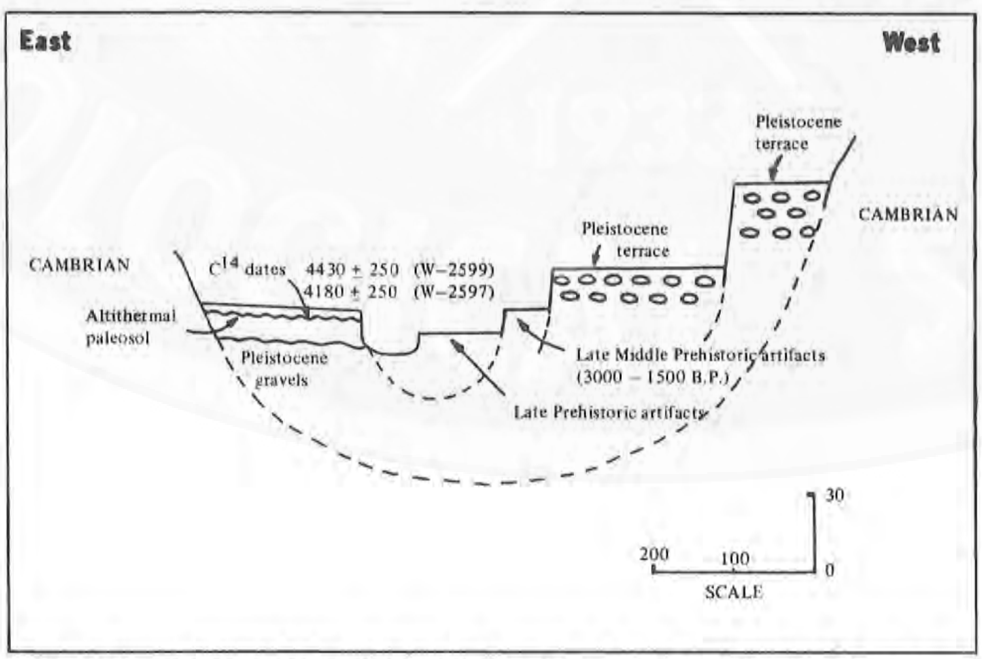


FIGURE 9. Cross-section of terrace deposits at the Dead Indian Site, in Sunlight Basin, Park County, Wyoming.

The Lightning Terrace is a depositional feature underlain by the alluvium of the Lightning Formation. Lightning deposition began approximately 600 to 700 years ago and was followed by a certain amount of erosion down to the present river level.

Leopold and Miller (<u>ibid</u>.), like us, noted a two-terrace system of Holocene age along the North Platte River drainage in Wyoming and western Nebraska. These terraces were not named.

As mentioned before, Leopold and Miller's study was a pioneering effort that was made without the benefit of radiocarbon dates. Hindsight and additional data indicate that Leopold and Miller's original proposals were too simplistic and that terrace and

TABLE II. HOLOCENE TERRACE DATA, WYOMING

LOCATION	DRAINAGE BASIN	STREAM ORDER	NUMBER OF TERRACES	HEIGHTS OF TERRACES (IN FT.)	AGE OF SEDIMENT BENEATH TERRACE	SOURCE OF DATA
Poison Spider Creek 17, T.33N, R.82W	North Platte River	5	3	3-11-20	Sediment one foot below oldest terrace surface contains Late Middle Period artifacts in situ, est. 3000-1500 years old.	Albanese, field notes
Coyote Creek 36, T.34N, R.86W	"	4	2	3-18	"	"
Wallace Creek 21, T.34N, R.87W	"	4	2	4-17	"	"
Middle Fork of North Casper Creek 27, T.34N, R.86W	"	4	2			"
Glenrock Buffalo Jump 11, T33N, R.76W	"	2	2	15-42	Alluvium underlying upper terrace; 4.25 feet below surface, radiocarbon date of 260 $\pm$ 100 years B.P. (M2350). 6 feet below surface, radiocarbon date of 190 $\pm$ 100 years B.P. (M2349).	Albanese, 1970
Scoggin Site 15, T.24N, R.86W	"	2	2	5-10	Alluvium underlying oldest terrace; 2.5 feet below surface, radiocarbon date of 4540 $\pm$ 110 years B.P. (RL-174). Charcoal associated with Early Middle Prehistoric artifacts.	Albanese, field notes; Lobdell, 1973
Mavrakis-Bentzen-Roberts Site 2, T.55N, R.80W	Powder River	2	2	25-37	Alluvium underlying youngest terrace; 11 feet below surface, radiocarbon date of 2600 $\pm$ 200 years B.P. (I-644), associated with Early Middle Prehistoric Period artifacts.	Albanese, field notes; Wyoming Archaeological Society, 1966
Buffalo Creek 35, T.56N, R.80W	"	5	3	3-10-25		Albanese, field notes
Ruby Site 29, T.43N, R.75W	"	3	2	12-36	Alluvium underlying oldest terrace; 11 feet below surface, radiocarbon date of 1670 $\pm$ 135 years B.P. (GX-1157). 20 feet below surface, radiocarbon date of 1800 $\pm$ 140 years B.P. (M2348).	Albanese, 1971
Sister's Hill Site 30, T.50N, R.82W	"	3	3	2-8-28	Approximately 13 feet below upper terrace, a radiocarbon date of 9650 $\pm$ 250 years B.P. (I-221) was obtained, associated with Hell Gap artifacts.	Haynes and Grey, 1965
Hanson Site Northeast of Greybull	Bighorn River	3	3	3-15-35	Radiocarbon date of 10,700 $\pm$ 670 years B.P. (RL-374), plus Folsom type artifacts, found 3 feet below top of upper terrace.	Albanese, field notes; Frison, written communication
Colby Site East of Worland	"	2	3	1-3-9	Three terraces are strath terraces that truncate Eocene sediments; lowest terrace also truncates arroyo fill sediment that contains mammoth bones which yielded radiocarbon date of 11,200 $\pm$ 220 years B.P. (RL-393).	Albanese, field notes; Frison, written communication

alluvial stratigraphic correlations over wide areas are very tenuous at best.

Table II is a chart showing selected Holocene terrace data obtained during the last seven years, mainly from archaeological sites. Examination of the chart indicates that within a given drainage basin, the number of terraces can vary with stream order and that the age of sediments in a given "fill terrace" can vary considerably from locale to locale.

Unpublished radiocarbon dates furnished by Dr. George C. Frison of the University of Wyoming coupled with geologic studies at the Medicine Lodge Creek Site (Secs. 16 and 21, T. 50 N., R. 89 W.) and the Dead Indian Site (Sec. 17, T. 55 N., R. 104 W.) indicate that in these locales the terrace surfaces are erosional features that truncate sediments of different ages. Figure 8 is a diagrammatic cross-section of a portion of the archaeological site at Medicine Lodge Creek. A four-foot hole on the south end of the cross-section would encounter sediments approximately 8,300 radiocarbon years old; while less than 100 feet to the north, the same penetration would encounter sediments approximately 1,500 radiocarbon years old.

A similar situation exists at the Dead Indian Site, as indicated in Figure 9. Sediments beneath the upper Holocene terrace surface on the east side of Dead Indian Creek contain Early Middle Prehistoric Period artifacts related to the McKean Complex. Radiocarbon dates obtained from charcoal associated with the artifacts were 4,430 ± 250 years B.P. (W-2599), from a position three inches beneath the surface; and 4,180 ± 250 years B.P. (W-2597), from a depth of four inches. On the opposite side of Dead Indian Creek, 200 feet to the west and 4 inches below the same terrace surface, a good collection of Late Middle Prehistoric Period artifacts was recovered, including projectile points. Based upon typology, these projectile points are probably between 3,000 and 1,500 years old. Thus the upper terrace surface cuts across sediments of different ages. This situation is probably duplicated along many drainages in Wyoming, and precludes correlation of upper terraces with sedimentary units as was done by Leopold and Miller (1954).

A possible exception to the above generalization is the Lightning Terrace - Lightning Formation correlation of Leopold and Miller (ibid.). In the few cases to date where artifacts and/or radiocarbon dates have been obtained from the Lightning Formation they are of very Late Prehistoric or Protohistoric age. The radiocarbon dates secured at Glenrock (Albanese, 1970), at the Forbes Site on Big Goose Creek (Frison, 1967a), and Piney Creek (Frison, 1967b) suggest that this unit is 600 to 700 radiocarbon years old or less. At Big Goose Creek in Sheridan County, Frison secured radiocarbon dates of 450 ± 110 years B.P. (M-1859) and 530 ± 110 years B.P. (M-1860) from charcoal 18 to 24 inches beneath the surface. At the Piney Creek Sites in Johnson County, a buffalo kill site contained within deposits of the terrace immediately above the creek level is suggested to be between 340 and 370 radiocarbon years old. At the Dead Indian Site, the lowest terrace sediments contain Protohistoric artifacts associated with modern horse bones.

Thus sediments of the Lightning Formation can vary from 600 or 700 to only a few hundred years in age. Lightning deposition essentially ceased with the advent of the modern erosion cycle which began about 1880-1900 A.D. in the northern Plains. The probable reason for the widespread and recognizable nature of the Lightning Formation deposits is that not enough time has elapsed since their creation to allow significant removal by erosion. In some local areas Lightning Formation deposits are being rapidly removed by the present erosion cycle, and as a result future stratigraphers will have a correspondingly more complex picture to deal with.

ACKNOWLEDGEMENTS

Much of this study has been made possible as a result of archaeological excavations initiated by Dr. George C. Frison, chairman of the Department of Anthropology, University of Wyoming. For this invaluable assistance, and for his continued encouragement, we are truly grateful.

Dr. Ronald W. Marrs and Dr. Roy M. Breckenridge of the Remote Sensing Laboratory, Department of Geology, University of Wyoming made the aerial photographs available to the junior author.

Mr. Carleton Belz and Mr. James J. Stewart assisted us in the collection of critical data. Diane J. Wilson provided information regarding provenience of radiocarbon dates. For their assistance, we thank them all.

REFERENCES

Albanese, John P.

1970 Geology of the Glenrock Site area, Wyoming. Plains Anthropologist Memoir 7, 15(50 part 2):56-66. Topeka, Kansas.

1971 Geology of the Ruby Site area, Wyoming. American Antiquity, 36(1):91-95. Washington, D.C.

Frison, George C.

1967a Archaeological Evidence of Crow Indians in Northern Wyoming: A Study of a Late Prehistoric Period Buffalo Economy. M.S., Ph.D. Dissertation (Anthropology), University of Michigan, Ann Arbor, Michigan.

1967b The Piney Creek Sites, Wyoming. University of Wyoming Publications, 33(1):1-92. Laramie, Wyoming.

1974 The Casper Site: a Hell Gap Bison Kill on the High Plains. Academic Press, New York, N.Y. 259 p.

Haynes, C. Vance, and Donald C. Grey

1965 The Sister's Hill Site and its bearing on the Wyoming postglacial alluvial chronology. Plains Anthropologist, 10(29):196-

207. Topeka, Kansas.

Hester, James J.
1967 The agency of Man in animal extinctions. In Paul S. Martin and H. E. Wright, Jr. (Eds.), Pleistocene Extinctions: the Search for a Cause: 169-192. Yale University Press, New Haven, Connecticut.

Leopold, Luna B., and John P. Miller
1954 A postglacial chronology for some alluvial valleys in Wyoming. U.S. Geological Survey, Water Supply Paper 1261:1-90. Washington, D.C.

Lobdell, John E.
1973 The Scoggin Site: An Early Middle Period *Bison* Kill. M.A. Thesis (Anthropology), University of Wyoming, Laramie, Wyoming. 82 p.

Mulloy, William
1958 A preliminary historical outline for the Northwestern Plains. University of Wyoming Publications, 22(1):1-235. Laramie, Wyoming.

Webb, S. David
1965 The osteology of Camelops. Bulletin of the Los Angeles County Museum, 1:1-54. Los Angeles, California.

Wilson, Michael
1974a Fossil bison and artifacts from the Mona Lisa Site, Calgary, Alberta. Part 1: Stratigraphy and artifacts. Plains Anthropologist, 19(63):34-45. Topeka, Kansas.

1974b The Casper Local Fauna and its fossil bison. In George C. Frison (Ed.), The Casper Site: a Hell Gap Bison Kill on the High Plains: 125-171. Academic Press, New York, New York.

Wyoming Archaeological Society (Sheridan Chapter)
1966 The Mavrakis-Bentzen-Roberts Bison Trap. The Wyoming Archaeologist, 9(7):27-39. Cheyenne, Wyoming.

THE COMBINED USE OF VARIED GEOLOGIC FEATURES IN BISON PROCUREMENT: AN EARLY MIDDLE PERIOD EXAMPLE FROM SOUTH-CENTRAL WYOMING

JOHN E. LOBDELL[1]

INTRODUCTION

Animal kills utilizing only jumps or traps are relatively numerous on the High Plains. In many bison procurement situations, however, diverse geologic features may be employed in combinations. These combinations vary, depending upon the specific site and procurement circumstances.

The reasons for the use of varied and combined topographic features are quite evident. If hunters took advantage of available geologic features, fewer man-made controls would have been required. The time needed for the building of drive line systems was reduced when natural formations could serve the driving purpose. The use of natural drive lanes freed individuals for other tasks related to the kill. Furthermore, the size of the overall labor force required for successful operation of the kill may well have been inversely proportional to the number and degree of natural constraints available and utilized. Thus it could have been possible for small nomadic micro-bands to exploit the bison resource in an effective manner.

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THE SCOGGIN SITE

The Scoggin site, located eighteen miles north of Sinclair in south-central Wyoming, provides an excellent opportunity to study the use of available geologic features in a specific procurement situation. The site is a combination jump and trap. It could also be described as a pound since the trap was man-made, somewhat resembling a structure excavated in eastern Wyoming (Frison, 1971:77). However, as the approaches to the trap were in all likelihood natural, the former nomenclature is preferable.

Post-holes delineate part of a compound in the trap area. The site contains a single component, as there is only one bone layer. The presence of boiling pits and other food processing areas necessitated deeper excavation in areas adjacent to the compound. Because of the presence of these areas it has not been difficult to recover ample charcoal for dating purposes. A carbon-14 date has been assigned at 4,540 $\pm$ 100 years B.P. (RL-174; 2590 B.C.). This date is corroborated by the nature of the projectile point assemblage. Projectile points of two major varieties indicate that the site is of Early Middle Period age. Many are of the large lanceo-

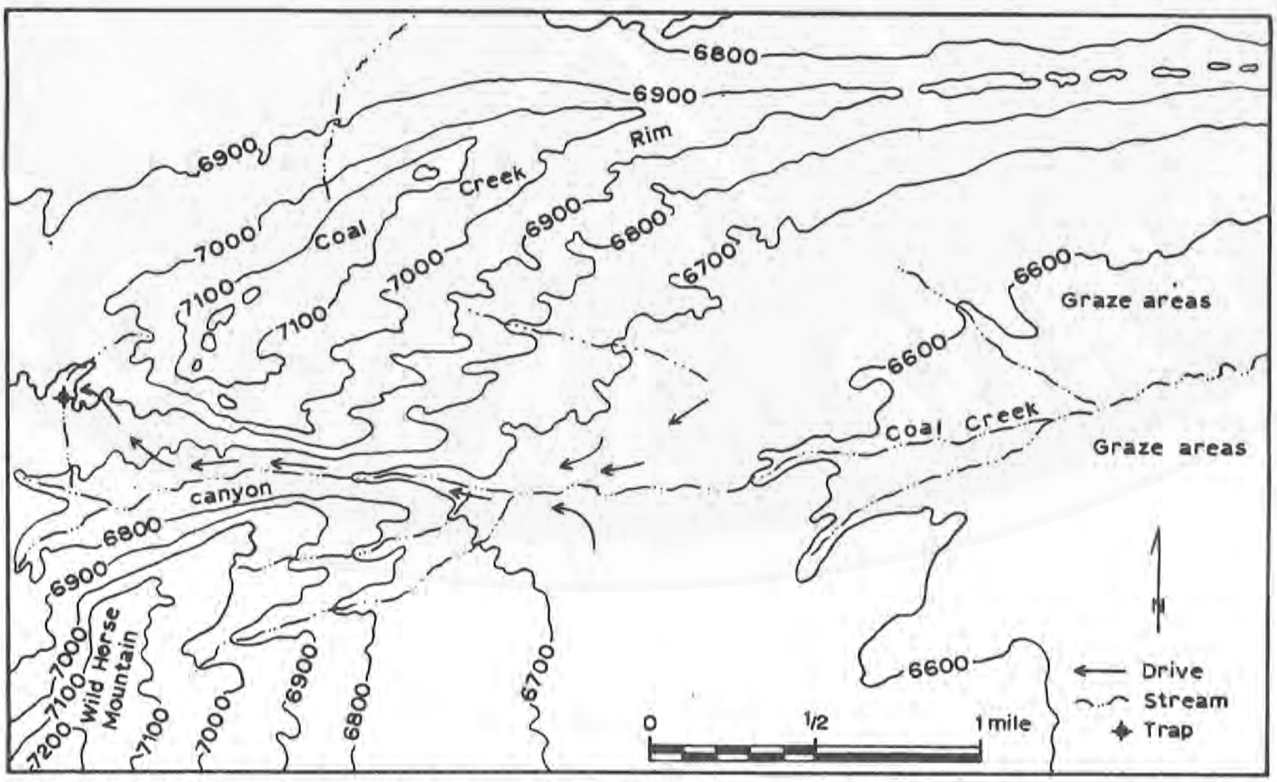

FIGURE 1. Topographic map of the Scoggin site area, showing the probable route of the bison drive.

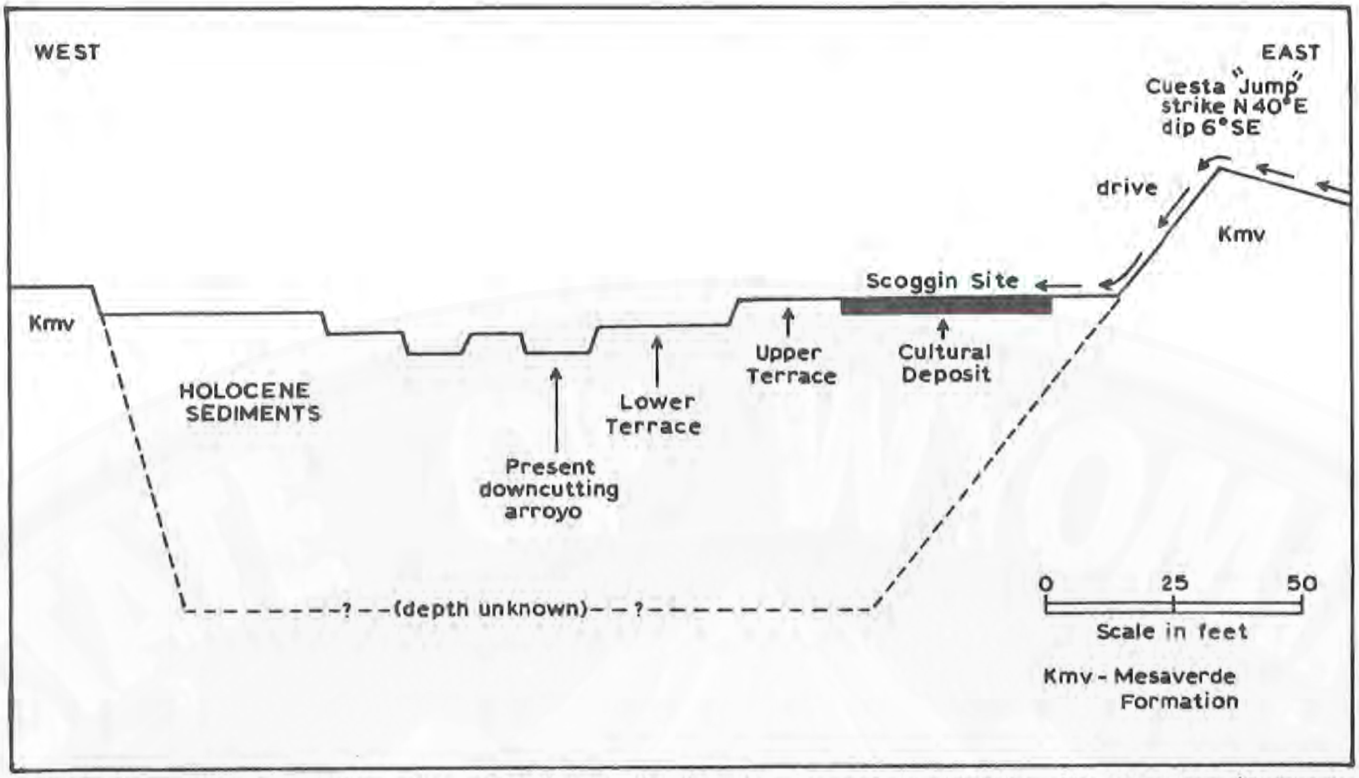

FIGURE 2. Schematic geologic cross-section of the Scoggin site and immediately adjacent areas (Courtesy of John P. Albanese).

late, indented base type elsewhere called McKean points. Broad side-notched points, some with basal notching, have also been recovered. Side-notched points become more common in conjunction with later buffalo kill sites on the High Plains. The material for almost all of these is a fine chert of variable color, probably found locally. Lithic workmanship is excellent; some of the points are quite thin as a result of careful collateral flaking to both sides. Lithic butchering tools are rare. Bone tools were probably used almost exclusively in the butchering process. For a more comprehensive description and analysis of the Scoggin site, see Lobdell (1973a and 1973b).

Seminoe Dam, located twelve miles east of the site, presently controls the flow of the North Platte River. The landscape of the area reflects the importance of the watercourse in earlier times. Though most of the region adjacent to the site is somewhat barren of grazing plants, the North Platte flood plain provided grasslands for ranging animals, and this was an attraction for herds of bison. Some shade trees and mud wallows along the river's banks existed until inundated by Seminoe Reservoir waters in the 1930's.

The Scoggin site trap compound is located a few feet east of a second order ephemeral stream that flows southward into Coal Creek (Fig. 1), a minor tributary of the North Platte (John P. Albanese, personal communication and field notes, 1973). It is likely that bison fed on grasses along stretches of Coal Creek. Today there is good graze up to a point about four miles east of the site, as evident from a few cattle that utilize it. As one nears the entrance to Coal Creek Canyon (Fig. 1), one mile east of the site, sagebrush dominates the landscape. Coal Creek, obviously an underfit stream, cut this 200-300 foot deep canyon through the southeast-dipping, uplifted outcrops of the Mesaverde Formation during Pleistocene times. Coal Creek Canyon is the bisecting feature that separates Wild Horse Mountain to the south from Coal Creek Rim to the north (Fig. 1). All of these physical features are of importance in terms of control and handling of the buffalo driven to the Scoggin site. These features served as drive components of the overall procurement system.

The nature of the site reveals that bison procurement was not an incidental activity, but one that required cooperation, careful planning, and execution. Groups of grazing bison would have to have been consolidated into larger groups and moved westward from the graze areas. It is doubtful that the operators simply waited for herds to drift into a favorable position, and then stampeded them; this opinion was also expressed by Frison (1970:5). Cautious driving and perhaps even decoying were used to channel the herd to a locale near the mouth of Coal Creek Canyon, where the final frantic stages of the drive could be initiated. In this case the behavior of the animals was probably satisfactory for a drive of this nature, as the drive was conducted during the fall of the year (cf. Frison, 1970:5).

The geologic features of the site area were quite conducive to the enactment of a buffalo drive. Coal Creek Rim, rising somewhat abruptly to the north, could have served to cut off a northward drift by the herd once the bison were within four miles of the trap. With drive lanes or a few drivers to the south and east the animals could have been drifted, driven, or decoyed to the mouth of Coal Creek Canyon. Once the bison were inside the canyon, the steep walls would have provided no escape. The buffalo could then have been stampeded to the trap, probably following the ancient stream bed. Handling of the animals in this manner would have been easier than a straight-line approach. The curvature of the stream bed would not have permitted the bison to view any coming obstructions and probably would have served to slow the stampede considerably. Any soft sand or mud would also have slowed the herd. To get to the hidden trap location the herd was then forced northward, away from the stream bed. Any obstructions used in turning the herd from Coal Creek probably have long been eroded away by stream action.

Although no drive lines have been found, it is likely that the drive used both the terrain and a final sharp right-angle turn to the west, thus concealing the man-made compound from the animals until the last possible moment. At this point the bison were driven off a small cuesta of uplifted Mesaverde sandstone (Fig. 2) into the trap. This jump was probably not enough to cause serious harm to the animals, but at least enough to hamper their retreat. The cuesta also helped to conceal the trap from the stampeding bison. In the trap compound the animals were dispatched and butchered, and the meat processed for future use.

CONCLUSION

Available land forms, behavior of animals, and the cooperative efforts of men were all exploited to ensure the success of the procurement activity. Here the use of an uplifted rim, a canyon, a stream bed, and a cuesta served the drive purpose. These natural features acted as constraints on the herd, and served to conceal planned obstructions and the trap compound. Careful survey and use of the geologic features permitted these Early Middle Period nomadic hunters to exploit the valuable bison resources of their portion of the High Plains, in addition to lessening the amount of labor and possibly the actual size of the labor force necessary for conduct of a successful kill.

ACKNOWLEDGEMENTS

The author would like to express his gratitude to a number of persons who participated in the Scoggin site excavations and subsequent analysis of the material. Dr. George C. Frison directed the excavation crew of which the author was a member. The crew was made up of students from the University of Wyoming and interested amateurs from several chapters of the Wyoming Archaeological Society.

In particular, thanks are expressed to Mr. John P. Albanese, consulting geologist, of Casper, Wyoming. Mr. Albanese undertook the detailed mapping of the site and interpreted the bedrock and Holocene geology of the area. Without his contribution, the present interpretation of activities at the site would not have been possible.

REFERENCES

Frison, George C.

1970 The Glenrock Buffalo Jump, 48CO304: Late Prehistoric Period buffalo procurement and butchering on the Northwestern Plains. Plains Anthropologist Memoir, 7, vol. 15(50, part 2):1-45. Topeka, Kansas.

1971 The Buffalo pound in Northwestern Plains Prehistory: Site 48CA302, Wyoming. American Antiquity, 36(1): 77-91. Washington, D. C.

Lobdell, John E.

1973a The Scoggin Site: An Early Middle Period *Bison* Kill. M.A. Thesis (Anthropology), University of Wyoming, Laramie, Wyoming. 82 p.

1973b The Scoggin Site: an Early Middle Period Bison kill. The Wyoming Archaeologist, 16(3):1-36, and 16(4):37-71. Cheyenne, Wyoming.

THE USE OF ARCHAEOLOGY IN DATING QUATERNARY DEPOSITS IN THE UPPER WOOD RIVER AREA, ABSAROKA RANGE, WYOMING

ROY BRECKENRIDGE[1]

INTRODUCTION

The glacial chronology of the Wyoming Rockies is based on the pioneering work of Eliot Blackwelder of the United States Geological Survey. Blackwelder (1915) recognized a pre-Wisconsin or "Buffalo" stage, an early Wisconsin or Bull Lake glaciation, and a late Wisconsin or Pinedale glaciation, all from tills in the Wind River Range. This terminology has been clarified and expanded throughout the Rocky Mountain area due largely to the work of Gerald Richmond (1960, 1965), also of the U. S. Geological Survey. Richmond and other recent workers have recognized a number of stades within the Bull Lake and Pinedale glaciations.

François Matthes (1939, 1940, 1942) was the first to recognize a post-glacial minor advance, which is now called the Neoglaciation. He used the work of E. V. Antevs (1938) to show that many of the mountain glaciers in North America completely disappeared during a warm post-glacial maximum called the Altithermal, between 8,000 and 5,000 years ago (see Porter and Denton, 1967, for a rigorous discussion of Neoglaciation). Matthes showed that his "Little Ice Age" represented a rebirth of alpine glaciers in the Cascades, Sierra Nevada, and many of the Rocky Mountain ranges. Until Matthes presented his hypothesis of a post-Wisconsin glacial resurgence in North America it was widely believed that modern glaciers were merely remnants of former Wisconsin ice masses. Subsequent investigations have extended the Neoglacial concept world-wide and have established a glacial chronology based on the data of geology, archaeology, botany, paleontology, pedology and oceanography.

Holmes and Moss (1955) named the early Neoglacial stade the Temple Lake, after a moraine-dammed lake in the southern Wind River Range of Wyoming. The late stade or Gannett Peak was designated by Richmond (1960), also from the Wind Rivers. Neoglaciation has been the subject of many recent studies in the Rockies, particularly in Wyoming and Colorado, and today a chronology of three stades seems to be developing.

ABSOLUTE DATING

Determining absolute dates is probably the biggest obstacle to chronology and correlation of glaciations in the central Rockies. Unlike the Cascades and Western Canadian Ranges, widespread ash from Quaternary volcanic activity in the Middle and Southern Rocky Mountain Provinces has not been recognized. Dendrochronology is seldom useful because most of the glaciated areas rise far above the present treeline. The extensive tundra zone has also produced few radiocarbon dates; while uncontaminated carbon-14 material available in the forested areas is scarce and usually represents maximum ages of moraines.

Although absolute dates are few, a number of relative dating techniques are useful, and some, with proper calibration, may yield absolute dates. Most of the relative dating techniques have been based on the changes that occur on freshly exposed rock surfaces. The assumption, of course, is that glaciation has reworked the rock material sufficiently to render it "fresh". Well-dated archaeological material is superior to qualitative methods based on weathering, and furthermore can serve as a means of calibration for the relative techniques.

ARCHAEOLOGY

The last Pinedale glaciers disappeared from Wyoming about 10,000 years ago. As yet, no archaeological material has been directly related to these late Wisconsin glacial deposits. The Altithermal, or warm climatic episode following the Wisconsin glaciation and preceding Neoglaciation, is an important and interesting interval of Quaternary time. During the Altithermal temperatures rose, vegetation and climate changed, the last Pleistocene animals disappeared[2], and the ice masses dwindled and disappeared.

Certainly the life style of North American man responded to these drastic changes in his environment. The cultural and economic habits of these people have been a subject of much discussion. For some time it was generally assumed that most of the occupants deserted the arid Great Plains during the Altithermal. Recently collected evidence suggests that a hunter-forager culture was prevalent in the region, and the emphasis merely changed from big-game hunting toward a more diversified culture, able to exploit many plant and animal resources. However, Reeves (1974:1246) suggests that the area of short-grass range may have enlarged (to the north) during the Altithermal, supporting bison and allowing a predominant communal bison-hunting system. In view of the fact that Reeves' own evidence is largely from the foothills of Alberta and other Plains-marginal sites; and in view of the

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[2]Editor's note: most of the Pleistocene extinctions had already occurred by this time; however, evidence is mounting that certain forms did persist to the start of the Altithermal. The ranges of other forms were changing: the black bear appeared for the first time in Wyoming apparently during late Altithermal times (see E. Anderson, this volume; p. 78-87).

fact that the bison did change (in the direction of physical diminution) during the Altithermal (see M. Wilson, this volume) his arguments are far from convincing.

The Mummy Cave site in the Absaroka Mountains west of Cody, Wyoming, shows that at least some groups began to occupy the mountains as the Wisconsin ice retreated. Occupation levels at the cave have been radiocarbon-dated from 9,000 to 400 years before present. Wedel, Husted, and Moss (1968) concluded that the cave was inhabited and abandoned many times during the last 9,000 years by people coming from different areas, yet who were similarly adapted to a diversified montane subsistence economy. On the other hand, the Horner site, in the Bighorn Basin near Cody, yielded artifacts of a plains-based bison-hunting culture dated to approximately 6,900 years B.P. Artifacts from sites of this time period suggest that even at this early date the people of northwestern Wyoming had developed separate cultural adaptations and characteristics in the plains and mountains.

SITES ON THE UPPER WOOD RIVER

In the course of a Quaternary geologic study in the upper Wood River valley of the southern Absarokas, the author recovered artifacts in several of the major cirques. Because any dates of post-glacial occupation would have application to the Neoglacial chronology, a diligent search was made for other sites of Indian occupation.

Two possible late Altithermal or "Temple Lake" sites were found high on the floors of cirque basins at elevations of 3,120 and 3,180 meters above sea level, and another was discovered on a bench above the Wood River at 3,150 meters. A number of Late Period points were recovered at lower elevations along the Wood River. A crude semicircular stone and stick structure occupying a large rockslide near the Double Dee Ranch was probably used as a blind for the hunting of bighorn sheep.

The Cascade Creek site is located in a cirque basin near the base of Cascade Peak. Artifacts were first discovered at a small tarn at the toe of a protalus rampart deposit. The pond occupies a small bedrock depression carved by Wisconsin glaciation and is fed by meltwater from the adjacent protalus ramparts and rock glaciers. Further searching revealed several more artifacts on a small bedrock knob overlooking the pond. A probable Early Middle Period point (Fig. 1, a) was found buried in the lake sediments. A core to a depth of 56 centimeters was obtained from the pond, but no additional material was encountered. Some areas of patterned ground formed by freeze-thaw action and disturbed sediment layers show that the stratigraphy has been mixed by periglacial processes and the trampling action of animals which drink at the pond. Therefore, the stratigraphic position of the point in these sediments is not certain. A biface (Fig. 1, b) found on the knoll nearby is not diagnostic of any period. The lichen species Rhizocarpon geographicum (see Andrews and Webber, this volume) has colonized a cutting edge of the scraper and the size of the lichen thallus indicates its minimum age to be 250 years B.P.

The point from the Cascade Creek site is a large dart point with broad side notches and a basal indentation. It is fashioned of a gray-brown chalcedony with numerous minor flaws. The point clearly falls within the range of variation of the by now loosely defined "McKean-Oxbow Complex", of earliest Middle Period age (M. Wilson, personal communication, 1974). It most closely resembles points of the Oxbow type, dated at several localities in the Canadian plains to approximately 5,000 years B.P.

Large side-notched points are known from a number of late Paleo-

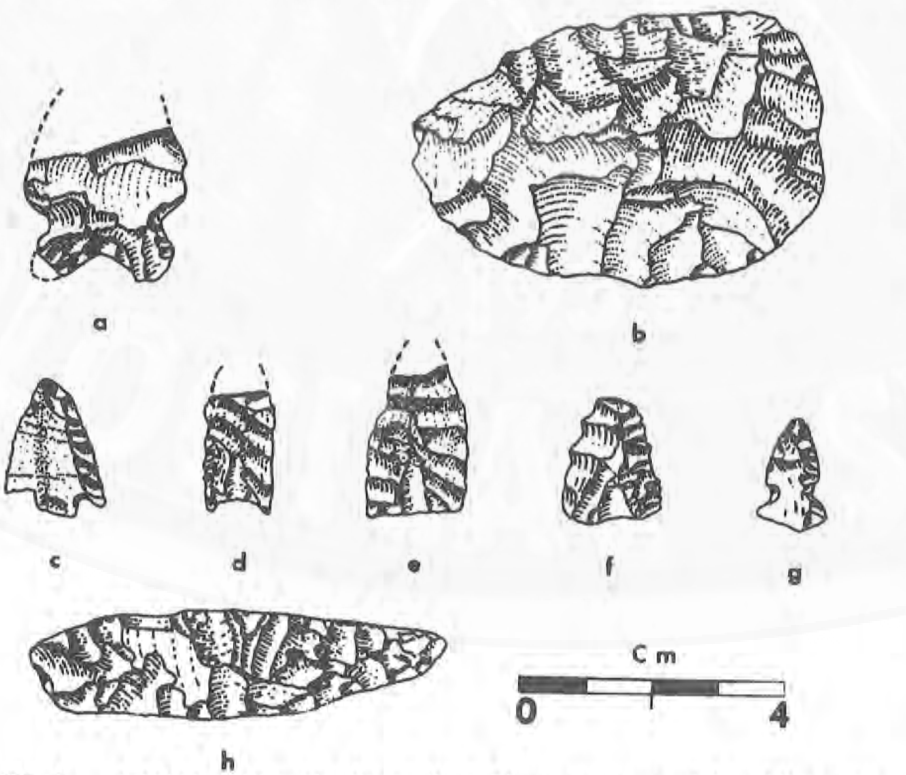

FIGURE 1. Artifacts from the Upper Wood River area: a. Oxbow-like point of Early Middle Period age (Cascade Creek); b. ovate biface (Cascade Creek); c-g. Late Prehistoric Period points (Meadow Creek Cirque); h. Late Prehistoric Period lanceolate biface (Meadow Creek cirque).

FIGURE 2. Meadow Creek Site

This site is typical of the high cirque sites and occupies a bedrock knob near an alpine bog or pond. Material was found scattered over a large area around (A). A small active rock glacier is advancing slowly downhill near the site. Note the peaks in background truncated by the Tertiary high-level erosion surface.

Indian sites on the plains; among them the Simonsen site in Iowa (Agogino and Frankforter, 1960), and the recently excavated Hawken site in Wyoming (George C. Frison, personal communication, 1974). Large side-notched points of a slightly different variety seem to characterize the Altithermal in several areas, from Idaho to Alberta. These points have been named "Bitterroot points", but broad application of this name tends to obscure the possible regional differences in cultural adaptations. A rather sketchy description of this complex is given by Reeves (1974:1244-1246).

Large side-notched points with clearly indented or deeply concave bases occur in Late Altithermal times and are designated as Oxbow points. Material of this complex has been dated to 5,200 ± 130 years B.P. at Oxbow, Saskatchewan (McCallum and Dyck, 1960:80), 5,000 ± 90 years B.P. at Moon Lake, Saskatchewan (McCallum and Wittenberg, 1968:377-378), and to 4,620 ± 150 (S-50), 4,620 ± 80 (S-52), and 4,650 ± 150 (S-53) years B.P. at Long Creek, Saskatchewan (McCallum and Wittenberg, 1962:75-76). However, material identified as Oxbow has also been dated to 1,560 ± 60 years B.P. at the Harder Site, Saskatchewan (S-490, Rutherford, Wittenberg, and McCallum, 1973:204). The latter situation is reminiscent of the case in Wyoming, where apparently similar stemmed, indented-base points from the Mavrakis-Bentzen-Roberts site and the Powers-Yonkee site (both of them buffalo kills) were dated to significantly different periods (Trautman, 1963:73-74). The temporal range of true Oxbow points remains indistinct as a result, but it does appear that the early sites (c. 3000 B.C.) are in the numerical majority.

Since the Early Middle Period is equivalent to the latest part of the Altithermal interval this site is of major significance in defining the maximum limit of the Neoglacial ice advances. The site would have been destroyed by the advance of Neoglacial ice farther down-valley. Thus Neoglacial ice was concentrated along the shaded north-facing cirque sides, rather than at the top of the Wisconsin headwall.

By delimiting the extent of Neoglaciation, the deposits lower in the cirques are shown to be latest Pinedale rather than early Neoglacial ("Temple Lake"), an important relationship that has been difficult to resolve in many other glaciated valleys of the Rockies.[3]

[3]The term "Temple Lake" used here refers to an early Neoglacial advance noted throughout the Middle and Southern Rocky Mountains. The Temple Lake type locality may actually be pre-Altithermal in age.

TABLE I. ARCHAEOLOGICAL SITES OF THE UPPER WOOD RIVER

Site	Location	Artifacts	Implications
Cascade Creek	high cirque	biface, point	Early Middle Period - geologically of major importance. Shows extent of Neoglacial advance and differentiates it from latest Pinedale.
Meadow Creek	two sites in high cirque meadow	flakes, blanks, points	Late Period - delimits extent of Late Neoglacial
Upper Wood River	terrace	flakes, points	Late Period - approximate date for terrace and rates of downcutting
Jojo Fan	alluvial fan	flakes, points	Late Period - alluviation rates on fan
Funnel Mountain	rockslide	shelter	Late Period - provides a minimum date for sliding

The Meadow Creek site is also located at a vantage point high in a cirque basin near a water source, in this case an alpine bog. Initially several points were found at a salt lick where the tundra and topsoil were eroded. Numerous Late Period points were subsequently found in sod used to cover the roof of a nearby sheepherder's cabin (Fig. 1, c-g). These are minimally retouched-flake points of several styles. A few possible Late Middle Period points were also recovered in addition to a lanceolate biface (Fig. 1, h) and a great number of chips and flakes.

Higher in the cirque at a prominent bedrock point a great number of chips covered an area over 10 meters in diameter, but no points were found. Presumably, this site is near the source of the material and was used to "rough-out" blanks. The lack of datable Altithermal and early Neoglacial artifactual material in the Meadow Creek Cirque does not allow an estimate of the Neoglacial ice extent. However, the substrate containing the artifacts is at least Gannett Peak in age based on stratigraphy, rates of erosion, and soil development.

Another site near the drainage divide of the Wood River on a terrace at an elevation of 3,120 meters contained chips and blanks, probably of Late Period age.

An inventory of the lithologic types and provenance of the artifacts shows several major sources:

1) Local jasperoid and chert from the Absaroka volcanics
2) Obsidian from Absaroka volcanics and the Yellowstone area
3) Dakota Sandstone from the Bighorn Basin.

Some flakes of smoky obsidian with dark euhedral crystals were found. Obsidian cobbles of a similar nature were noted by Fred Fisher of the U. S. Geological Survey (oral communication, 1972) on a high-level erosion surface of Cathedral Mountain, sixty miles southwest of the Wood River area. The source of this diagnostic obsidian is not known.

In addition to the sites discovered during this geologic investigation, local residents have described several other "finds" in the Wood River drainage, but the artifact types are not known to the author. The known sites and geologic implications are summarized in Table I.

SUMMARY

Archaeological materials show that cirque basins in the Wood River drainage were occupied by man during part of Altithermal and Neoglacial times. The position and age of the sites serve to delineate the extent of glaciers during Neoglacial time and to differentiate the late Pinedale (Wisconsin) and "Temple Lake" (Neoglacial) deposits. More intensive archaeological surveys in the Absaroka Range would certainly yield additional datable material. Besides the potential for direct dating, artifacts can be used to help calibrate more indirect methods such as lichenometry and pedology, leading to a clarification of the Neoglacial chronology in Wyoming.

REFERENCES

Agogino, G. A., and W. D. Frankforter
1960 A Paleo-Indian bison-kill in northeastern Iowa. American Antiquity, 25(3):414-415. Salt Lake City, Utah.

Anderson, Elaine
n.d. A survey of the late Pleistocene and Holocene mammal fauna of Wyoming. This volume: 78-87.

Andrews, J. T., and P. J. Webber
n.d. A review of lichenometry and the dating of weathered rock surfaces in the High Cordillera. This volume: 65-70.

Antevs, E. V.
1938 Postpluvial climatic variations in the Southwest. American Meterological Society Bulletin, 19:190-193. Lancaster, Pennsylvania.

Blackwelder, Eliot
1915 Post-Cretaceous history of the mountains of central western Wyoming. Journal of Geology, 23:97-117, 193-217, 307-340. Chicago, Illinois.

Holmes, G. W., and J. H. Moss
1955 Pleistocene geology of the southwestern Wind River Mountains, Wyoming. Geological Society of America Bulletin, 66:629-654. Boulder, Colorado.

Matthes, François E.
1939 Report of the Committee on Glaciers. American Geophysical Union Transactions, 20:518-523. Washington, D.C.
1940 Committee on Glaciers, 1939-1940. American Geophysical Union Transactions, 21: 396-406. Washington, D.C.
1942 Glaciers. In Meinzer, O. E. (Ed.), Hydrology, 149-219. New York, New York.

McCallum, K. J., and W. Dyck
1960 University of Saskatchewan radiocarbon dates II. Radiocarbon, 2:73-81. New Haven, Connecticut.

McCallum, K. J., and J. Wittenberg
1962 University of Saskatchewan radiocarbon dates III. Radiocarbon, 4:71-80. New Haven, Connecticut.
1968 University of Saskatchewan radiocarbon dates V. Radiocarbon, 10(2):365-378. New Haven, Connecticut.

Porter, S. C., and G. H. Denton
1967 Chronology of Neoglaciation in the North American Cordillera. American Journal of Science, 265:177-210. New Haven, Connecticut.

Reeves, Brian
1974 The concept of an Altithermal cultural hiatus in Northern Plains prehistory. American Anthropologist, 75(5):1221-1253. Washington, D.C.

Richmond, Gerald M.
1960 Glaciation of the east slope of Rocky Mountain National Park, Colorado. Geological Society of America Bulletin, 71: 1371-1382. Boulder, Colorado.
1965 Glaciation of the Rocky Mountains. In Wright, H. E., Jr., and Frey, D. G. (Eds.), The Quaternary of the United States:217-230. Princeton, New Jersey.

Rutherford, A. A., J. Wittenberg, and K. J. McCallum
1973 University of Saskatchewan radiocarbon dates VI. Radiocarbon, 15(1):193-211. New Haven, Connecticut.

Trautman, M. A.
1963 Isotopes, Inc. radiocarbon measurements III. Radiocarbon, 5:62-79. New Haven, Connecticut.

Wedel, W. R., W. M. Husted, and J. H. Moss
1968 Mummy Cave: prehistoric record from Rocky Mountains of Wyoming. Science, 160(3824):184-185. Washington, D.C.

Wilson, Michael
n.d. History of the Bison in Wyoming, with particular reference to early Holocene forms. This volume: 91-99.

PRELIMINARY INVESTIGATION OF COMPARATIVE SOIL DEVELOPMENT ON PLEISTOCENE AND HOLOCENE GEOMORPHIC SURFACES OF THE LARAMIE BASIN, WYOMING

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ABSTRACT

Pleistocene and Holocene geomorphic surfaces of the Laramie Basin possess varying degrees of soil development, dependent largely upon the ages of the surfaces and partly upon intervening erosional-depositional and drainage modification. Holocene surfaces have soils with A-C horizonation, whereas Pleistocene surfaces show increasing development of textural B-horizons corresponding generally to increasing age of surface. The oldest Pleistocene surface, however, lacks full horizonation due to truncation and alteration of the original soil.

INTRODUCTION

Erosional benches (sloping eastward from the Medicine Bow Range at 15 to 100 feet per mile) dominate the landscape of the floor of the Laramie Basin (Fig. 1). The benches, resembling pediment surfaces except where they grade into flood plains or alluvium proper, date from early Pleistocene to late Holocene. Names have been applied to these surfaces by Brainerd Mears, Jr. (personal communication) and de la Montagne (1951). These are, from highest and oldest to lowest and youngest: (1) Table Mountain, (2) Airport, (3) Harmony Bench, (4) Pahlow, (5) Stock Farm, and (6) Flood Plain (Fig. 1). Precise dates have not been assigned to these surfaces, but they represent Quaternary erosional and depositional events in the region. Thus, the benches have been subjected to variable amounts of pedogenesis, and representative surficial profiles from each of the benches should differ in a manner relative to the available formational time of each profile. In addition, description of soil morphologies should aid in geomorphic interpretation of the region.

FIELD DATA AND INTERPRETATIONS

Flood Plain Soils

Table I illustrates a profile from the Big Laramie Flood Plain surface (Fig. 1). Significantly, weak soil development reflects its youthful, Holocene age. Soils thus have only A-C horizonation with no indication of carbonate deposition or formation of color B-horizons. Shallowness of the water table, generally at 36 inches, retards oxidation, weathering, leaching, and thus soil maturity, as would be expressed by presence of a color or textural B. Such shallowness of the water table locally results in gleying at depths of as little as 24 inches.

In like manner, the nature of weathering of C-horizon alluvial materials manifests youthfulness of Flood Plain soils. Non-cemented sand and gravel clasts of igneous and metamorphic origin are rounded, fresh-appearing, and intact, with virtually no sign of pedologic decomposition or disintegration. However, thicknesses, dark colors, and high organic contents of A-horizons suggest a comparatively long time span of pedogenesis. A-horizon thickness and organic content appear greater than in older soils discussed in this report. This reflects formation in the poorly drained, essentially closed environment of the Flood Plain. Other signs of pedologic maturity are entirely absent.

In summary, soil formation in the region during at least the latter part of the Holocene has resulted in soils characterized by A-C horizonation with weak weathering of C-horizons. But these soils may have thick and well-developed A-hori-

TABLE I. FIELD DESCRIPTION OF FLOOD PLAIN SOIL.

Elevation: 7,130 ft. Location: NW 1/4 S32, T16N, R73W. Vegetation: willows and grasses. Parent material: alluvium. Slope: 1%. Aspect: N. Drainage: imperfectly drained (ground water at 36 in.). Stoniness: less than 1% throughout. Color and consistence under moist conditions.

A11	0 to 3 inches, very dark grayish brown (10YR 3/2) silt loam with medium to coarse weak subangular blocky structure; very friable; slight reaction; clear smooth boundary.
A13	3 to 7 inches, dark brown (10YR 3/3) silt loam with medium to moderate subangular blocky structure; very friable; slight reaction; abrupt broken boundary.
C1	7 to 36 inches, brownish yellow (10YR 6/6) sand; structureless; loose; no reaction; clear smooth boundary.
C2	36+ inches, reddish yellow (7.5YR 6/6) sand; structureless, nonsticky, nonplastic; no reaction.

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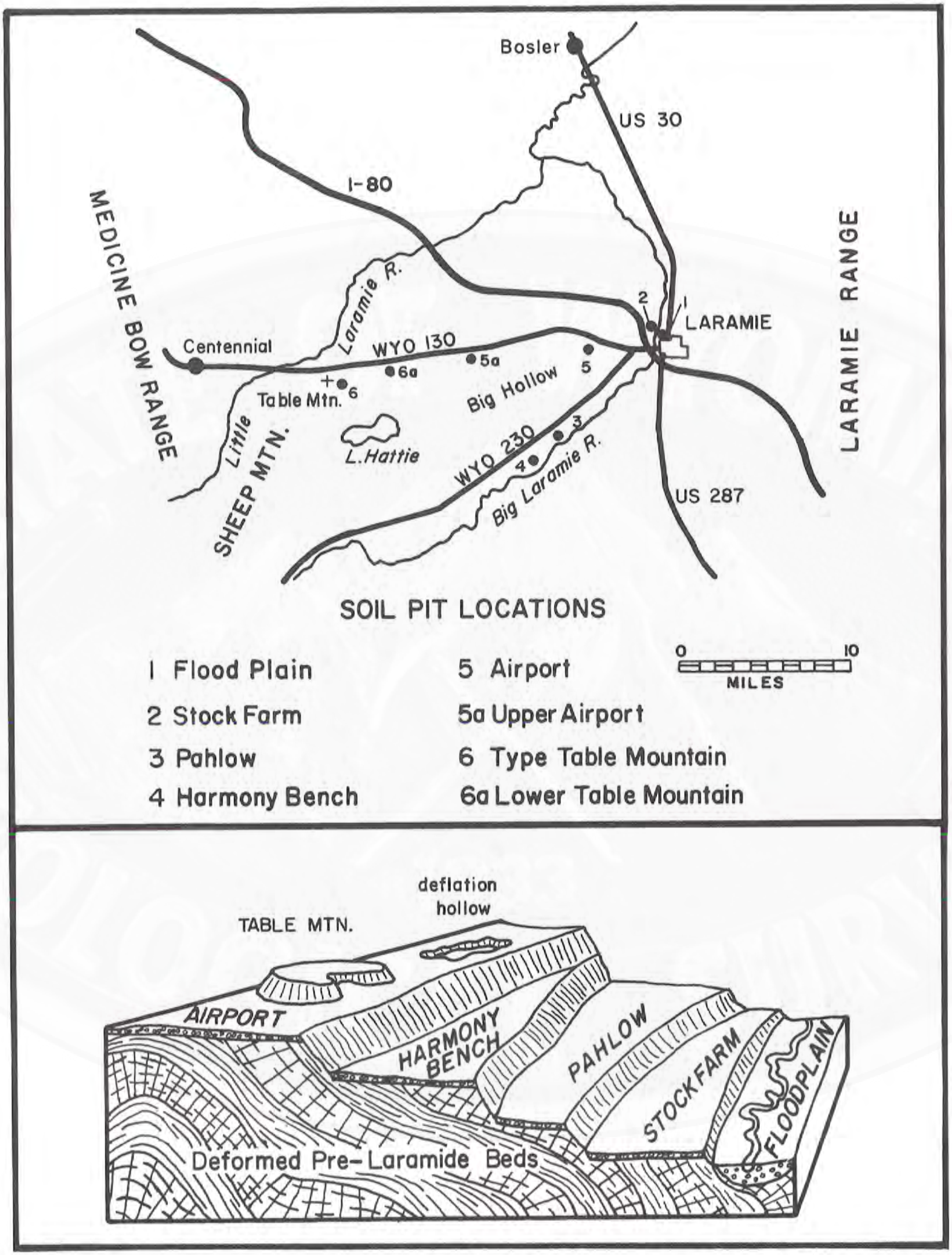

FIGURE 1. Top, map showing principal geographic features of the Laramie Basin area and pit locations of soils investigated in this report. Bottom, block diagram schematically showing the topographic relationships of the Pleistocene and Holocene surfaces.

zons, the development of which depends upon topographic stability, drainage qualities, and consequent effects on vegetation.

Stock Farm Soils

In contrast to the immaturity of Flood Plain soils, those occurring on the Stock Farm surface at 10 feet higher elevation possess a mature morphology (Table II; Fig. 1). In essence, these profiles exhibit textural B-horizons with blocky structures and calcium carbonate concentrations in the lower subsoil. Particle size analysis shows 27% clay and 27% silt in the B2ca-horizon. The soil in this instance is developed on limestone, which contributes to its relative stoniness. But notably such stones, elsewhere including igneous and metamorphic varieties, show weak weathering characteristics.

At the site studied, soils are well drained and display no indication of mottling or gleying. However, at other locations the water table lies as close to the surface as 48 inches and gleying consequently prevails in subsoils. In these cases, poor drainage inhibits leaching and oxidation processes and so prevents development of textural and oxidized B-horizons. Such horizons occur only at well drained sites of the Stock Farm surface.

Nonetheless, it is significant that soils of the Stock Farm surface exhibit textural B-horizons. Therefore, it appears that the surface dates no younger than early Holocene; more probably it dates to the late Wisconsin, for it is known regionally, (Hunt, 1954; Hunt and Sokoloff, 1950) that textural B-horizons generally are diagnostic of surfaces of Pleistocene age. This is most probably the case with the Stock Farm surface in view of the aridity of the local climate (11.14 in./yr.). Such aridity would not be conducive to rapid *in situ* or illuvial development of a textural B-horizon in well drained sites, but would allow such development only over a long period.

Pahlow Soils

Pahlow profiles (Table III; Fig. 1) exhibit textural B-horizons with blocky structures; in this and other aspects resembling Stock Farm soils. For example, non-cementing carbonates are present in the subsoil and the C-horizon displays weak weathering. However, soils are primarily developed on alluvium of igneous and metamorphic origin. High stoniness counts in lower B- and C-horizons reflect the coarseness of this material. No indication of gleying occurs in the Pahlow soil, and the profile has suffered Holocene modification: its A-horizon, estimated to be about six inches thick, has been truncated by slope wash

TABLE II. FIELD DESCRIPTION OF STOCK FARM SOIL.

Elevation: 7,140 ft. Location: NW 1/4 S32, T16N, R73W. Vegetation: grasses. Parent material: limestone. Slope: 2%. Aspect: N. Drainage: well drained. Color and consistence under moist conditions.

A1	0 to 2 inches, dark brown (7.5YR 3/2) sandy loam with medium to coarse moderate subangular blocky structure; very friable; slight reaction; clear smooth boundary; 1% stoniness.
A3	2 to 5 inches, brown to dark brown (7.5YR 4/2) sandy loam with medium to coarse moderate subangular blocky structure; very friable; strong reaction; clear smooth boundary; 2% stoniness.
B1	5 to 13 inches, brown to dark brown (7.5YR 4/4) loam with medium to coarse weak subangular blocky structure; very friable; strong reaction; clear s ooth boundary; 3% stoniness.
B2ca	13 to 21 inches, brown to dark brown (7.5YR 4/4) silt loam with coarse moderate subangular blocky structure; very friable; strong reaction; clear smooth boundary; 7 to 10% stoniness.
B3ca	21 to 25 inches, reddish yellow (7.5YR 6/6) loam with coarse moderate subangular blocky structure; very friable; strong reaction; clear smooth boundary; 10 to 15% stoniness.
Cca	25 to 30 inches, reddish yellow (7.5YR 6/6) sandy loam with coarse weak moderate subangular blocky structure; very friable; strong reaction; gradual wavy boundary; 25% stoniness.
R	30+ inches, weathered limestone.

TABLE III. FIELD DESCRIPTION OF PAHLOW SOIL.

Elevation: 7,200 ft. Location: NE 1/4 S32, T15N, R74W. Vegetation: grasses. Parent material: alluvium. Slope: 2%. Aspect: SE. Drainage: well drained. Color and consistence under moist conditions.

B1	0 to 8 inches, yellowish brown (10YR 5/4) silt loam with medium to coarse moderate subangular blocky structure; very friable; slight reaction; clear smooth boundary; 5 to 7% stoniness.
B2ca	8 to 18 inches, brownish yellow (10YR 6/6) loam with medium to coarse moderate subangular blocky structure; very friable; moderate reaction; clear smooth boundary; 10% stoniness.
C1ca	18 to 27 inches, yellowish brown (10YR 5/8) sandy loam with fine to medium moderate subangular blocky structure; very friable; moderate reaction; abrupt smooth boundary; 50% stoniness.
C2ca	27+ inches, brownish yellow (10YR 6/6) gravelly sand; structureless; loose; strong reaction; 50% stoniness.

and eoliation. In consequence lag gravels litter much of the soil surface.

Clay and silt fractions amount to 33% and 20% respectively in the B2ca-horizon. As indicated, Stock Farm soils most probably date from the late Wisconsin. Pahlow soils, on a higher surface, are chronologically older, yet differences in the surfaces are not expressed demonstrably in a pedologic sense. Thus the Pahlow surface probably is not significantly older than the Stock Farm surface, and therefore it dates no older than the late Wisconsin.

Harmony Bench Soils

Harmony Bench soils (Table IV; Fig. 1) in part resemble Stock Farm and Pahlow soils, but simultaneously show strong differences from them. Similarities include the presence of a textural B-horizon and weak weathering of igneous and metamorphic alluvial sands and gravels in the C-horizon. High stoniness counts are characteristic of the parent material.

In contrast, major differences consist of a greater clay accumulation in the B-horizon (40% clay and 20% silt in the B2-horizon) and a complete absence of gleying. However, the C-horizon is marked by pronounced iron oxide staining on pebble surfaces. These concentrations are probably the result of oxidation of iron which was once localized in a poorly drained, oxygen-reducing environment -- that is, in a gley condition during and following deposition of alluvium. Carbonates derived from pedogenesis now locally impregnate the iron-stained materials. The presence of these two minerals in one horizon denotes pedologic polygenesis, the transformation of a poorly drained soil to one of good drainage and oxidation under semi-arid conditions. The presence of carbonates, however, is probably the most notable feature giving evidence of maturity in Harmony Bench soils. Carbonate deposition in the B3ca-horizon completely influences the texture, imparting a mealy, friable consistence. Carbonates in C1ca- and C2ca-horizons cause cementation, but concentration in the C3ca-horizon is not yet sufficient to result in induration.

In light of the morphologic characteristics of Harmony Bench soils, such soils probably date no younger than early Wisconsin and may range back to Yarmouth time. Volcanic ash within Harmony Bench may prove to be equivalent to the Pearlette ash, but as yet no laboratory analysis conclusively dates this material.

TABLE IV. FIELD DESCRIPTION OF HARMONY BENCH SOIL.

Elevation: 7,245 ft. Location: NE 1/4 S6, T14N, R74W. Vegetation: grasses. Parent material: alluvium. Slope: 1%. Aspect: E. Drainage: well drained. Color and consistence under moist conditions.

A1	0 to 4 inches, brown to dark brown (10YR 4/3) loam with very fine to fine moderate crumb, to fine to medium moderate subangular blocky structure; very friable; slight reaction; clear smooth boundary; 5 to 7% stoniness.
B1	4 to 7 inches, yellowish brown (10YR 5/6) loam with medium to coarse moderate platy structure; very friable; moderate to strong reaction; clear smooth boundary; 7 to 10% stoniness.
B2	7 to 15 inches, brownish yellow (10YR 6/6) loam with medium to coarse moderate subangular blocky structure; very friable; moderate to strong reaction; clear smooth boundary; 7 to 10% stoniness.
B3ca	15 to 20 inches, yellow (10YR 7/6) loam with fine to medium moderate subangular blocky structure; very friable; strong reaction; abrupt irregular boundary; 25% stoniness.
C1ca	20 to 32 inches, very pale brown (10YR 8/3) sandy loam with medium to coarse moderate subangular blocky structure; friable; strong reaction; abrupt irregular boundary; 25% stoniness.
C2ca	32 to 50 inches, very pale brown (10YR 7/4) sand with medium to coarse moderate subangular blocky structure; firm; strong reaction; abrupt wavy boundary; 50% stoniness.
C3ca	50+ inches, yellowish brown (10YR 5/8) sand with medium to coarse weak subangular blocky and structureless structure; very friable; strong reaction; 50% stoniness.

Airport Soils

Airport soils exhibit profiles with textural B-horizons with blocky structures having 13% clay and 40% silt in the B2-horizon (Table V; Fig. 1). High sand and silt contents reflect eolian accumulation. A-horizons are weakly developed and lack sizeable organic concentration. Stoniness counts are comparatively low, except for the C-horizons where there are rounded fragments of Medicine Bow Quartzite with diameters of two to three inches.

Overall the soil is friable, fine-textured and little cemented. These characteristics are largely the result of deposition of fine sands and silts derived from upwind deflation of Big Hollow in the poorly consolidated Mesaverde Formation (Cretaceous). Lesser cementation as compared to Harmony Bench soils probably results from the noncalcareous nature of the materials when deposited. As a result of the accretion of such materials, the Airport soil is not a simple relict profile, but is a complex composite. However, it does not show profile development demonstrably older than the Harmony Bench surface soils. The original soil may have been completely truncated or may lie buried beneath a veneer of eolian and alluvial materials.

During the course of our study, the question arose as to whether site 5a (Fig.

TABLE V. FIELD DESCRIPTION OF AIRPORT SOIL.

Elevation: 7,265 ft. Location: NE 1/4 S34, T16N, R74W. Vegetation: grasses. Parent material: alluvium. Slope: 2%. Aspect: E. Drainage: well drained. Color and consistence under moist conditions.

A	0 to 8 inches, brown to dark brown (10YR 4/3) silt loam with medium moderate subangular blocky structure; very friable; slight to moderate reaction; clear smooth boundary; 1% stoniness.
B1	8 to 16 inches, dark yellowish brown (10YR 4/4) silt loam with medium to coarse moderate subangular blocky to angular blocky structure; very friable; moderate reaction; clear smooth boundary; 1% stoniness.
B2	16 to 24 inches, yellowish brown (10YR 5/6) silt loam with medium to coarse moderate subangular blocky to angular blocky structure; very friable; strong reaction; abrupt smooth boundary; 2 to 3% stoniness.
B3ca	24 to 37 inches, brownish yellow (10YR 6/6) silt loam with medium to coarse moderate subangular blocky structure; very friable; strong reaction; clear smooth boundary; 2 to 3% stoniness.
Cca	37+ inches, yellowish brown (10YR 5/6) gravelly sand with fine to medium moderate subangular blocky structure; very friable; strong reaction; 50% stoniness.

TABLE VI. FIELD DESCRIPTION OF UPPER AIRPORT SOIL.

Elevation: 7,460 ft. Location: SW 1/4 SW 1/4 S33, T16N, R75W. Vegetation: grasses. Parent material: pediment gravels (?). Slope: 2%. Aspect: SE. Drainage: well drained. Color and consistence under moist conditions.

A1	0 to 3 inches, dark brown (10YR 3/3) silt loam with medium moderate subangular blocky structure; very friable; slight reaction; clear smooth boundary; 20% stoniness.
B1ca	3 to 5 inches, dark yellowish brown (10YR 4/4) silt loam with medium to coarse moderate subangular blocky structure; very friable; slight reaction; clear smooth boundary; 20% stoniness.
B2ca	5 to 8 inches, yellowish brown (10YR 5/4) silt loam with medium to coarse moderate subangular blocky structure; very friable; strong reaction; clear smooth boundary; 25% stoniness.
B3ca	8 to 18 inches, yellowish brown (10YR 5/4) sandy loam with medium to coarse moderate subangular blocky structure; very friable; strong reaction; diffuse smooth boundary; 25% stoniness.
Cca	18+ inches, light yellowish brown (10YR 6/4) sandy loam with medium to coarse moderate subangular blocky structure; very friable; strong reaction; 30% stoniness.

1) was equivalent to the type Airport surface or to the Table Mountain surface discussed below. Table VI provides description of the soil, here referred to as Upper Airport, and indicates essentially the same morphology as that at the type location. Both Airport soils exhibit textural blocky B-horizons developed in fine earths derived from the Mesaverde Formation (27% clay and 30% silt occur in the B2ca-horizon of Upper Airport). Medicine Bow Quartzite is found in both C-horizons. However, the Upper Airport soil is not as thick as that at the type locality, yet it contains a greater degree of cementation and stoniness. These conditions result from the fact that Upper Airport is not downwind from Big Hollow and has not experienced the degree of eolian accumulation as at Airport proper. Nonetheless, morphologies indicate that Airport and Upper Airport profiles are equivalent, and moreover, that the surfaces upon which they occur are correlative.

Table Mountain Soils

The Table Mountain surface (Fig. 1) may date as old as Nebraskan time and may be equivalent to the Rocky Flats surface of the Colorado Piedmont (Malde, 1955). It would appear ironic, however, that soils of this oldest surface do not possess B-horizons, color or textural. The soil in Table VII, described from Table Mountain proper, possesses A-C horizonation. The A1- and A3-horizons actually are composed of reworked fine earths of the Mesaverde Formation, into and upon which the Table Mountain surface is cut. This thin eolian capping, derived from the dissected flanks of the mountain, now mantles approximately half of the surface, held in place by a sparse grass cover. Where eolian material is lacking, cobbles and boulders (pediment gravels?) of Medicine Bow Quartzite (6-18 in. dia.) from the C-horizon form a desert pavement complete with ventifacts. Thus the C-horizon is the only remnant of the original soil, and the A-horizon comprises a modern geomorphic and pedologic horizon developed on the truncated relict soil.

Despite the disturbed morphology of the Table Mountain profile, it does show significant evidence of great age. Foremost here is the heavy cementation by caliche of the C-horizon. It is this induration which has resulted in preservation of the flat surface of Table Mountain. Once the A- and B-horizons of the original soil were removed, most probably by progressive eolian deflation, the cemented C-horizon remained as a relict feature. In turn, Medicine Bow Quartzite cobbles and boulders -- deposited on the truncated Mesaverde Formation during original devel-

TABLE VII. FIELD DESCRIPTION OF TABLE MOUNTAIN SOIL.

Elevation: 7,905 ft. Location: NW 1/4 S3, T15N, R76W. Vegetation: grasses. Parent material: pediment gravels (?). Slope: 0 to 1%. Aspect: E. Drainage: well drained. Color and consistence under moist conditions.

A1	0 to 2 inches, yellowish brown (10YR 5/4) loam with very fine to fine weak crumb and subangular blocky structure; very friable; no reaction; clear smooth boundary; 25% stoniness.
A3	2 to 8 inches, yellowish brown (10YR 5/4) loam with fine to medium weak subangular blocky structure; very friable; slight reaction; clear smooth boundary; 25% stoniness.
ACca	8 to 13 inches, brownish yellow (10YR 6/6) sandy loam with fine to medium weak subangular blocky structure; friable; strong reaction; abrupt wavy boundary; 45% stoniness.
Cca	13+ inches, very pale brown (10YR 7/4) sandy loam with medium to coarse weak angular blocky structure; firm; strong reaction; 45% stoniness.

opment of the surface -- have resisted much further pedogenesis, A-horizons forming readily only where Mesaverde sands and silts have been re-deposited.

During investigation of Table Mountain soils, it appeared possible that the surface at 6a (Fig. 1), here referred to as Lower Table Mountain, was either part of the Table Mountain surface proper or the Airport surface. As shown in Table VIII, the soil at this site is unlike the Upper Airport profile (Table VI, but clearly resembles the profile of type Table Mountain (Table VII) -- minus observable accumulations of Mesaverde materials. Instead, its A-horizon is superposed directly on the relict C-horizon, as a result being highly alkaline at the soil surface in contrast to A-horizons developed in relatively fresh, acidic Mesaverde materials. Nonetheless, the soil at 6a (Fig. 1) must be regarded as equivalent to the type Table Mountain soil (6, Fig. 1), and therefore, the Lower Table Mountain surface is probably an extension of the Table Mountain surface proper.

TABLE VIII. FIELD DESCRIPTION OF LOWER TABLE MOUNTAIN SOIL.

Elevation: 7,700 ft. Location: NW 1/4 S3, T15N, R76W. Vegetation: grasses. Parent material: pediment gravels (?). Slope: 2%. Aspect: NE. Drainage: well drained. Color and consistence under moist conditions.

A1	0 to 6 inches, dark brown (10YR 3/3) sandy loam with fine weak subangular blocky structure; very friable; moderate reaction; clear smooth boundary; 20% stoniness.
ACca	6 to 10 inches, yellowish brown (10YR 5/4) sandy loam with fine moderate subangular blocky structure; friable; strong reaction; clear smooth boundary; 50% stoniness.
Cca	10+ inches, very pale brown (10YR 7/4) sandy loam with medium to coarse moderate subangular blocky structure; friable; strong reaction; 50% stoniness.

SUMMARY AND CONCLUSIONS

Preliminary investigation of soils of Pleistocene and Holocene benches of the Laramie Basin indicates a correlation between geomorphic surface age and soil age, although eolian erosion and deposition and water table characteristics modify these general relationships. Other unobserved or extinct modifying agents may further have influenced soil morphologies through time and thereby complicated the fundamental soil-surface-age associations recognized in this report. Soils of the three oldest surfaces display prominent signs of polygenesis or disturbance in contrast to more simple morphologies of the youngest.

It is interesting and perhaps of regional importance that the results of this study do not correspond to those of Sansom (1972) in the Medicine Bow Mountains immediately west of the area investigated. Sansom found little correlation between moraine age and soil development. Rather than soil development being principally governed by the time factor on moraines of Bull Lake and Pinedale ages, pedogenesis was controlled chiefly by the combination of climate and vegetation as determined by altitude. In no cases did he find textural B-horizons -- although they occur widely in the Laramie Basin.

These apparent contradictions warrant further investigation so we may understand pedogenesis in basinal environments as opposed to mountainous environments in Wyoming. The answer probably lies in the unique combination of geographical characteristics in one environment and their different or contrasting arrangements in the other. An understanding of the interaction of these characteristics within each environment and comparisons among them could explain much about modern soil distribution in Wyoming.

ACKNOWLEDGMENTS

Gratitude is extended to Dr. Brainerd Mears, Jr. for providing access to his property to examine the Pahlow soil.

Credit is acknowledged to Mr. Peter Jachowski for drafting Figure 1.

REFERENCES

Hunt, C. B.
1954 Pleistocene and Recent deposits in the

Denver area, Colorado. United States Geological Survey Bulletin, 996-C:91-140. Washington, D.C.

Hunt, C. B. and V. P. Sokoloff
1950 Pre-Wisconsin soil in the Rocky Mountain region: a progress report. United States Geological Survey Professional Paper, 221-G:109-123. Washington, D.C.

Malde, H. E.
1955 Surficial geology of the Louisville Quadrangle, Colorado. United States Geological Survey Bulletin, 996-E:217-259. Washington, D.C.

de la Montagne, John
1951 Geomorphology of the North End of Centennial Valley -- Table Mountain Area, Wyoming. M.A. Thesis (Geology), University of Wyoming, Laramie. 121 p.

Sansom, Benjamin R.
1972 Morphology and Analysis of Soils on Wisconsin Moraines of the Libby Creek Area, Medicine Bow Mountains, Wyoming. M.A. Thesis (Geography), University of Wyoming, Laramie. 78 p.

Soil Survey Staff
1962 Soil Survey Manual. U.S. Department of Agriculture, Soil Conservation Service, Agriculture Handbook, 18:503 p. Washington, D.C.

ERTS MSS IMAGERY APPLIED TO MAPPING OF SAND DUNES IN WYOMING[1]

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ABSTRACT

Active and stabilized dune fields of regional extent were mapped using Earth Resources Technology Satellite (ERTS) imagery. Previously mapped dune fields (Ahlbrandt, 1973; Houston, 1973; Love, Weitz, and Hose, 1955; Roehler, 1969) were confirmed by the ERTS image study, and some new dune fields were discovered. Additional confirmation was provided by field work and high-altitude aerial photographs which were available for some areas.

Results indicate that color composite ERTS images are most helpful in locating active dune fields. This is attributed to subtle color differentiation between active dunes, clouds, sandy alluvium, pediments, alkali flats, snowfields, and light-colored rock formations. The color composite images were also employed in mapping stabilized dune fields which usually exhibited a brown-green coloration characteristic of sparse and relatively dormant vegetation. The contrast between both stable and active dunes and the surroundings was most apparent on the image transparencies, because the transparencies have higher resolution and greater flexibility in the intensity of illumination than do the prints. Color prints were most convenient for field use. Another general advantage of ERTS imagery is the display of regional linear patterns and topographic features. Crosscut relations between dune fields and surrounding rock formations were also recognized.

The disadvantages of ERTS imagery are: 1) the imagery is of a small scale, and small dune fields were sometimes missed; and 2) there is sometimes a lack of distinct color and tonal contrast between a stabilized dune field and its surroundings.

The mapping with ERTS was evaluated by comparing the ERTS map with a similar map prepared using high-altitude aircraft photography. The comparison shows an impressive similarity.

It was hypothesized that the differences between active and stabilized dunes might be a record of a shift in wind directions from prehistoric to recent times. More research is needed to determine when this shift occurred.

PART I: TECHNIQUES AND PROCEDURE IN APPLYING REMOTE SENSING TO THE MAPPING OF SAND DUNES IN WYOMING

INTRODUCTION

Due to the abundance of source rock, a climate which favors mechanical weathering, and the strong transport of high winds, Wyoming has many active and stabilized sand dunes and dune fields. The principal objectives of this investigation were to compile a map of all the sand dunes in Wyoming, to note differences in directional movement of stabilized and active dunes, and to confirm a technique of mapping sand dunes using ERTS imagery.

PROCEDURE

In order to map sand dunes accurately from ERTS imagery, it was first necessary to conduct a literature search concerning dune types (Bagnold, 1954; Cooper, 1958; Chadwick and Dalke, 1965). The literature also indicated specific dune fields which had been studied or mapped in Wyoming (Ahlbrandt, 1973; Houston, 1973; Roehler, 1969; Love, Weitz, and Hose, 1955). After known dune fields were researched, preliminary field work was carried out to familiarize the author with the vegetative and physiographic environment associated with the sand dunes. Techniques for mapping dune fields using remote sensing were then researched (McKee, Breed, and Harris, 1973). Finally, ERTS imagery was used to locate known dune fields for reference purposes. An understanding of dune field characteristics as displayed on these images allowed subsequent identification of probable areas of unmapped dunes. Confirmation was then sought from high-altitude aerial photographs and field work. A map of all identified dune fields was compiled (Fig. 1).

<u>Selection of ERTS Imagery Based on Technique</u>

Dunal shape, stabilized vegetation cover, sand coloration, and regional lineation patterns are important parameters in mapping dune fields from ERTS imagery. Color composite ERTS imagery of bands four, five and seven was used rather than individual ERTS

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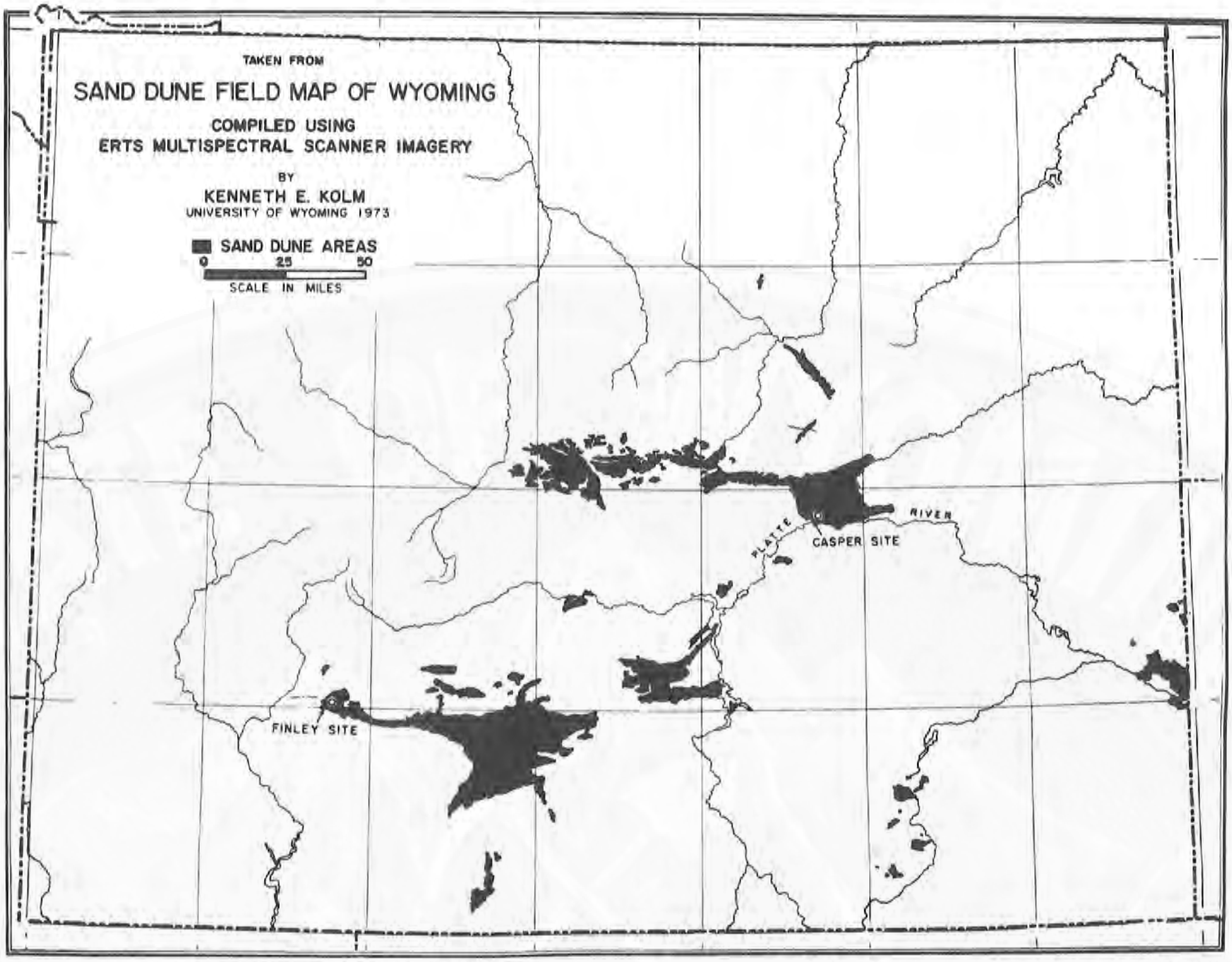

FIGURE 1. Map of sand dune fields in Wyoming. The dark areas include both active and stabilized Holocene dunes.

bands to differentiate between the yellow color of active dune fields, the white clouds, the light-colored alluvium, the pediments, the snow fields, the alkali flats, and the light-colored rock formations. Color-composite imagery also provides a distinct contrast between some stabilized dune fields, whose characteristic vegetation appears dark brown and brownish-green in ERTS imagery, and surrounding environments consisting of lighter soil shades or brilliant red vegetation. However, field-checking is still required when working with vegetation-covered, stabilized dunes. Transparency images were used in the laboratory instead of prints because the greater flexibility in controlling the illumination results in a higher resolution of detail. Color prints were most advantageous for field checking. Regional lineation patterns, geologic crosscutting of dune fields, and shapes of active dune fields within an area can be easily defined in ERTS images. Again, color composite images offer more contrast between the dune field and its surroundings.

Problems Encountered

The major problem encountered in working with ERTS imagery is mapping in small scale. The reduction of detail increases the possibility of missing small dune fields, especially if no active dunes are present in the dune area.

A second problem directly related to lack of detail is the common lack of color or tonal contrast between a stabilized dune and its surroundings. This problem is even more pronounced when black and white imagery is used. Both of these problems can be resolved with low-level photo-interpretation and field checks.

Comparison of ERTS Imagery with High-Level Aerial Photography

To determine the relative accuracy of mapping sand dunes using ERTS imagery, a small area of the Wind River Basin sand dune field was mapped using high-level aerial photography. A comparison of the ERTS- and aircraft-derived maps demonstrates that ERTS imagery gives an accurate representation of the location of sand dunes.

PART II: THE DUNE FIELDS OF WYOMING

GENERAL INFORMATION

There are five kinds of dunes common in the active and stabilized dune regions of Wyoming (Ahlbrandt, 1973, and this volume). Four are described in McKee's evolutionary sequence of active dunes: dome, transverse, barchan, and parabolic. These dune types, if active, can be identified by their characteristic yellow color on the color composite ERTS image and by their shape (if not in a dune complex). Seif dunes and barchan dunes are the most common stable dunes. More research is needed to determine the significance of dunal types, their directions and their age relationships.

Dunes become stabilized when vegetation takes root in the sand and prevents further movement of the dunal structure downwind. The details of plant succession during stabilization have been summarized by Chadwick and Dalke (1965) and Ahlbrandt (1973). The succession is summarized in the present volume by Ahlbrandt (q.v.). As he notes, the oldest dormant dunes (in the stabilized dune fields of Wyoming) are stabilized by Artemisia tridentata (sagebrush) and the cactus Opuntia. This vegetation, combined with the sandy soil, gives some stabilized dune regions their characteristic dark brown, brownish-geeen coloration on a color composite image.

REGIONAL DUNE FIELDS OF WYOMING

Killpecker

The western end of the Killpecker dune field lies north of Rock Springs and about five miles east of Eden, Wyoming. From here it extends sixty miles east-northeastward. A detailed enlargement prepared by Thomas Ahlbrandt (1973) shows the western area of this dune field to be composed of active dunes trending about N 65° E (average direction from twenty randomly selected dunes). These dunes are easily distinguished on color composite ERTS imagery by their yellow color and shape. The eastern section of the Killpecker region is a mixture of active and stabilized dunes grading eastward into predominantly stabilized dunes trending N 50° E. They are easily distinguished on ERTS by their regional linear paleomigration pattern.

Other smaller dune fields occur in the region surrounding the main body of dunes. One small dune field, consisting of stabilized dunes, lies twelve miles northeast of Farson on Wyoming Highway 28. Other small dunes are scattered throughout a six-hundred square mile area south of the Killpecker dune field (Blackstone, 1973). These are the result of mechanical weathering of nearby sand units and wind accumulation of playa lake sands. Some of these dunes can be mapped from ERTS, but others lack discernible tonal differences and large-scale linear patterns which would permit identification.

Washakie Basin

The Washakie Basin dune region of southwestern Wyoming lies fifteen miles south of Tipton, Wyoming. The northern part of the dune field and the southern portion trends northeast-southwest (Roehler, 1969). No dunal orientations have been recorded in this area. The Washakie Basin dunes were difficult to locate using ERTS imagery due to a similarity between coloration of dune fields, alkali flats, and exposed sandstone units. In some parts of the field, the dark brown color of dunal vegetation was helpful in defining a dune field boundary.

Seminoe and Pathfinder Reservoirs

The dune field near Seminoe and Pathfinder Reservoirs extends northwest from Seminoe Reservoir along the south side of the Ferris Mountains. Regionally, it trends east-west with a tail that extends northeast to Pathfinder Reservoir. Smaller dune fields are found about two miles north of the northeast-trending tail, five miles north of Pathfinder Reservoir, two miles south of Pathfinder Reservoir along the North Platte River, and east of the southern part of Seminoe Reservoir (Love, Weitz, and Hose, 1955). Active dunes are found along the northern boundary of the eastern portion of the main dune field, and its northeast extension. They have an average trend of N 70° E in the major field and N 45° E along the tail. The active dunes are easily identified on ERTS imagery by their yellow color and their characteristic shape. The stabilized dunes have an average trend of N 58° E and can be identified on ERTS images by their dark brown color. The western section on the field is predominantly a sand basin with small dunes.

Jeffrey City

A small northeast-trending dune field is located just east of Jeffrey City, Wyoming. It is composed of stabilized dunes trending about N 62° E. These were difficult to identify on ERTS imagery because they lack vegetation contrast.

Wind River Basin and Casper Area

A large, continuous dune field trending east-west extends from just east of Shoshoni to west-central Converse County, Wyoming (Houston, 1973). Active dunes are scattered throughout the field and are most prevalent in the area north and northeast of Casper, Wyoming. Their average trend is N 70° E. Stabilized dunes and sand basins are the most common physiographic features of this dune field, and stabilized dune trends range from N 80° E at Moneta and N 63° E at Hiland to N 50° E at Casper. The field was easily identified using ERTS imagery because both the characteristic dark brown vegetation coloring of the stabilized dunes and the yellow color and shapes of the active dunes were present.

Torrington

Dune fields in eastern Wyoming, such as the one at Torrington, generally trend southeastward. Small dune fields were found five miles northeast of Huntley, two miles

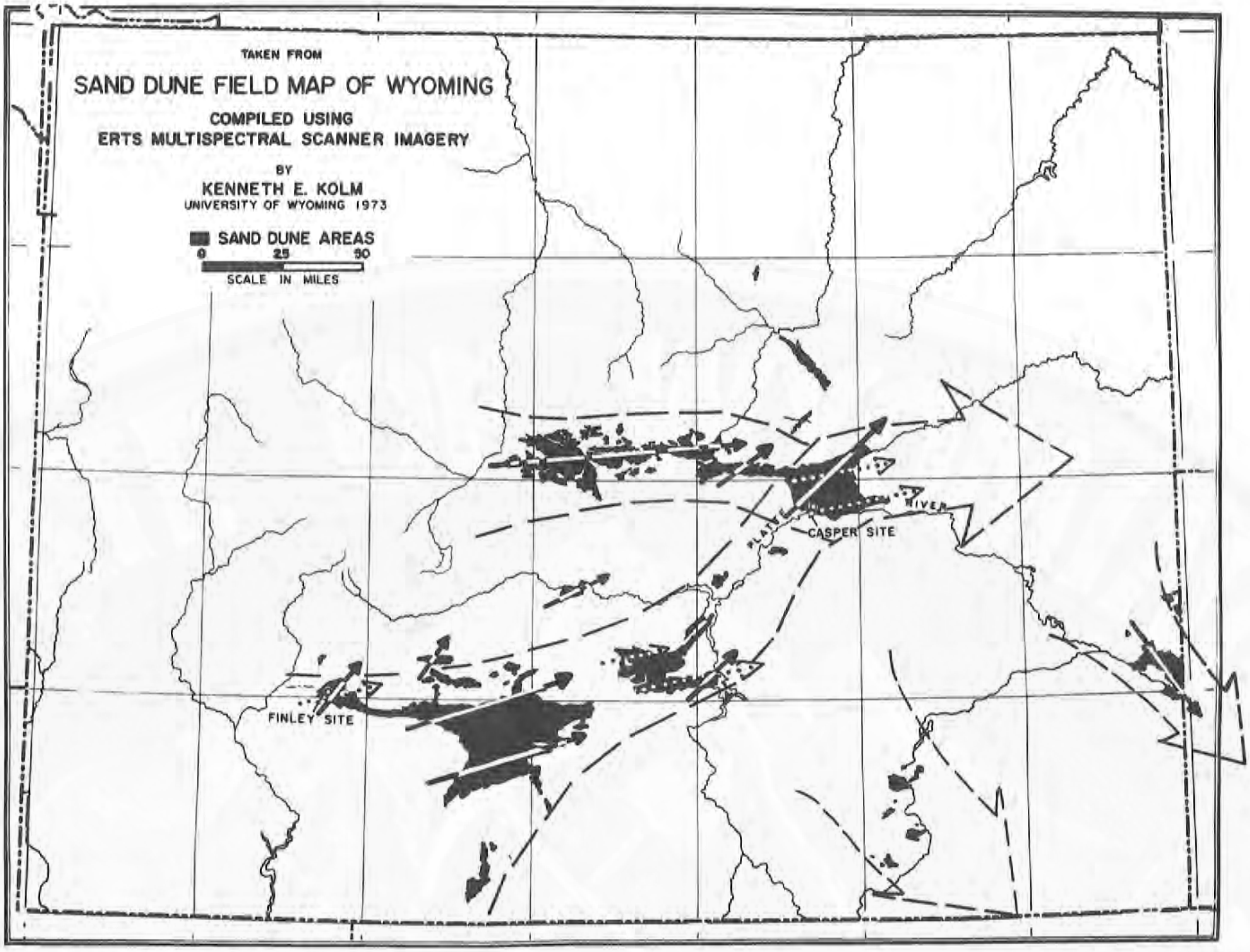

FIGURE 2. Map of sand-dune fields shows migration directions of stabilized (solid arrows) and active (dotted arrows) dunes. Apparent wind directions are indicated by large, dashed arrows.

southeast of Lingle, thirty-four miles south of Lusk on U. S. Highway 85, and fifteen miles due east of Jay Em. Most dune fields of this region are composed of stabilized dunes with average trends of S 35° E. They are very difficult to map on ERTS imagery because they lack vegetative and topographic contrast with the surrounding range and farm lands.

Laramie Basin

The Laramie Basin of southeastern Wyoming has scattered active dune fields associated mostly with playa lakes. Mappable playa lake areas with dunes can be seen at Lakes Ione, Cooper, James, and Hattie. The sand dunes are derived from lake-bottom sediment accumulated during windy, dry seasons. Other playa lakes have associated dunes but the scale is too small for effective ERTS mapping. The Laramie Basin dunes are confined to the eastern and southeastern lake shores and migration patterns trend southeastward.

One other dune field is found in the northern part of the basin along Wyoming Highway 489 about twenty-three miles from Casper. It is composed of stabilized dunes trending southeast and is very difficult to map from ERTS imagery because of a lack of physiographic and vegetative contrast with its surroundings.

Powder River Basin

Field reconnaissance revealed small, scattered, active dunes in the eastern Powder River Basin. Dunes were found near Linch, Midwest, seven and one-half miles south of Midwest at Teapot Creek, and thirteen miles north of Kaycee along Interstate Highway 25. These dunes are directly associated with the weathering of a surrounding sandstone unit and are not organized into a dune field. They could not be mapped on ERTS imagery due to their extremely small size.

Active dunes indicate the dominant present-day wind directions. The stabilized dunes may well record dominant wind directions of some time in the past. Therefore, it should be possible to determine transport directions for stabilized dunes, date the most recent movement and derive paleo wind directions. Regardless of how far in the past changes occurred, comparisons of stabilized dunes with active dunes could indicate major shifts in wind directions and could then be documented and related to other geologic events.

The dunes of Seminoe and Casper are excellent examples. In the Seminoe area, the stabilized dunes trend N 58° E whereas the active dunes trend N 70° E. There is an apparent shift of roughly 12° to the east. At Casper, the wind shift is about 20° east.[3]

Archaeologists have used the sand dunes map as a source of information about dunal trends and possible archaeological site location, in efforts to find and interpret ancient artifacts and bone matter (Frison, in press). Evidently, the dunes can be related to specific types of prehistoric bison procurement systems, where they were used as trap elements (Ahlbrandt, this volume; Albanese, this volume).

Paleontologists note shifts in wind patterns over time and relate this to changing environments during the Holocene. Pedologic and mineralogic data from the dune fields also yield environmental information and can indicate climatic change (Ahlbrandt, this volume). Such environmental data serve as input into studies of faunal changes through time.

CONCLUSIONS

This study demonstrates that, on a regional scale, ERTS imagery is very useful in locating and mapping dune fields. Color composite images combining bands four, five, and seven were most helpful in mapping dunes because of the color distinction between active dunes and alluvium, pediments, clouds, snowfields, salt flats, and surrounding light-colored rock units. Some stabilized dunes and surrounding rock formations were discernible via color distinctions of characteristic vegetation found in each. The ERTS imagery also provides a regional perspective which emphasizes dune migration patterns and crosscut relationships with surrounding rock formations.

The disadvantages of using ERTS-1 imagery are an occasional lack of contrasts between stable dunes and their surroundings; similarities between active sand dunes, alkali flats, and exposed sandstone units; and the small scale of ERTS imagery. Densitometry and color filtration techniques should be of value in attempts to differentiate between stabilized and active dunes and their surroundings. The overall evaluation in accuracy of mapping with ERTS was favorable.

[3]Editor's note: John P. Albanese (this volume:46-50) cites the direction of the dunes at Casper to be N 65° E to N 75° E; this agrees with Kolm's determination of active dune directions at Casper (N 70° E; above, p. 36). However, Kolm determines the stabilized dune trend to be N 50° E -- documenting a wind shift of 20° east. If this is the case, such a shift must have occurred prior to 10,000 years B.P., as the reconstructed dune at the Casper site showed a direction in agreement with that of modern dunes. Further study is warranted.

REFERENCES

Ahlbrandt, T. S.
1973 Sand dunes, Geomorphology and Geology, Killpecker Creek area, North Sweetwater County, Wyoming. Ph.D. Dissertation (Geology), University of Wyoming, Laramie, Wyoming. 174 p.
n.d. Dune stratigraphy, archaeology, and the chronology of the Killpecker Dune Field. This volume: 51-60.

Albanese, J. P.
n.d. Geology of the Casper Archaeological Site, Natrona County, Wyoming. This volume: 46-50.

Bagnold, R. A.
1954 The Physics of Blown Sand and Desert Dunes. Methuen and Co., London, England. 265 p.

Blackstone, D. L., Jr.
1973 Geology of Photo Linear Elements, Great Divide Basin, Wyoming. University of Wyoming Department of Geology, Special Report under Contract NAS5-21799. Laramie, Wyoming.

Chadwick, H. W., and P. D. Dalke
1965 Plant succession on sand dunes in Fremont County, Idaho. Ecology, 46:766-785. Duke University Press, Durham, North Carolina.

Cooper, W. S.
1958 Coastal dunes of Oregon and Washington. Geological Society of America Memoir 72: 1-169. New York, New York.

Frison, G. C. (Ed.)
in press The Casper Site: a Hell Gap Bison Kill on the High Plains. Academic Press, New York, New York. 259 p.

Houston, R. S.
1973 Unpublished maps. Department of Geology, University of Wyoming, Laramie, Wyoming.

Kolm, K. E.
1974 ERTS MSS Imagery Applied to Mapping and Economic Evaluation of Sand Dunes in Wyoming. Special Report under Contract NAS 5-21799. Available from National Technical Information Services, U. S. Department of Commerce, Springfield, Virginia 22151. 31 p.

Love, J. D., J. L. Weitz, and R. K. Hose
1955 Geologic Map of Wyoming. United States Geological Survey, Washington, D.C.

McKee, E. D.
1966 Structures of dunes at White Sands National Monument, New Mexico (and a comparison with structures of dunes from other selected areas). Sedimentology, 7(1):1-69. Amsterdam, Holland.

McKee, E. D., C. S. Breed, and L. F. Harris
1973 A study of morphology, provenance, and movement of desert sand seas in Africa, Asia, and Australia. Type I Progress Report for Period II, January, 1973 - February, 1973, for ERTS-1 NASA/Goddard Space Flight Center. Greenbelt, Maryland.

Roehler, H. W.
1969 A review of Eocene stratigraphy in the Washakie Basin, Wyoming. U. S. Geol. Survey, Guidebook, Field Conference on Tertiary Biostratigraphy of Southern and Western Wyoming, 1972: 3-19. Denver, Colorado.

United States Department of Commerce
1971-1973 Climatological Data. Series of monthly publications from January, 1971, to August, 1973. Washington, D.C.

Editor's note: Kolm's study resulted in a very detailed map distinguishing active and stabilized dune areas and combinations thereof. The detail was too great for reduction here, so we drafted a new map (above, Fig. 1) showing distribution of dune fields. The detailed map is available in Kolm (1974, cited above), but at a level of reduction which makes it rather difficult to interpret in detail.

CROSS-STRATIFICATION IN HOLOCENE SANDS

JAMES R. STEIDTMANN[1]

ABSTRACT

Cross-stratification is found in sands of every major depositional environment. It generally consists of foreset strata inclined at some angle to the boundaries of a sedimentation unit or bed. Most commonly it is formed by the preservation of foreset bedding in bed forms such as ripples, dunes or sand waves, but it may also form by the infilling of scours and by accretion on point bars and beaches. Except for beaches and point bars, most cross-stratification has a general downcurrent dip.

Some major depositional environments can be recognized on the basis of the occurrence of certain stratification and cross-stratification types. In some environments, paleohydraulic parameters such as channel width, water depth and flow velocity can be estimated by relating types of cross-stratification to bed forms which are known to form under specific flow conditions. Finally, the general downcurrent dip of most cross-stratification allows the reconstruction of paleoslope, sediment dispersal patterns, paleowind directions, and sediment sources. Several statistical techniques are particularly applicable to this type of analysis.

INTRODUCTION

Cross-stratification (also known as cross-bedding, current bedding and cross-lamination) is one of the most common and easily recognizable primary structures in modern and ancient sands. It is found in every major depositional environment: fluvial, littoral, marine and eolian. According to Pettijohn and others (1972:108), cross-stratification is a particular type of inclined bedding which is confined to a single sedimentation unit (Otto, 1938:575) and is characterized by internal bedding or lamination, called foreset bedding, inclined to the principal surface of accumulation. By restricting cross-stratification to a single sedimentation unit, Pettijohn and others (1972:108) exclude the inclined bedding of talus deposits, lateral accretion deposits such as point bar slopes, and other stratification with a high initial dip such as that formed by the basinward growth of a delta front and the lower angle stratification related to a prograding beach. On the other hand, Blatt and others (1972:112) describe cross-stratification as internal structures inclined at an angle to the bed boundaries; thus they do not use the concept of a sedimentation unit in their definition. As a result, accretionary deposits of beaches and point bars are considered cross-stratification (<u>ibid.</u>:118).

There have been a number of attempts to classify cross-stratification. Although no one system has gained complete acceptance, that proposed by McKee and Weir (1953) is probably most commonly used. According to this terminology a single group of cross-strata is called a <u>set</u>. A group of similar sets is called a <u>coset</u>. Furthermore, the cross-strata are classified according to seven criteria, the most useful of which are (1) the scale of the sets, (2) the shape and attitude of cross-strata, and (3) the shape and nature of the lower and upper bounding surfaces of the sets.

As pointed out by Blatt and others (1972:112) a distinction is frequently made between <u>tabular</u> sets, bounded by essentially plane, <u>parallel</u> surfaces; <u>wedge-shaped</u> sets, bounded by plane, <u>non-parallel surfaces</u>; and <u>trough</u> sets, whose lower bounding surfaces are trough-shaped (Fig. 1). For further details on this and other classifications the reader is referred to McKee and Weir (1953), Allen (1963), and Conybeare and Crook (1968). Numerous excellent examples of the wide variety of cross-stratification types are shown by Potter and Pettijohn (1963), Pettijohn and Potter (1964), and Conybeare and Crook (1968).

The mechanisms which produce cross-stratification have received quite a bit of attention, both experimentally in laboratory flumes and observationally in modern environments. Most commonly it results from deposition on the lee slopes of bed forms such as ripples, dunes, and sand waves which are formed by the interaction of moving fluid with sediment. In general, this deposition takes place as grains are eroded from the upcurrent side of a bed form and transported to the crest where they then avalanche down the lee slope forming foreset stratification. In this way both sediment and bed form move in a downcurrent direction and the internal structure of the bed form displays downcurrent-dipping foreset strata. Where bed aggradation is such that the entire bed form is not destroyed by erosion on its upcurrent side, a portion of the bed form and its internal foreset bedding will remain as a cross-stratified deposit. Where aggradation is very rapid, very little erosion of bed forms occurs and both the bed form and its internal stratification are preserved in the deposit.

Cross-stratification may also form in other ways. The infilling of scours by

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avalanching sediment produces cross-stratification which dips downcurrent. Very low-dipping cross-stratification is formed by accretion of sediment on point bars, where it dips approximately normal to the current, and on beaches, where it dips offshore. In rare cases, upcurrent-dipping cross-stratification, formed under extremely high-energy flow conditions, is preserved in sediments.

The significance of cross-stratification in interpreting the history of a deposit stems directly from the causal relations between fluid flow and sediment transport. With this fact in mind, several lines of reasoning are particularly useful. They are: (1) some depositional environments can be recognized on the basis of types of cross-stratification and their association with other stratification and lithologies; (2) conditions of deposition in some depositional environments can be determined from the analysis of cross-stratification; and (3) current directions, paleoslope and sediment dispersal patterns can be determined from an analysis of the dip directions of cross-stratification.

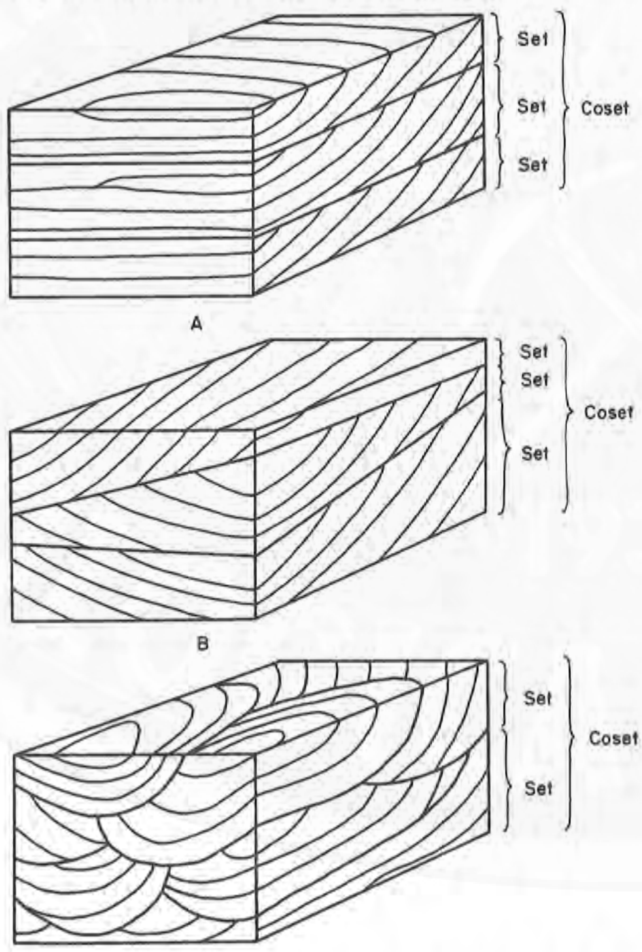

FIGURE 1. Cross-stratification terminology after McKee and Weir (1953). (A) tabular sets; (B) wedge-shaped sets; and (C) trough-shaped sets containing trough cross-stratification. Adapted from Blatt and others (1972).

ENVIRONMENTAL RECOGNITION

Of the many depositional environments where cross-stratification forms, four are most commonly encountered in studies of the Holocene record in Wyoming. They are: (a) meandering streams, (b) braided streams, (c) alluvial fans, and (d) eolian dunes. Associations of stratification types found in each of these environments are depicted schematically in Figure 2.

Meandering streams (Fig. 2A) deposit cross-stratified sand primarily by forming point bars on the inside of each meander (Harms and others, 1963). As the stream combs across its flood plain these point-bar deposits coalesce to form a fluvial sheet sand contained in an envelope of fine-grained overbank sediment deposited at times of flooding. The stratification in the sand records the modes of sediment transport and deposition on different parts of the bar. The base of the sand is erosional and often contains coarse lag gravel. The lower part of the bar sand may be composed of low-dipping cross-strata which represent deposition and accretion on the streamward-sloping surface of the point bar. The upper part of the bar is composed of cosets of trough cross-stratification which form by the filling of spoon-shaped scours and the migration of dunes over the upper bar surface. This may in turn be overlain by small-scale ripple cross-stratification. In general, grain size decreases upward in this sequence.

Braided streams (Fig. 2B) deposit sand as transverse and longitudinal bars (Williams and Rust, 1969; Ore, 1965). Where longitudinal bars are formed stratification is generally poorly defined, discontinuous and horizontal. Little cross-stratification is apparent. Transverse bars, however, are waves of sediment which move downstream by the same mechanism described earlier for ripples and dunes. As a result, foreset cross-stratification is common in deposits formed originally as transverse bars. Where ripples or dunes have migrated over the top of these bars, small scale trough cross-stratification or ripple cross-stratification is formed on top of the larger bar-front or foreset cross-strata. These deposits are generally much thinner than point-bar sequences and are associated with other channel deposits than the overbank sediments which accompany point-bar sands.

Deposition on alluvial fans (Fig. 2C) takes place from both running water and debris or mud flows (Bull, 1972) and thus a wide range of complexly related stratification and cross-stratification may occur. In general, however, most of the water-laid sediments consist of sheets of sand deposited by a network of braided distributary channels; and they display cross-stratification similar to that of other braided streams. Other water-laid deposits occur where entrenched stream channels are backfilled during subsequent runoff. These deposits generally are coarser and more

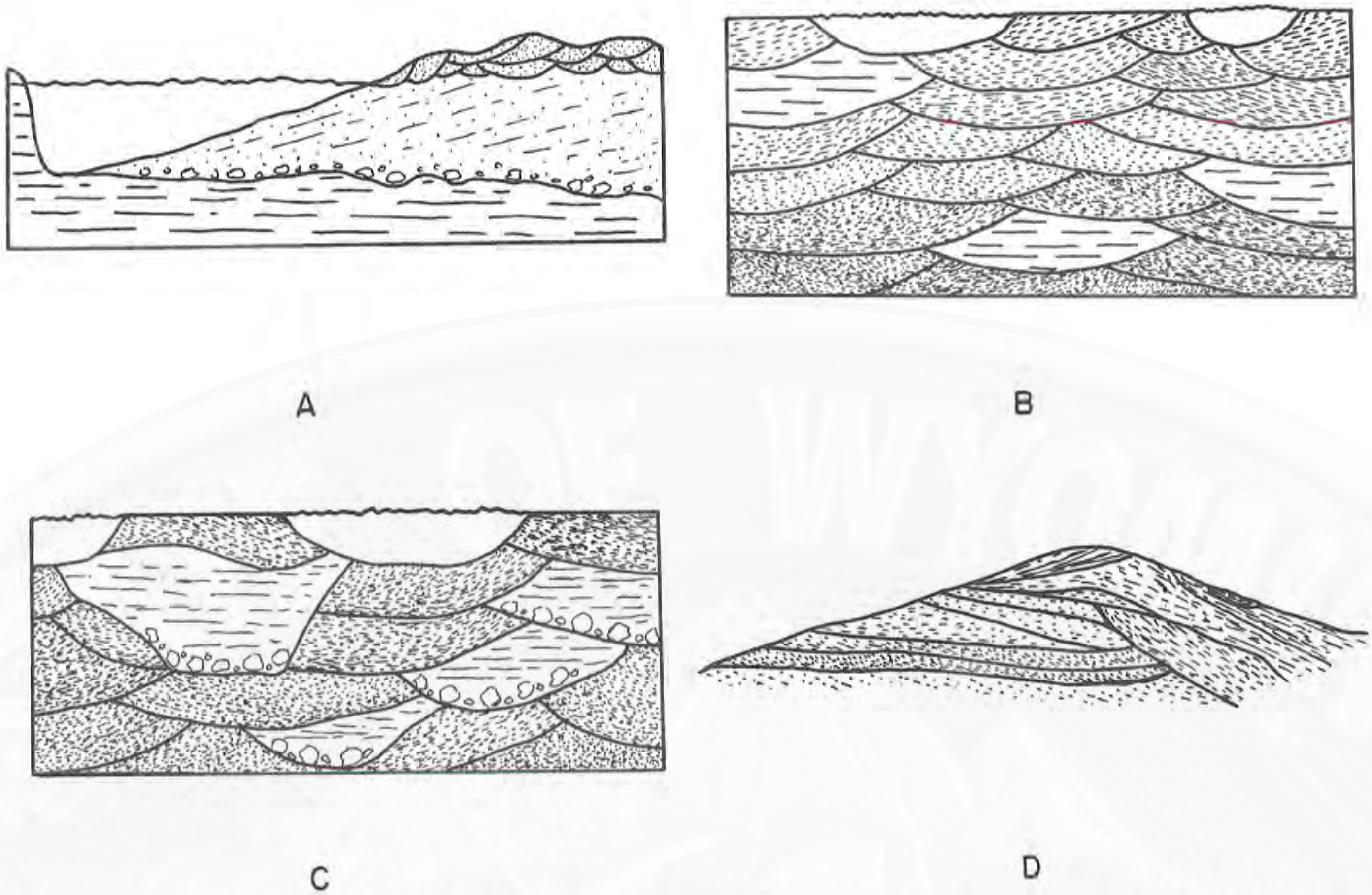

FIGURE 2. Schematic diagrams depicting types of stratification and cross-stratification found in deposits of several terrestrial environments. (A) meandering stream; (B) braided stream; (C) alluvial fan; and (D) eolian dune.

poorly stratified than the sheet sands and both commonly are limited in areal extent as a result of truncation by scour during later high flow conditions. Alluvial fan deposits are therefore recognized not so much by the type of cross-stratification but rather by the association of braided-stream cross-stratification with poorly stratified channel-fill sand and the cobbles, boulders, and poorly sorted matrix of debris flow deposits.

Eolian cross-stratification (Fig. 2D) generally consists of large- to medium-scale tabular or planar sets containing planar laminae which may be slightly concave upward (McKee, 1966; Bigarella, 1972). Eolian trough cross-stratification is much less common. The dip of internal stratification in modern dunes approaches the angle-of-repose (34°) for sand, especially near the crests where well-developed avalanche faces are present. However, ancient eolian cross-stratification commonly dips between 15° and 30°, probably because the upper, steeper portion is removed by erosion. In any case, eolian cross-stratification does not necessarily dip at 34°.

Intuitively one might expect that the vast difference in characteristics of eolian and aqueous environments would be reflected in the cross-stratification. Unfortunately this is not entirely true and it is often necessary to use other criteria to definitely identify a cross-stratified deposit as eolian (Walker and Harms, 1972). Such criteria may include lack of aquatic fossils and evidence for subaerial exposure such as desiccated surfaces and truncated ripples (Steidtmann, 1973).

RECONSTRUCTION OF DEPOSITIONAL CONDITIONS

In controlled experiments with flumes transporting sand, a sequence of bed forms is noted as discharge is increased. Ripples are the first to develop, followed in order by dunes, plane bed, standing waves and antidunes (Simons and Richardson, 1961, 1962a, 1962b).

Harms and Fahnestock (1965) have shown that fluvial cross-stratification types are related to specific bed forms and that they can be interpreted in terms of the hydraulic conditions associated with these bed forms. They hasten to point out, however, that discharge is not the sole variable controlling bed forms. Rather it is a complex of interrelated and dependent variables, including depth, slope, grain size and shape, sediment sorting, particle specific gravity, density and viscosity of the water-sediment mixture, and channel shape. Because of this, one cannot expect to interpret all cross-stratification accurately in specific terms of depth, velocity or slope. Rather, interpretations of stratification may result in a general understanding of hydraulic conditions (e.g., flow regime of Harms and Fahnestock, 1965). This line of reasoning applied to observations on sediments of the Rio Grande has resulted in an excellent summary of information concerning general relations between bed forms, cross-stratification, stream type, water depth, particle motion, and several other hydraulic variables. For specific information, the reader is referred to Harms and Fahnestock (1965:Plate 1).

Southard (1971) has attempted to clarify the relationships between bed forms and major controlling factors by constructing "depth-velocity-size diagrams" in which the various bed forms are plotted as a function of these variables. Wherever bed forms can be identified from cross-stratification, grain size can be measured and thus a range of values for depth and mean flow velocity can be determined.

Other workers have attempted to interpret more specifically cross-stratification and other primary features in sand. Allen (1965), Moody-Stuart (1966) and Steidtmann (1969) have used the thickness of intervals of low-dipping, accretionary point bar cross-stratification (Fig. 2A) as an indicator of channel depth at bankfull stage and the horizontal projection of these same cross-strata as an indicator of point bar width. Since point bar width is approximately two-thirds that of the channel (Moody-Stuart, 1966), channel width as well as depth can be approximated. This line of reasoning, along with several others, was used by Moody-Stuart (1966) in his study of deposits of high- and low-sinuosity streams in the Devonian of Spitzbergen.

Cotter (1971) went even farther in his study of Cretaceous fluvial deposits in Utah. Channel width and depth were estimated as described above for accretionary point bar stratification. Having determined through examination of sandstone texture the type of sediment carried, he then used empirical relations derived by Schumm (1960a, 1960b, 1963a, 1963b, 1967, 1968, 1969) from modern rivers to estimate channel sinuosity, meander length, mean annual discharge, channel slope and flow velocity.

PALEOCURRENT DETERMINATION

Cross-stratification which originated as foreset bedding in bed forms is an indicator of the direction of flow which deposited the sediment. Current direction is indicated by the dip direction of planar cross-strata and the direction of plunge of the axes of trough cross-strata. Because of the variability in current direction data, it may be necessary to make numerous measurements of orientations of cross-strata at different localities, treat the data statistically, and display the results as paleocurrent maps. Guidelines for conducting such studies are summarized below. For a more detailed treatment of the subject, see Potter and Pettijohn (1963:252).

1. If possible, conduct preliminary sampling to get an estimate of the variability of the data and from this, an idea of the number of readings needed at each sample point to give the required accuracy for an estimate of the mean.
2. In regions of tilted or folded strata (unlikely in the Holocene of Wyoming) cross-strata no longer retain their original orientations. It is necessary, therefore, to restore them to their original position before analyses can be made. This correction can be made either trigonometrically or with the aid of a stereonet (Potter and Pettijohn, 1963:259).
3. Observations can be displayed easily for visual inspection through construction of a current rose which is essentially a histogram converted to a circular distribution (Fig. 3C). The best procedure is to plot the percent of the observations in each class (usually 30^o segments) and indicate the total number of observations used to construct the diagram.
4. It is always best to compute the vector mean rather than the arithmetic mean for current direction data to eliminate the problems which arise from working with a circular distribution. An obvious example of such a problem is shown by the arithmetic averaging of two azimuths, 45^o and 315^o, and getting 180^o or due south when it is obvious that the meaningful value is the vector mean which is 0^o (or 360^o) or due north. Calculations for vector mean and associated statistics for grouped data are:

$$V = \sum_{i=1}^{n} n_i \cos x_i \qquad R = (V^2 + W^2)^{1/2}$$

$$W = \sum_{i=1}^{n} n_i \sin x_i \qquad L = (R/n)100$$

$$\bar{x} = \arctan W/V$$

where x_i is the mid-point azimuth of the i^{th} class interval, $\bar{x}$ is the azimuth of the vector mean, n_i is the number of observations in each class, n the total number of observations, R the magnitude or length of the mean vector and L the percent magnitude of the mean vector. Magnitude of the mean vector is a measure of concentration of azimuths about the vector mean. The greater L,

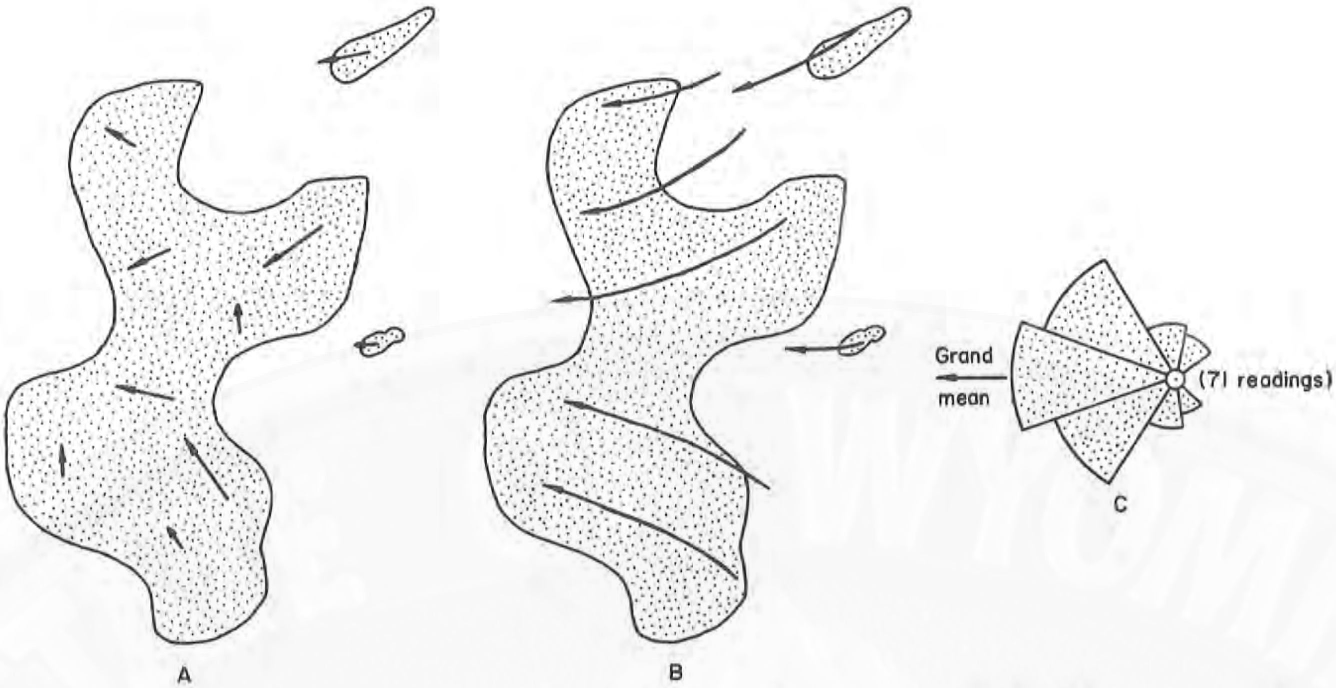

FIGURE 3. Display of current direction data. A: outline of rock unit examined, with vector mean of outcrop data indicated by arrows. Length of arrow proportional to number of readings. B: interpretive map, showing author's interpretation of current directions, based on all available data. C: current rose showing distribution of all data, grand vector mean and number of readings used.

the greater the concentration and the less the variability.

5. Actual and summary data should be presented on maps of various types, examples of which are shown in Figure 3 (A and B). Arrows plotted on outcrop maps should show vector means calculated from data taken at that point. Length of the arrows can be made proportional to the number of readings from which the mean was derived. Finally, an interpretive map based on all available information should be drawn.

Once this information is assembled, paleoslope (in the case of subaqueous cross-stratification) or prevailing wind direction (in the case of eolian cross-stratification) can be determined. This in turn, gives clues as to the sediment sources, patterns of sediment distribution and the general paleogeographic setting.

REFERENCES

Allen, J. R. L.
1963 The classification of cross-stratified units with notes on their origin. Sedimentology, 2:93-114. Amsterdam, Holland.
1965 The sedimentation and paleogeography of the Old Red Sandstone of Anglesey, North Wales. Proceedings of the Yorkshire Geological Society, 35:139-185. Leeds, Yorkshire, England.

Bigarella, J. J.
1972 Eolian environments -- their characteristics, recognition and importance. In J. Keith Rigby and W. Kenneth Hamblin (Eds.), Recognition of ancient sedimentary environments. Society of Economic Paleontologists and Mineralogists Special Publication, 16:12-62. Tulsa, Oklahoma.

Blatt, H., G. Middleton, and R. Murray
1972 Origin of Sedimentary Rocks. Prentice-Hall, Englewood Cliffs, N. J. 634 p.

Bull, W. B.
1972 Recognition of alluvial-fan deposits in the stratigraphic record. In J. Keith Rigby and W. Kenneth Hamblin (Eds.), Recognition of ancient sedimentary environments. Society of Economic Paleontologists and Mineralogists Special Publication, 16:63-82. Tulsa, Oklahoma.

Conybeare, C. E. B., and K. A. W. Crook
1968 Manual of sedimentary structures. Australia Bureau of Mineral Resources, Geology, and Geophysics, Bulletin, 102: 1-327. Canberra, Australia.

Cotter, E.
1971 Sedimentary structures and the interpretation of paleo-flow characteristics of the Ferron Sandstone (Upper Cretaceous), Utah. Journal of Sedimentary Petrology, 41:129-138. Tulsa, Oklahoma.

Harms, J. C., and R. K. Fahnestock
1965 Stratification, bed forms and flow phenomena (with an example from the Rio Grande). Society of Economic Paleontologists and Mineralogists Special Publication, 12:84-115. Tulsa, Oklahoma.

Harms, J. C., D. B. Mackenzie, and D. G. McCubbin
1963 Stratification in modern sands of the Red River, Louisiana. Journal of Geology, 71:566-580. Chicago, Illinois.

McKee, E. D.
1966 Structures of dunes at White Sands

National Monument, New Mexico (and a comparison with structures of dunes from other selected areas). Sedimentology, 7:1-70. Amsterdam, Holland.

McKee, E. D., and G. W. Weir
1953 Terminology for stratification and cross-stratification in sedimentary rocks. Geological Society of America Bulletin, 64:381-390. New York, N. Y.

Moody-Stuart, M.
1966 High- and low-sinuosity stream deposits with examples from Devonian of Spitzbergen. Journal of Sedimentary Petrology, 36:1101-1117. Tulsa, Oklahoma.

Ore, H. T.
1965 Characteristic deposits of rapidly aggrading streams. Wyoming Geological Association, Nineteenth Field Conference Guidebook: 195-202. Casper, Wyoming.

Otto, G. H.
1938 The sedimentation unit and its use in field sampling. Journal of Geology, 46: 569-582. Chicago, Illinois.

Pettijohn, F. J., and P. E. Potter
1964 Atlas and Glossary of Primary Sedimentary Structures. Springer-Verlag, New York, N. Y. 370 p.

Pettijohn, F. J., P. E. Potter, and R. Siever
1972 Sand and Sandstone. Springer-Verlag, New York, N. Y. 618 p.

Potter, P. E., and F. J. Pettijohn
1963 Paleocurrents and Basin Analysis. Academic Press, New York, N. Y. 296 p.

Schumm, S. A.
1960a The effect of sediment type on the shape and stratification of some modern fluvial deposits. American Journal of Science, 258:177-184. New Haven, Connecticut.
1960b The shape of alluvial channels in relation to sediment type. United States Geological Survey Professional Paper, 352-B:17-30. Washington, D.C.
1963a A tentative classification of alluvial river channels. United States Geological Survey Circular, 477:1-10. Washington, D.C.
1963b Sinuosity of alluvial rivers on the Great Plains. Geological Society of America Bulletin, 74:1089-1100. New York, N. Y.
1967 Paleohydrology: application of modern hydrologic data to problems of the ancient past. International Hydrology Symposium, Fort Collins, Colorado, Proceedings, 1: 185-193. Fort Collins, Colorado.
1968 Speculations concerning paleohydrologic controls of terrestrial sedimentation. Geological Society of America Bulletin, 79:1573-1588.
1969 River metamorphosis. American Society of Civil Engineers Proceedings, Journal of Hydraulics Division, 95:255-273. New York, N. Y.

Simons, D. B., and E. V. Richardson
1961 Forms of bed roughness in alluvial channels. Proceedings of the American Society of Civil Engineers, 87:87-105. New York, N. Y.
1962a Resistance to flow in alluvial channels. Transactions of the American Society of Civil Engineers, 127:926-953. New York, N.Y.
1962b Studies of flow in alluvial channels -- the effect of bed roughness on depth-discharge relations in alluvial channels. United States Geological Survey Water Supply Paper 1498-E:1-26. Washington, D.C.

Southard, J. B.
1971 Representation of bed configurations in depth-velocity-size diagrams. Journal of Sedimentary Petrology, 41:903-915. Tulsa, Oklahoma.

Steidtmann, J. R.
1969 Environmental reconstruction from cross-stratification: an example from the Pass Peak Formation (Eocene), western Wyoming. Contributions to Geology, 8:168-170. Laramie, Wyoming.
1973 Structures in the moist, cold-climate sand dunes of southwestern Wyoming. Wyoming Geological Association, Twenty-fifth Field Conference Guidebook: 209-213. Casper, Wyoming.

Walker, T. R., and J. C. Harms
1972 Eolian origin of flagstone beds, Lyons Sandstone (Permian), type area, Boulder County, Colorado. Mountain Geologist, 9:279-288. Denver, Colorado.

Williams, P. F., and B. R. Rust
1969 The sedimentology of a braided river. Journal of Sedimentary Petrology, 39: 649-679. Tulsa, Oklahoma.

GEOLOGY OF THE CASPER ARCHAEOLOGICAL SITE NATRONA COUNTY, WYOMING

JOHN P. ALBANESE[1]

LOCATION AND SETTING

The Casper site is located on the northwest edge of the city of Casper in the northeast quarter of Section 5, Township 33 North, Range 79 West; at an elevation of 5,240 feet. The eastward-flowing North Platte River lies three-quarters of a mile east of the site, occupying a valley cut through the upper Cretaceous Steele Shale. The 2 to 2-1/2 mile-wide valley is 140 feet deep, and is bordered by five terraces. The two lowest are of Holocene age and the upper three are of Pleistocene age. The Casper site lies on the northwest side of this valley, situated 100 feet above the river on the fourth highest terrace.[2]

Sand dunes partially cover the Pleistocene terraces in the vicinity of the site. These dunes lie on the southwest edge of a large, generally stabilized, parabolic dune field, adjacent to and north of the valley of the North Platte River.[3] The dune field extends eastward from Casper for about 30 miles, and varies in width from 6 to 18 miles. The trend of the dunes as measured on aerial photographs varies from N 65° E to N 75° E.[4] The resultant direction of the dominant prevailing southwest winds at Casper is N 60°-70° E (U. S. Geological Survey, 1970). Isolated, elongate, "hairpin" shaped, active parabolic dunes are common along the southern margin of the dune field. These dune features vary from one-quarter mile to a mile in length and may reach a height of as much as 60 feet. Active "blowouts", usually associated with the

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[2]Editor's note: see maps of Casper terraces (Albanese and Wilson, this volume, p. 8-18).

[3]Editor's note: see paper by K. E. Kolm, this volume, for further discussion of this dune field.

[4]Editor's note: this agrees with Kolm's figure of N 70° E. Kolm has also noted the presence of older dunes with a trend of N 50°E, but these are difficult to discern. They presumably antedate the Casper site dunes by a considerable span of time.

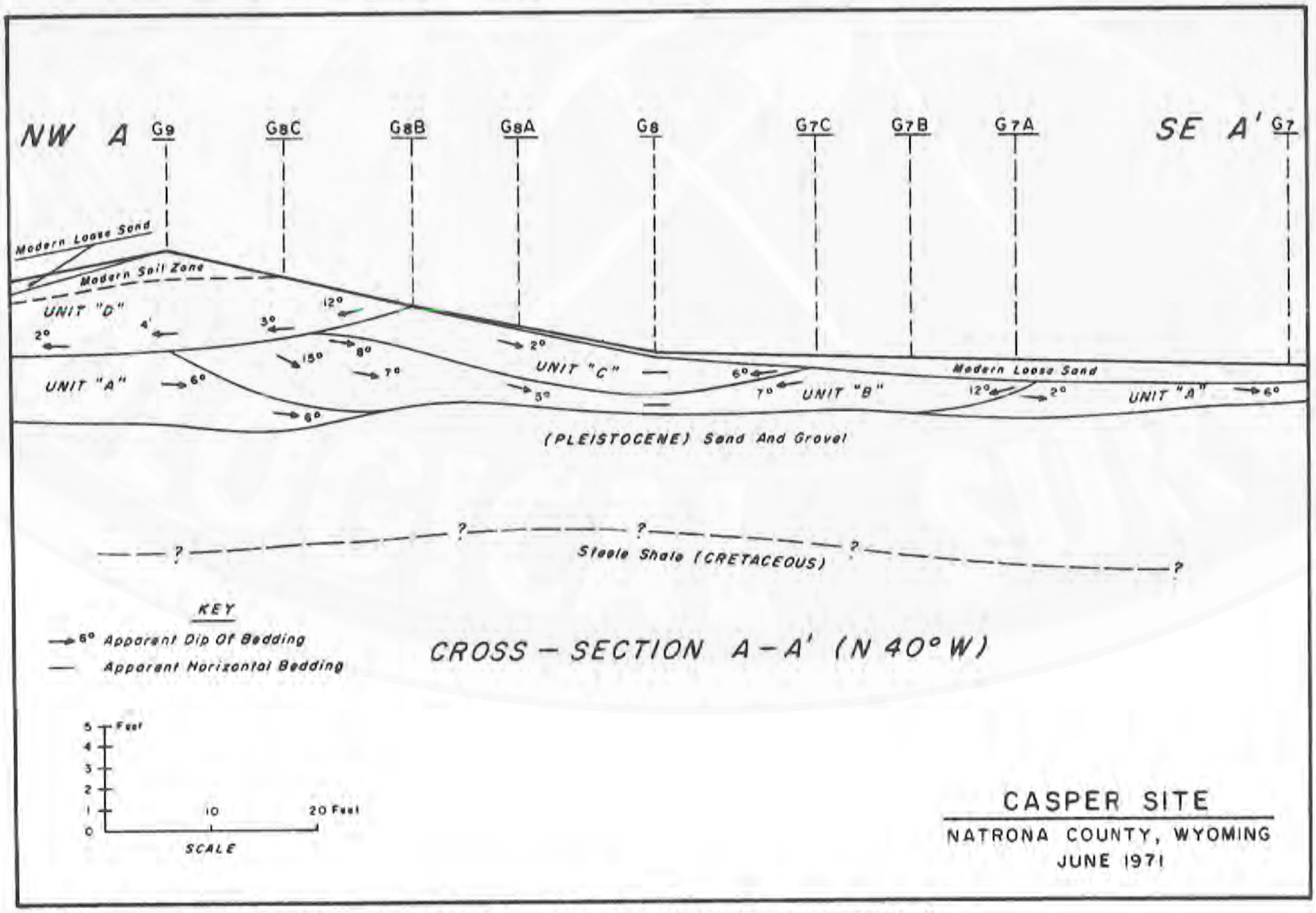

FIGURE 1. Stratigraphic cross-section. Line of section shown on Figure 2.

TABLE I. LITHOLOGIC DESCRIPTION OF UNITS A-D AT THE CASPER SITE

	Unit A	Unit B	Unit C	Unit D
THICKNESS (FEET)	0 - 7.0	0 - 2.6	0 - 2.1	0 - 3.3
COLOR	light yellow	white	brown	light tan
AVG. GRAIN SIZE	medium*	medium-coarse*	fine to silt	coarse-very coarse
SORTING	moderately well sorted	moderately well sorted	poor to moderately well sorted	well to moderately well sorted
SPHERICITY	.79 - .95	.79 - .95	.79 - .95	.79 - .95
ROUNDNESS	rounded - well rounded	rounded - well rounded	rounded - well rounded	rounded - well rounded
ACCESSORY MINERAL AND ROCK GRAINS	feldspar 7-27% schist trace-8% chert 0-3%	feldspar 7-25% schist 0-5% chert 0-3%	feldspar 13-25% schist 0-5% chert 0-2% muscovite 0-trace	feldspar 12-20% schist 0-5% chert 0-trace
CEMENT	none	none	calcareous	none
BEDDING	0.25 - 1.0 in. parallel layers with some low angle cross-bedding	0.5 - 6.0 in. parallel lenticular layers, grades to massive, some low angle cross-bedding	massive	massive to indistinct bedding
MISCELLANEOUS	contains calcareous root casts; quartz grains are frosted and pitted	contains calcareous root casts; quartz grains are frosted and pitted	contains root molds .25 - .50 mm in diameter	quartz grains are frosted and pitted
SEDIMENT ORIGIN	eolian	eolian	lacustrine	eolian

* contains some thin layers of very coarse sand

"hairpin" shaped parabolic dunes, are also common in the dune field. In the vicinity of Casper some of these elongate depressions are 800 to 2,000 feet long, 100 to 400 feet wide, and 40 to 50 feet deep. The inner walls parallel to the long axis usually slope at an angle of 33 degrees. Perennial ponds commonly occupy the center of the "blowout" depressions along the southern margin of the dune field. These ponds vary considerably in size, but lakes 500 to 1,100 feet long and one-fourth to one-half as wide are common east of Casper.

The climate in the dune field is semi-arid. Precipitation varies from 10 to 14 inches per year. The stabilized dunes support a good growth of grass and sagebrush. Classified as a "grama-needlegrass-wheatgrass" grassland (U. S. Geological Survey, 1970), the area is presently utilized by both the livestock industry and the native antelope. Former utilization by bison is evident from the occasional presence of bison bones in "blowouts" throughout the area.

SITE GEOLOGY

The geologic investigation of the site was carried out simultaneously with the archaeological excavation. An area 250 by 500 feet was mapped using the plane table and alidade. Two 100-foot-long trenches were dug especially for examination of the geologic profile. Five post-Cretaceous lithologic units were recognized at the site and are shown in Figure 1. The oldest unit is a 5-foot-thick, poorly sorted, sandy arkosic gravel of Pleistocene age which rests upon the Upper Cretaceous Steele Shale. This gravel caps the fourth terrace above the North Platte River. Resting atop the terrace is a remnant of the stabilized sand dune that contained the archaeological material, which consisted of the butchered remains of 74 Bison antiquus[5] plus Hell Gap projectile points, bone tools, and a few miscellaneous stone artifacts.

Prior to partial removal by power machinery, the dune was 25 feet high and was covered with grass and sagebrush. After the bulldozers had completed their work, a wedge of sand was left which ranged from 0 to 8 feet in height and covered a 200 by 300-foot area. Four lithologic units can be recognized in the dune remnant. The units are here labeled, from oldest to youngest, A, B, C, and D. Units A, B, and D are unconsolidated, eolian, quartz sands. Unit C is a lacustrine deposit composed of silt and fine sand. The lithologic descriptions of these units are shown in Table I. Their depositional relationships are shown in Figure 1.

Unit B contains the archaeological material recovered at the site. This unit was deposited in an elongate trough that had been "scooped" out of Unit A by wind action. The wind removed all of Unit A along the axis of the trough plus some of the fines in the underlying Pleistocene

[5]Editor's note: I elsewhere refer to these as Bison bison antiquus (this volume, p. 93) but this is merely a taxonomic preference.

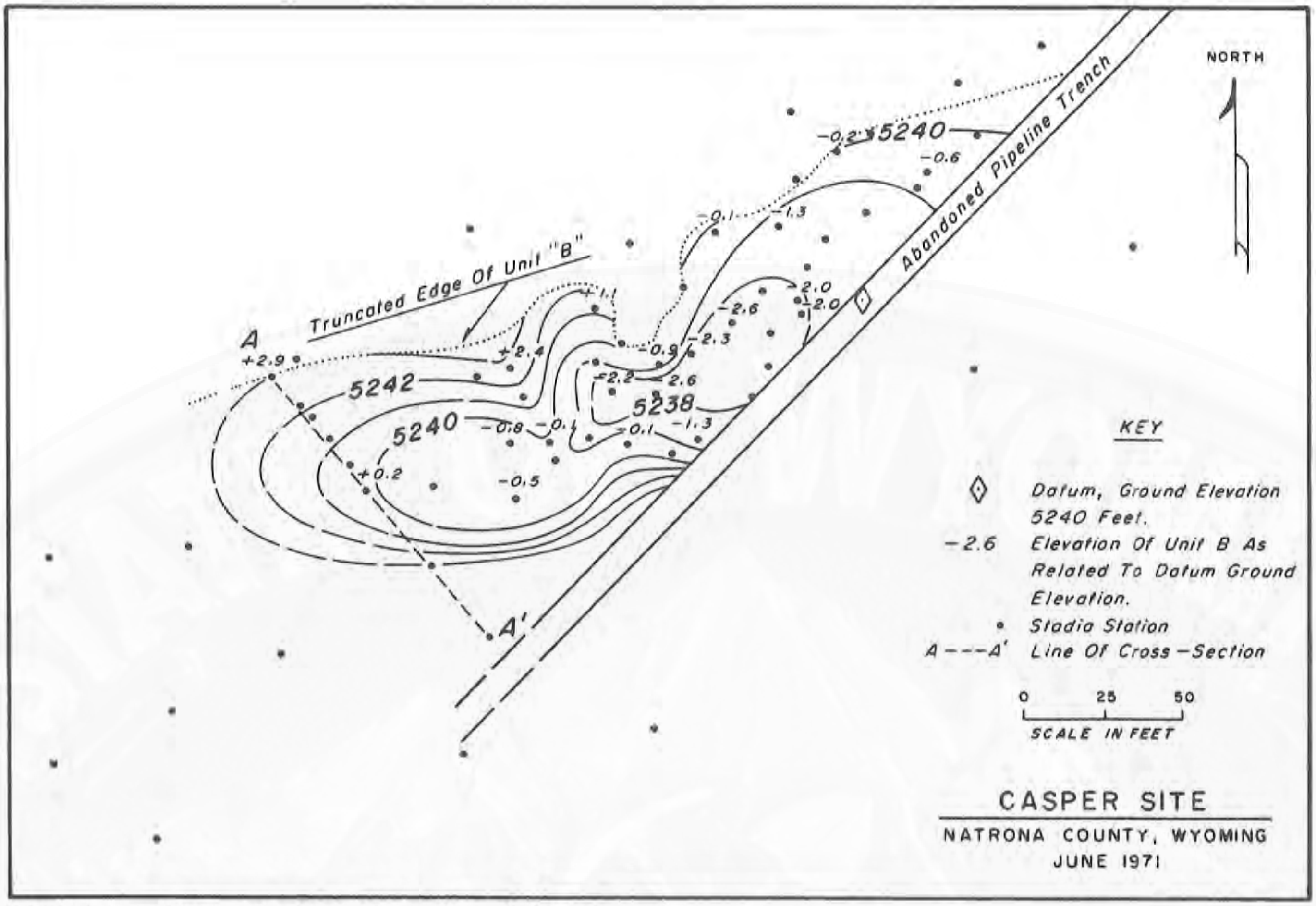

FIGURE 2. Contoured elevations on top of Unit B.

gravel. This resulted in the creation of a two-foot-deep deflation hollow in the terrace surface. Figure 2 shows the configuration of the trough, which is interpreted to be the former hollow depression of a sand "blowout". The skeletal remains of the 74 Bison antiquus found at the site were located at the base of Unit B and were distributed in the form of a "windrow" along the axis of the "blowout" (Fig. 3) Unit B generally consists of even, lenticular layers of sand usually 0.5 to 6 inches thick. The strike and dip of the bedding conform to the shape of the "blowout". Some bedding is slightly undulating, and low angle (2^{o} to 6^{o}) cross-bedding is present in the southeastern portion of the site. Areas of layered sand may grade laterally into massive sands.

The sand grains in Unit B are mostly coarse to medium in size; however, grains ranging from 1.0 to 2.0 millimeters in diameter comprise the greater portion of some layers. The other eolian units at the site also contain sand grains of this size. Eolian sand grains this large are apparently rare as Allen (1970:103) reports that windblown sands have "a mean size seldom less than 0.20 millimeter and rarely greater than 0.45 millimeter." Gilluly and others (1968:319) state that "sieving dune sands through graded screens shows that grains 0.3 millimeter to 0.15 millimeter in diameter greatly predominate." Moss (1951) found that eolian sand grains in western Wyoming (near Eden) varied between 0.125 and 0.270 millimeter in length. However, Glennie (1970) has described eolian sands in Libya and the Trucial States that contain sand grains measuring 5 millimeters in diameter. Bigarella (1972:12) may have had the last word when speaking of the distinctive textural and compositional features of dunes he states "the mean grain size seems to be of little value."

The presence of very coarse eolian sand grains at Casper can readily be explained if one turns to page 112 of the National Atlas (U. S. Geological Survey, 1970). During the late fall and early winter months (November through February), Casper has one of the highest average wind velocities of any city in the United States. The average wind velocity at Casper during January is 13 miles per hour and winds blow out of the southwest 70 percent of the time. On the average, only 3 days in January are free of measurable wind (U. S. Geological Survey, 1970). A not uncommon windy day for this time of the year occurred on December 24, 1972 when winds blew constantly for a twelve-hour period, at velocities ranging between 20 and 45 miles per hour with gusts up to 60 miles per hour. Using

FIGURE 3. Skeletal remains of butchered Bison antiquus in Unit B.

formulas developed by Bagnold (1954), one can calculate that a 2-millimeter sand grain will start to move (fluid threshold) when wind velocities reach 19 miles per hour, 4 inches above the sand surface. As previously noted, winds of this magnitude are not unknown in the Casper area. During the month of January, 1973, the wind was actively moving 2-millimeter sand grains across the Casper site area and creating sand ripples that averaged 47 inches from crest to crest.

In addition to the Bison antiquus, other faunal skeletal remains were recovered in Unit B. They include Richardson ground squirrel, pronghorn antelope, coyote, jackrabbit, bobcat, red fox, and pocket gopher. All of these animals are presently living in the vicinity of the site. The snail Succinea sp., cf. S. stretchiana or S. grosvenori was also recovered from Unit B. These specimens seem to belong to the S. ovalis group, which "prefer rather dry situations" (Aurèle LaRocque, personal communication to Dr. George C. Frison, 1972). Pollen samples were collected from all lithologic units in the dune remnant and submitted for analysis. Unfortunately pollen preservation was poor and did not allow construction of a profile.

Two radiocarbon dates were secured from Unit B. A charcoal sample yielded a radiocarbon age of 9,830 ± 350 years B.P. (RL-125) and a bone sample yielded a date of 10,060 ± 170 (RL-208) radiocarbon years. Thus it appears that Unit B is approximately 10,000 radiocarbon years old.

Unit C conformably overlies Unit B (Fig. 4). Most of Unit C was removed by the bulldozer and as a result its original thickness is not known. A maximum thickness of 2.1 feet was preserved; it consists of massive, thick-bedded, brown, silty, calcareous sand, grading to sandy silt. The sand is generally fine-grained but coarse fractions are present and in some cases constitute up to 20% of the sample. Grass root molds are abundant and vary between 0.25 and 0.50 millimeter in diameter. The unit is interpreted as a lacustrine sediment that accumulated in a lake that formed in the "blowout" depression, after Unit B had been deposited. The silt grains are the "loess particles" that the wind would ordinarily winnow out of the sand and remove from the area. However, these wind-blown silt particles would be trapped on the surface of a pond and precipitate to the bottom. The same mechanism would trap the sand grains. Sediments very similar to Unit C were noted in modern lakes that occupy the center of "blowout" depressions in the Casper area. The sites of former ponds are grass-covered. This would explain the presence of root molds in Unit C.

The fine sediment in Unit C formed a seal which prevented the destruction of the underlying Unit B by wind deflation. It is unlikely that the archaeological deposit would have been preserved if a pond had not formed at the site.

CONCLUSIONS

Parabolic sand dunes form in areas where vegetation is able to establish itself widely over the sand (Gilluly and others, 1968; Flint, 1971; Butzer, 1964).

FIGURE 4. Unit C (dark bands) overlying Unit B. Dark color is caused by greater retention of water in silty Unit C than in the more permeable Unit B. Note concave contact between the two units.

Elongate "hairpin" dunes and "blowouts" are common features of parabolic fields. Both of these features are widespread in the present generally stabilized dune field near Casper, which is characterized by a good cover of vegetation. Modern "blowout" depressions near Casper may reach a depth of 50 feet and a length of 2,000 feet. These features would form ideal traps for animals. It is believed that the ancient "blowout" at the Casper site, at the time it was used, resembled the large modern "blowouts" (Fig. 5). Modern ponds are abundant in "blowout" depressions near Casper and are the modern analogue of the ancient pond that formed at the site.

The large sand grains recovered at the site along with the orientation of the "blowout" axis would indicate that the wind

FIGURE 5. Southwest view of modern blowout in stabilized parabolic dunes, 14 miles northeast of Casper. Approximately 50 feet of relief from top of ridge on extreme left to bottom of blowout. See man for scale.

blew from the same direction and as strongly 10,000 years ago as it does at the present time. The skeletal remains recovered at the site (except for the Bison antiquus) are all modern fauna that presently live in the area.[6]

It can be concluded that the general biologic, climatic, and geologic setting of the Casper area 10,000 years ago was similar to that of the present date.[7]

[6]Editor's note: even B. bison antiquus is merely the larger ancestral form of the modern plains bison.

[7]Editor's note: a more detailed description of the geology by Mr. Albanese, along with archaeological and paleontological papers by several authors concerning the Casper site, is to be found in George C. Frison (Ed.) The Casper Site: A Hell Gap Bison Kill on the High Plains, currently in press from Academic Press, New York.

REFERENCES

Allen, John R.
1970 Physical Processes of Sedimentation. American Elsevier Publishing, New York, N. Y. 248 p.

Bigarella, Joao
1972 Eolian environments; their characteristics, recognization, and importance. In J. Keith Rigby (Ed.), Recognization of Ancient Sedimentary Environments: 12-62. Society of Economic Paleontologists and Mineralogists, Special Publication No. 16, Tulsa, Oklahoma.

Bagnold, R. A.
1954 The Physics of Blown Sand and Desert Dunes. Methuen, London, England. 265 p.

Butzer, Karl W.
1964 Environment and Archaeology. Aldine, Chicago, Illinois.

Flint, Richard Foster
1971 Glacial and Quaternary Geology. John Wiley and Sons, New York, N. Y. 892 p.

Gilluly, James, Aaron C. Waters, and A. O. Woodford
1968 Principles of Geology (3rd Edition). W. H. Freeman, San Francisco, California. 687 p.

Glennie, K. W.
1970 Desert Sedimentary Environments. Elsevier, Amsterdam, Holland. 222 p.

Moss, John R.
1951 Early Man in the Eden Valley. University of Pennsylvania Museum, Museum Monographs, 6:124 p. Philadelphia, Pennsylvania.

United States Geological Survey
1970 The National Atlas of The United States of America. Department of the Interior, Washington, D.C. 417 p.

DUNE STRATIGRAPHY, ARCHAEOLOGY, AND THE CHRONOLOGY OF THE KILLPECKER DUNE FIELD

THOMAS S. AHLBRANDT[1]

ABSTRACT

Quaternary geologic studies are greatly enhanced when archaeology can provide a chronologic framework. The Killpecker sand dune field, located in south-central Wyoming, has been an area of human occupation for at least 11,000 years. The dune field contains both active and dormant dunes over an area of 170 square miles. The active dune morphology forms an evolutionary sequence from windward to leeward respectively of dome, transverse, barchan, and parabolic dunes. Three sand

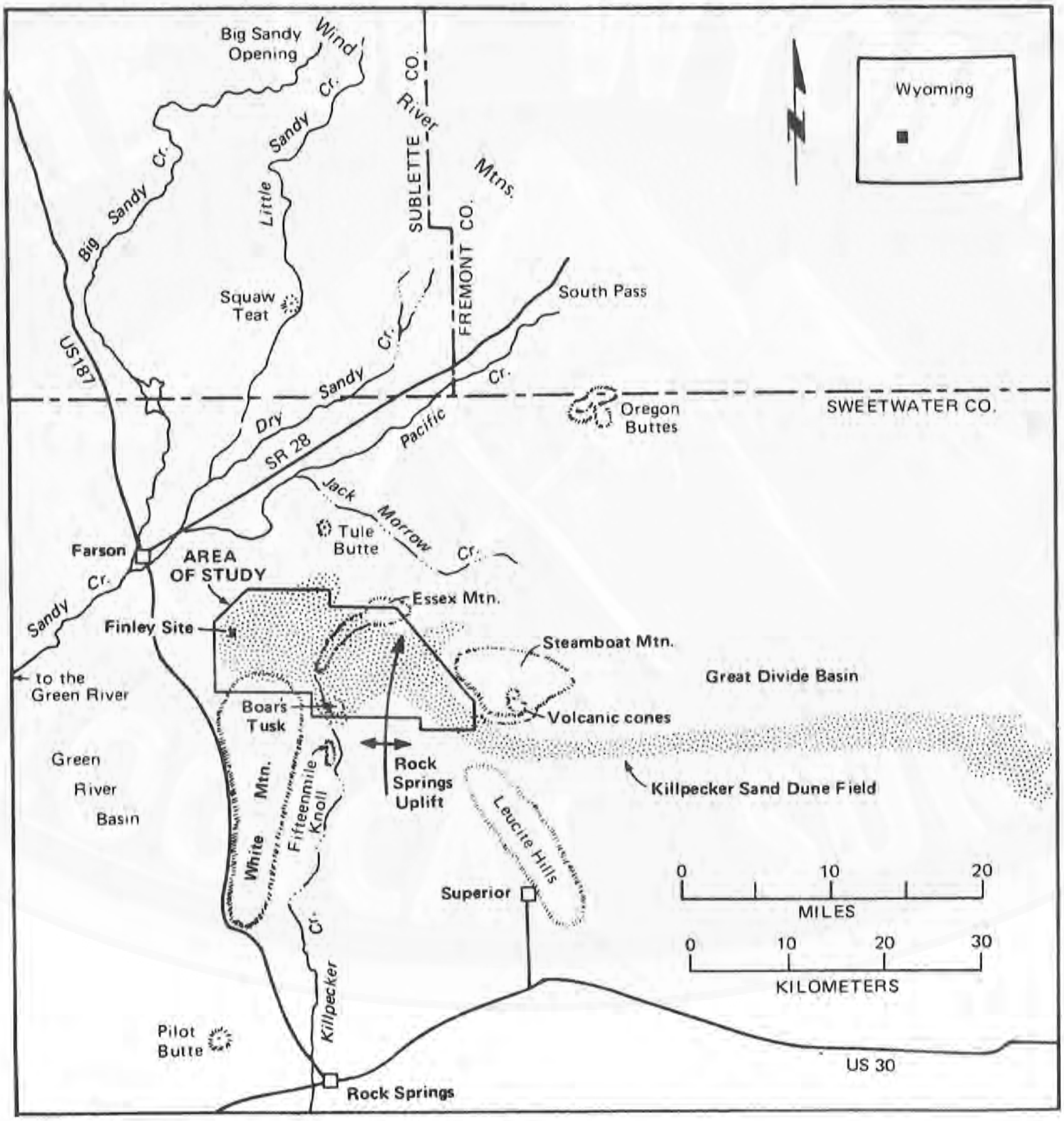

FIGURE 1. Location map of the study area.

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median ridge had practically disappeared and the shoulders and stems were pronounced. None of the points were obliquely flaked. The Eden and Scottsbluff points probably date between 7,000 and 10,000 years B.P. while the Folsom point dates on a typological basis to 10,000 or 11,000 years B.P. Moss and others (1951) found Plano artifacts at several levels in the middle sand at the site but the artifacts were concentrated near the top of the sand and were associated with pond marls. Schultz and Frankforter (in Moss and others, 1951) concluded that specimens of buffalo bone at the site were Bison occidentalis; however, additional material suggests that the Finley site bison more clearly resemble B. antiquus (Wilson, n.d.).

Numerous Middle Prehistoric points and a few Early and Late Prehistoric points were found during my field work (Appendix, Figs. 5,6). The Early Period points were only found on the western margin of the dune field near the Finley site. More recent artifacts were found to the east in the dune field, particularly in association with dormant or reactivated parabolic dunes, or springs which occur adjacent to faults along the crest of the Rock Springs uplift.

Figure 5(h,i) shows Late Middle Prehistoric points that were collected on the reactivated trailing arm of a dormant parabolic dune 4 miles west of Essex Mountain. These artifacts were surface finds; however, they were associated with an organic-rich interdunal pond marl. Burned bison bone associated with scrapers was found weathering out from a dormant dune 3 miles south of Essex Mountain. The bone gave a radiocarbon date of 755 ± 90 years (A.D. 1190), which is indicative of the Late Prehistoric Period. The artifacts found in the dune field area were made of locally derived cherts, flints, quartzites, etc. except for a few made of black obsidian apparently brought to the area from the Yellowstone Park region.

Buffalo bones and artifacts are frequently associated with interdunal pond marls, particularly in areas adjacent to parabolic dunes. There are several explanations for the concentrations of these materials near or in such interdunal ponds. The dunes may have been buffalo jumps with the bones being discarded near water sources such as interdunal ponds. An alternative hypothesis is that the dunes served as traps, canalizing and confining bison, which may have been mired. The latter solution seems more plausible to me for several reasons. The local cuestas of the Rock Springs uplift would be much more suitable for buffalo jumps than would the dunes. Horses and cattle easily traverse the dunes with loose sand cushioning the descent down the slipfaces (the maximum angle of repose is 34°). The dunes reach heights in excess of 100 feet, but parabolic dunes do not exceed a height of 50 feet and the dunes in the vicinity of the Finley site are even smaller (<30 feet high); certainly these would have been even less likely sites for buffalo jumps. Present interdunal ponds are frequently quicksand in nature and have been fatal to cattle in the area and nearly so to my horses on several occasions. Transverse dunes could have been used to canalize buffalo to such ponds; or parabolic dunes could have been used as natural traps in which buffalo were confined near ponds, where they would mire and be slaughtered.

It is likely that other archaeological sites will be discovered in the dune field as dormant dunes are reactivated. A site of a different nature, worthy of further investigation, is located south of the dune field area in an alcove which has developed in the Ericson Formation, 5 miles west of South Table Mountain in the Leucite Hills. Piping through the Ericson has produced the alcove and there are amateur excavations in part of it. Charcoal and bone occur throughout the trench wall of the excavations and charcoal sampled by me from the lowest level obtainable was dated at 1,450 ± 90 years B.P. (Lab #I-6488). There are two smaller tunnels extending back from the main alcove which were not explored. It is hoped that the site will receive professional attention before the deposits are thoroughly disturbed by vandals.

CHRONOLOGY OF THE KILLPECKER DUNES

The stratigraphy of the Killpecker dune field may correlate with the alluvial chronology of the southwestern United States

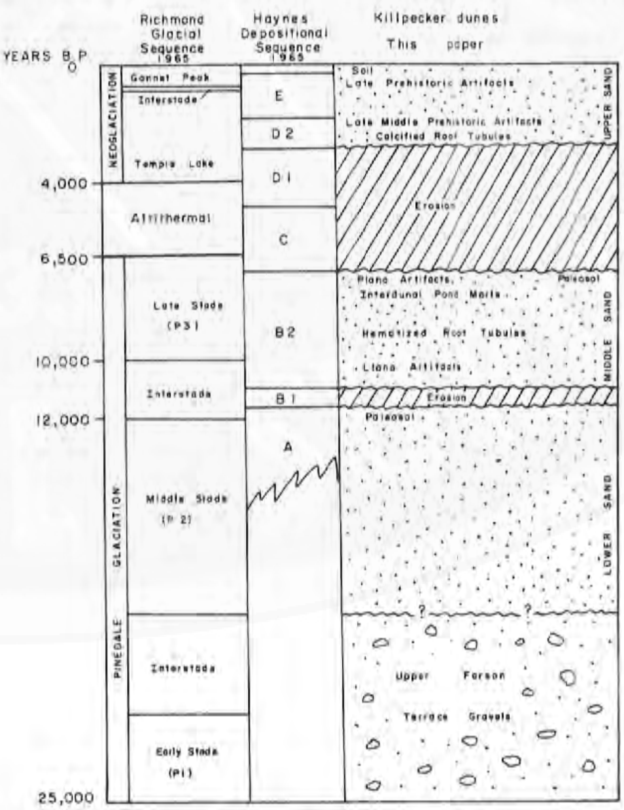

FIGURE 4. Comparison of sequence of events in Killpecker dormant dunes with other Rocky Mountain area sequences.

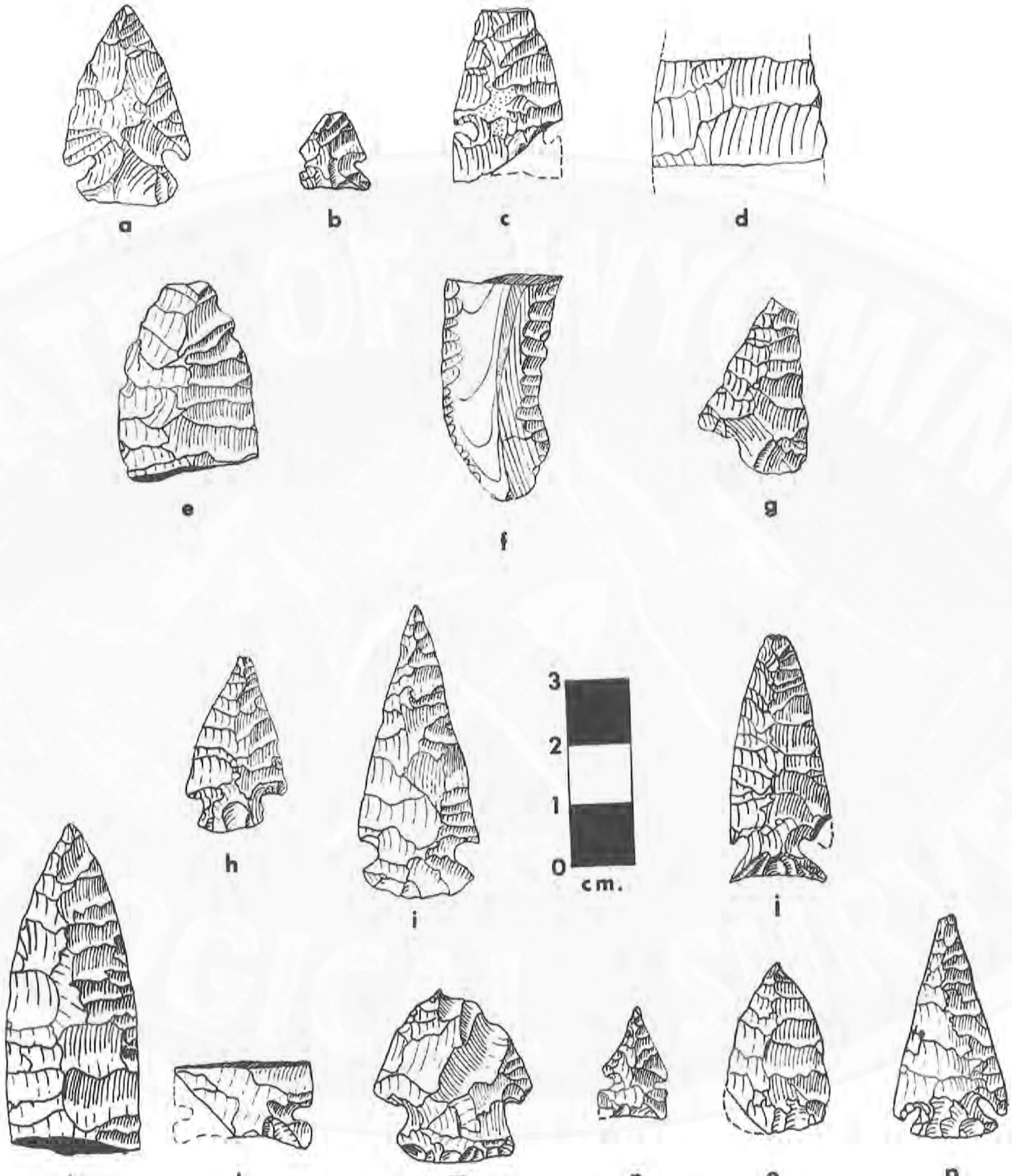

FIGURE 5. Artifacts from the Killpecker dunes. a-d. f-g, Site No. 1; e, Site No. 2; h-i, Site No. 3; j, Site No. 4; k-m, Site No. 5; n-p, Site No. 6.

described by Haynes (1965). He describes five periods of deposition of late Quaternary alluvium (Fig. 4).

The Killpecker dunes rest on gravels of the upper Farson terrace which were traced to early Pinedale moraines in the Wind River Mountains by Moss and Holmes (1955). The climate during early Pinedale time was probably periglacial with relatively little eolian activity.

The lower sand in the Killpecker dunes may correlate with Deposition A of Haynes (1965) due to the presence in both of hydrated iron and manganese oxides replaced by calcium carbonate or sulphate. Deposition A is dated to 11,500 years B.P. or older (Haynes, 1965). Moss and others (1951) considered the lower sand to have been deposited during a period of ice advance in the Wind River Mountains. Presumably this advance would have been the middle stade of the Pinedale Glaciation, since the middle sand apparently contains artifacts greater than 10,000 years old.

The middle sand contains Folsom, Eden and Scottsbluff artifacts, the latter associated with bones of Bison antiquus. There is an immature soil developed in the middle sand, interdunal pond marls are present, and the middle sand becomes finer upward; all of which agree with Haynes' B2 Deposition. The hematized root tubules near the top of the middle sand reflect oxidation related to a receding water table as the interdunal ponds disappeared in a xeric climate. B2 Deposition dates between 7,000 and 11,000 years B.P.; thus the middle sand may have been deposited during the late stade of the Pinedale Glaciation. Warming due to the Altithermal is indicated by the hematized root tubules near the top of the middle sand.

Calcified root tubules found near the Finley Site and dated to 5,845 ± 115 years B.P. are the only evidence found of the Altithermal. Active sand movement may have continued until the onset of Neoglaciation as evident from a very wide-spread horizon of calcified root tubules, dated to 2,820 ± 95 years B.P., found at the base of the upper sand. This date falls within the Late Middle Prehistoric Period, and suggests the influence of Neoglaciation on the dune field (Fig. 4). Apparently deposition prevailed throughout most of the Neoglacial as evident from my radiocarbon date of 755 ± 90 years B.P. on buffalo bones from near the top of the upper sand. This date falls within the late Prehistoric period.

The chronology thus outlined suggests deposition of sand may be coincident with stades of Pinedale Glaciation and Neoglaciation and eolian activity may be associated with interstades.

ACKNOWLEDGEMENTS

Dr. Dennis Knight of the Botany Department of the University of Wyoming identified plant specimens. Dr. Brainerd Mears, Jr., Dr. J. D. Love and Dr. J. R. Steidtmann provided technical advice for this study. I am grateful to them all. My wife, Cristie Anderson Ahlbrandt, provided invaluable aid and inspiration. This study is the result of graduate work at the University of Wyoming which was supported by the Wyoming Geological Survey, Esso Production Research Company, Amoco Petroleum Production Corporation, a National Science Foundation Fellowship, and the Department of Geology of the University of Wyoming. Dates were run by Teledyne, Inc.

REFERENCES

Ahlbrandt, T. S.
1973 Sand dunes, geomorphology and geology, Killpecker Creek area, northern Sweetwater County, Wyoming. Ph.D. Dissertation (Geology), University of Wyoming, Laramie, Wyoming. 174 p.

Amos, W. H.
1959 The life of a sand dune. Scientific American, 201(1):91-99. New York, N.Y.

Antevs, E.
1955 Geologic-climatic dating in the West. American Antiquity, 20:317-335. Salt Lake City, Utah.

Bigarella, J. J., R. D. Becker, and G. M. Duarte
1969 Coastal dune structures from Parana (Brazil). Marine Geology, 7:5-55. Amsterdam, Holland.

Chadwick, H. W., and P. D. Dalke
1965 Plant succession on sand dunes in Fremont County, Idaho. Ecology, 46:766-785. Duke University Press, Durham, North Carolina.

Glennie, K. W.
1970 Desert sedimentary environments. Developments in Sedimentology, 14:222 p. Elsevier Publishing Company, Amsterdam, Holland, and New York, N.Y.

Haynes, C. V., Jr.
1965 Geochronology of late Quaternary alluvium. In R. B. Morrison and H. E. Wright, Jr. (Eds.), Means of Correlation of Quaternary Successions: 591-631. University of Utah Press, Salt Lake City, Utah.

Howard, E. B., and J. T. Hack
1943 The Finley site. American Antiquity, 8: 224-241. Salt Lake City, Utah.

Howard, E. B., L. Satterthwaite, Jr., and C. Bache
1941 Preliminary report on a buried Yuma site in Wyoming. American Antiquity, 7:70-74. Salt Lake City, Utah.

McKee, E. D.
1966 Structures of dunes at White Sands National Monument, New Mexico (and a comparison with structures of dunes from other selected areas). Sedimentology, 7(1):1-69. Amsterdam, Holland.

McKee, E. D., J. R. Douglass, and S. Rittenhouse
1971 Deformation of lee-side laminae in eolian dunes. Geological Society of America Bulletin, 82(2):359-378. Boulder, Colorado.

Moss, J. H.
1951 Glaciation in the Wind River Mountains and its relation to Early Man in the Eden Valley, Wyoming. In Moss, J. H. and others (1951): 9-92.

Moss, J. H. and others
1951 Early Man in the Eden Valley. University of Pennsylvania Museum, Museum Monographs,

6:124 p. Philadelphia, Pennsylvania.
Moss, J. H., and W. G. Holmes
1955 Pleistocene geology of the southwestern Wind River Mountains, Wyoming. Geological Society of America Bulletin, 66:629-654. New York, N.Y.
Randell, Derek
1958 The dune system and dune slack habitat. Journal of Ecology, 47:571-601. Cambridge University Press, Cambridge, England.
Richmond, G. M.
1965 Glaciation of the Rocky Mountains. In H. E. Wright, Jr., and D. G. Frey (Eds.), The Quaternary of the United States: 217-230. Princeton University Press, Princeton, New Jersey.
Schultz, C. B., and W. D. Frankforter
1951 A preliminary report on the bison remains from the Finley site (Eden Bison Quarry). In J. H. Moss and others (1951): 119-124.
Scott, G. R.
1965 Nonglacial Quaternary geology of the southern and middle Rocky Mountains. In H. E. Wright, Jr., and D. G. Frey (Eds.), The Quaternary of the United States: 243-254. Princeton University Press, Princeton, New Jersey.
Wilson, Michael
n.d. History of the Bison in Wyoming, with particular reference to early Holocene forms. This volume: 91-99.
Zeller, H. D., and E. V. Stephens
1969 Geology of the Oregon Buttes area, Sweetwater, Sublette and Fremont Counties, southwestern Wyoming. United States Geological Survey Bulletin 1256:60 p. Washington, D.C.

APPENDIX

DESCRIPTION OF ARTIFACTS FROM THE KILLPECKER DUNE FIELD, WYOMING

Michael Wilson[1]

Introduction

The following artifacts were received for description by the author from Dr. T. S. Ahlbrandt. They were collected in and around the Killpecker dune field, generally as surface finds. More detailed data concerning site locations are on file with the Department of Anthropology, University of Wyoming, Laramie.

SITE NO. 1

Three miles west of Essex Mountain, east of Eden, Wyoming; around a spring.

a. Projectile point, corner-notched (Fig. 5a). Dark brown chalcedony. Not basally ground. Slightly asymmetrical stem; straight base. Length: 34.5 mm.; width: 22.7 mm. Diagnosis: Late Middle Period[2].

b. Projectile point, side-notched (Fig. 5b). Gray chert. Not basally ground. Straight to slightly concave base. Tip broken. Length: 14+ mm.; Width: 11.2 mm. Diagnosis: Late Prehistoric.

c. Projectile point, side-notched (Fig. 5c). Dark brown oolitic chalcedony. Not basally ground in preserved fragment. Base incomplete; notch sharply defined and constricted. Tip broken. Length: 29+ mm.; width: 18+ mm. Diagnosis: possibly Late Middle Period; type not well known.

d. Biface midsection with collateral flaking (Fig. fd). Gray-brown chalcedony. No lateral grinding. Width: 28.2 mm.

e. Side scraper on blade (Fig. 5f). Gray-brown chert, banded. Worked unifacially on both margins. Length: 39.9+ mm.; width: 20.8 mm.

f. Asymmetrial tanged biface, knife? (Fig. 5g). Gray-brown chert. Vaguely resembles Cody knife but base shows little similarity. Tip broken. Length: 28.3+ mm.; width: 19 mm.

g. Miscellaneous: 7 point or biface fragments; one core fragment (not illustrated).

Summary: Site has been occupied in Late Middle and Late Prehistoric periods. Artifact inventory not sufficient to indicate type of site.

SITE NO. 2

Two miles west-northwest of Essex Mountain, east of Eden, Wyoming.

a. Biface midsection (Fig. 5e). Light gray chert. Not laterally ground. Length: 34.5+ mm.; width: 25.0

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[2]These temporal units will be discussed at the end of the report.

mm. Age unknown.

SITE NO. 3

Four miles west of Essex Mountain, east of Eden, Wyoming.

a. Projectile point, corner-notched (Fig. 5h). Dark yellow-brown chert. Not basally ground. Expanding stem, convex base. Length: 29.9 mm.; width: 17.1 mm. Diagnosis: Late Middle Prehistoric.

b. Projectile point, side-notched to corner-notched (Fig. 5i). Brown oolitic chert. Convex base. Length: 49.7 mm.; width: 22 mm. Diagnosis: Late Middle Period.

c. Biface base (not shown). Gray-tan chert. Length: 36+ mm.; width: 28.3 mm.

d. Biface (point blank ?) (not shown). Dark brown chalcedony. Length: 32.3+ mm.; width: 25.2 mm.

Summary: Site has been occupied in Late Middle Period times. Type of site not determined.

SITE NO. 4

Six and one-half miles west-southwest of Boar's Tusk, southeast of Eden, Wyoming.

a. Projectile point, corner-notched (Fig. 5j). Gray-brown mottled chert. Base concave, not ground. Diagnosis: Late Middle Period.

SITE NO. 5

Four miles southeast of Eden, Wyoming.

a. Projectile point lacking base (Fig. 5k). Patinated gray-brown oolitic chert. Slight lateral grinding near base. Length: 57.3+ mm.; width: 23.2 mm. Diagnosis: probably Early Prehistoric Period.

b. Projectile point fragment, side-notched (Fig. 5l). Dark brown chalcedony. Base concave, not ground. Width: 22.5 mm. Diagnosis: Middle Period.

c. Projectile point, stemmed, with lateral barbs (Fig. 5m). Gray chert. Convex base. Reworked distally into graver. Length: 29.2 mm.; width: 27.5+ mm. Diagnosis: Late Middle Period.

d. Miscellaneous: biface blank fragment; worked flake.

Summary: Site probably has been occupied during Early and Middle Prehistoric Periods. Type of site not determined.

SITE NO. 6

Seven miles east of Eden, Wyoming, on northwest corner of a butte.

a. Projectile point, side-notched (Fig. 5n). Red to yellow-brown jasper. Base straight, not ground. Length: 18.8 mm.; width: 11.0 mm. Diagnosis: Late Prehistoric.

b. Projectile point, ovoid, unnotched (Fig. 5o). Dark brown chalcedony. Base convex, not ground. Length: 26.5 mm.; width: 17.5 mm. Diagnosis: Late Prehistoric.

c. Projectile point, corner-notched (Fig. 5p). Gray chert. Base slightly concave, slightly ground. Length: 38.1 mm.; width: 18.9 mm. Diagnosis: Late Middle Prehistoric.

d. Projectile point, corner-notched. broken (not shown). Brown chalcedony. No measurements. Diagnosis: Late Middle Prehistoric.

e. Ovate biface (not shown). Orange-brown chert. Length: 46.2 mm.; width: 29.7 mm.

f. Two biface bases (not shown). Brown oolitic chert and gray-brown chert.

Summary: Site occupied during Late Middle and Late Prehistoric Periods. Type of site not determined.

SITE NO. 7

One mile northwest of Boar's Tusk, southeast of Eden, Wyoming.

a. ?Projectile point base, stem (Fig. 6a). Gray-brown oolitic chert. Base square, very lightly ground. Width: 20.2 mm. Diagnosis: possibly Early Period, but evidence slender.

b. Projectile point, corner-notched (Fig. 6b). Buff quartzite. Base straight, very lightly ground. Length: 25+ mm.; width: 20.3+ mm. Diagnosis: Late Middle to Late Prehistoric.

c. Projectile point, stemmed (Fig. 6c). Light gray-brown chert. Base slightly concave, not ground. Length: 42.1+ mm.; width: 18.7 mm. Diagnosis: Late Middle Prehistoric.

d. Projectile point, stemmed (Fig. 6d). Banded black and gray obsidian. Base convex, point wind-eroded. Length: 23.3 mm.; width: 16.2 mm. Diagnosis: Late Prehistoric Period.

e. Projectile point, stemmed (Fig. 6e). Gray chert. Base convex, not ground. Length: 28.8+ mm.; width: 15.9 mm. Diagnosis: Late Prehistoric Period.

f. Miscellaneous: Serrated point tip; biface fragments (4); flake (not shown).

Summary: Site occupied from at least Late Middle to Late Prehistoric Period. Type of site not determined.

SITE NO. 8

Three miles southwest of Boar's Tusk, southeast of Eden, Wyoming.

a. Projectile point, corner-notched (Fig. 6f). Light brown chert. Base concave, lightly ground. Length: 42.9 mm.; width: 23.7 mm. Diagnosis: Late Middle Period.

b. Flake scraper (Fig. 6g). Dark brown chert. Plano-convex.

c. Scraper/drill (Fig. 6h). Cream and black moss agate. Drill tip bifacially worked; scraper base unifacially worked. Length: 35.3 mm.; width: 32.1 mm.

d. Miscellaneous: Obsidian point blank; brown chalcedony biface fragment; oolitic chert biface blank.

Summary: Site occupied in Late Middle Period. Range of artifacts suggests camp site, but sample very small.

SITE NO. 9

Extensive surface scatter approximately 2 miles west of Essex, east of Eden, Wyoming.

a. Projectile point, stemmed, indented base (Fig. 6i). Pale green quartzite. Base ground. Length: 35+ mm.; width: 20.3 mm. Diagnosis: Early Middle Prehistoric Period.

b. Projectile point, expanding-stemmed (Fig. 6j). Dark brown oolitic chert. Bibevelled.

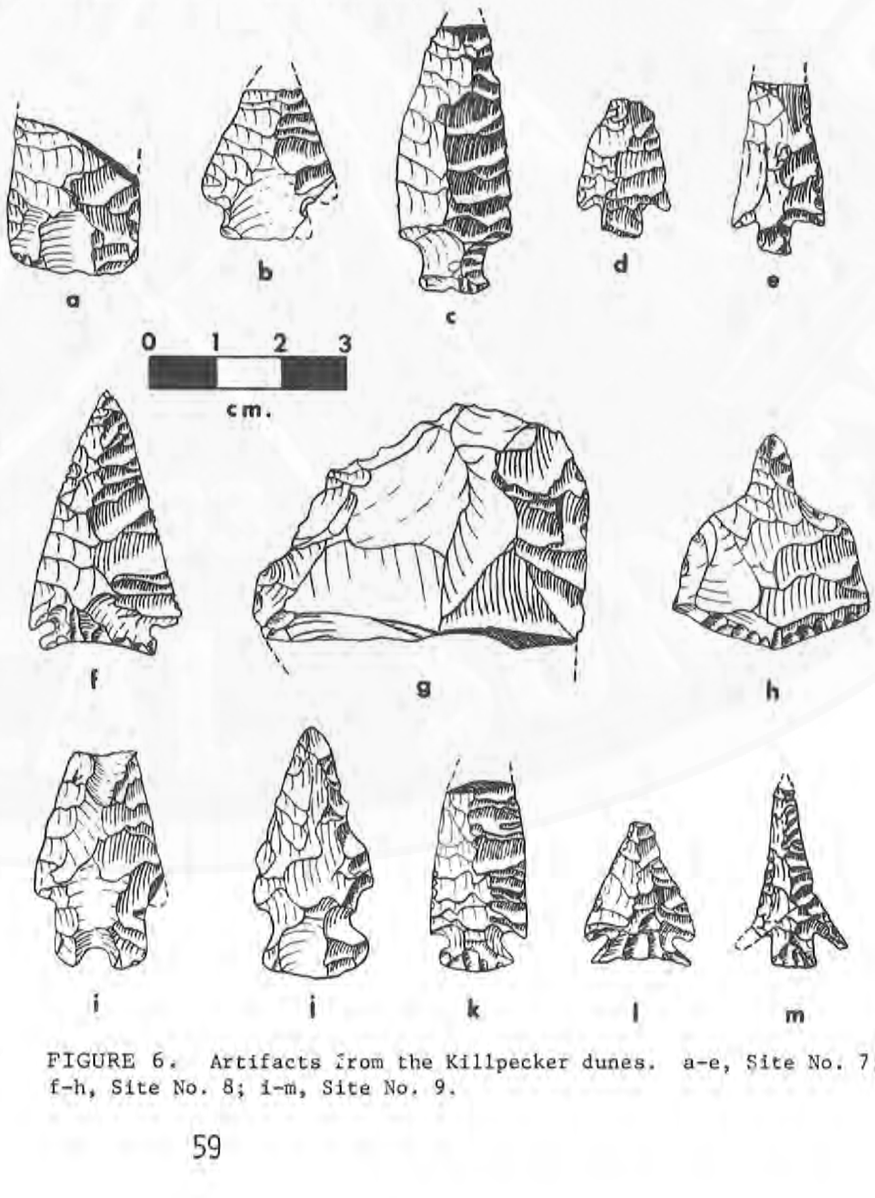

FIGURE 6. Artifacts from the Killpecker dunes. a-e, Site No. 7; f-h, Site No. 8; i-m, Site No. 9.

Base convex, not ground. Length: 41.5 mm.; width: 20.1 mm. Diagnosis: Late Middle Period.

c. Projectile point, corner-notched (Fig. 6k). Clear agate. Base convex, slightly ground. Length: 30.0+ mm.; width: 16.1 mm. Diagnosis: Late Middle or Late Prehistoric Period.

d. Projectile point, corner-notched (Fig. 6l). Dark yellow-brown chert. Base concave, not ground. Length: 23.2 mm.; width: 17.2 mm. Diagnosis: Late Middle Period.

e. Projectile point, barbed and stemmed (Fig. 6m). Dark brown chalcedony. Base convex, not ground. Length: 27.7+ mm.; width: c. 19 mm. Diagnosis: Late Prehistoric Period.

f. Miscellaneous: Broken corner-notched point; bipointed biface; biface blank fragments (7); flake scraper (plano-convex); 2 worked obsidian flakes; unworked flake (not shown).

Summary: Not a single site, but a diffuse scatter of materials of differing ages.

SITE NO. 10

Four miles southwest of Boar's Tusk, southeast of Eden, Wyoming; down from a spring.

a. Miscellaneous: Point midsection; 2 worked flakes; 7 unworked flakes; 2 chips (not shown).

SITE NO. 11

Four miles west of Essex Mountain, east of Eden, Wyoming.

a. Miscellaneous: Large end scraper; biface fragment; side scraper; retouched uniface (not shown).

SITE NO. 12

Three miles west of Essex Mountain, east of Eden, Wyoming.

a. Miscellaneous: Point midsection (not shown).

Comments

The analysis of artifacts tends to support Ahlbrandt's (above) suggestion that Early Period artifacts were more numerous at the west end of the sand dune field. This probably reflects more extensive erosion on the upwind side of the dune field: Early Period materials are likely to be more deeply buried in the east.

Dates for the prehistoric periods are somewhat subjective, in that boundaries must be revised as new radiocarbon dates are received. However, in very general terms we can consider the Early Prehistoric Period to have lasted from approximately 12,000 or more years before present to about 7,000 years ago. The poorly known Altithermal Period (a climatic interval) lasted from about 7,000 to 4,500 years before present. The Middle Prehistoric Period lasted from about 4,500 to 1,500 years before present. The Late Prehistoric Period began about 1,500 years ago and lasted until White contact times, about 200 to 400 years ago.

These artifacts from the Killpecker dunes extend our knowledge of the variation present in southwestern Wyoming archaeological materials. Side-notched points (Fig. 5b, 5n) resemble those from the Wardell site in the Upper Green River Basin, dated to about A.D. 700 to A.D. 1000 (Frison, 1973). They also resemble points from the Pine Spring site, in southwestern Sweetwater County, referred to the Desert Side-Notch type of the Late Prehistoric Period (Sharrock, 1966:60). The stemmed, indented-base point (Fig. 6i), the corner-notched points (Fig. 5a, 5j, 5m, 5p; Fig. 6b, 6f, 6l), and the small stemmed points (Fig. 6d, 6e, 6m) all occur at Pine Spring in somewhat mixed but stratified context (Sharrock, 1966). The small stemmed points resemble Butler's (1968) Columbia Valley corner-notched type, of Late Prehistoric age in Idaho.

REFERENCES

Ahlbrandt, Thomas S.
n.d. Dune stratigraphy, archaeology, and the chronology of the Killpecker Dune Field. This volume: 51-60.

Butler, B. Robert
1968 A Guide to Understanding Idaho Archaeology. Second (Revised) Edition. Idaho State University Museum, Special Publication. 117 p. + 25 figs. Pocatello, Idaho.

Frison, George C.
1973 The Wardell Buffalo Trap 48SU301: Communal procurement in the Upper Green River Basin, Wyoming. University of Michigan Museum of Anthropology, Anthropological Papers, 48:1-88. Ann Arbor, Michigan.

Sharrock, Floyd W.
1966 Prehistoric occupation patterns in southwest Wyoming and cultural relationships with the Great Basin and Plains culture areas. University of Utah Anthropological Papers, 77:1-191. Salt Lake City, Utah.

THE APPLICATION OF VOLCANIC AND NON-VOLCANIC NATURAL GLASS STUDIES TO ARCHAEOLOGY IN WYOMING

GEORGE C. FRISON[1]

INTRODUCTION

During the past several years, data concerning obsidian have been accumulating from Wyoming. Some of these data may now be synthesized. Accumulation of data began due to a fortunate early association of archaeologists with work in neutron activation, in attempts to trace the sources of Hopewell archaeological obsidian from sites in Ohio, Illinois, and adjacent states. Most of the subsequent interest and activity has centered around the use of neutron activation to trace archaeological site samples to geologic sources; however, some hydration dating has also been accomplished. Increased interest in archaeological surveys of some obsidian-producing areas has been the result. One major problem with such work has been an unreasonable delay between submission of neutron activation samples and return of results.

The method of neutron activation has been well described (Gordus and others, 1968) and is based for the most part upon the presence of nearly constant ratios of sodium to manganese (Na/Mn) within a given obsidian source, but differing ratios between different sources. Other elements may be used to differentiate sources if the Na/Mn ratios are not sufficiently distinct. The quantities of the various elements present are measured by means of neutron activation of samples for a given period. The subsequent decay of various isotopes is then measured. After a decay period, the process may be repeated on the same samples.

NON-VOLCANIC NATURAL GLASS

By definition, obsidian is a natural glass formed through volcanic action. In addition, there is at least one known local source (and undoubtedly others) of non-volcanic natural glass, which can be subjected to similar analytic procedures. The latter occurs in the form of small pockets of glass in burned-out coal beds in northeastern Wyoming and southeastern Montana. At least one geologist (J. D. Love, personal communication, 1971) feels that much of the coal-burning activity may have occurred in late Pliocene or early Pleistocene times. Also resulting from this phenomenon are extensive sources of metamorphosed shales widely used for stone flaking material.

One known quarry site for the non-volcanic natural glass is located about twelve miles from the Wyoming line in Montana, approximately midway between the Tongue and Powder Rivers. It was completely exhausted of usable material in prehistoric times. Similar material was noticed last summer (1973) a few miles north of Sheridan, Wyoming, in slag-like deposits removed during the strip mining of coal. The writer has observed some samples of similar material, weighing several pounds, claimed to have been derived from another source close to Decker, Montana. This location has not yet been visited by the writer although several attempts have been made to locate it.

In general this natural glass occurs in small quantities and is of poor quality. However, small nodular pieces up to seven centimeters or so in diameter are often of excellent quality. The colors are usually distinctive and range from a light gray through several shades of green, and from a light maroon to black. Small specks of slag are usually, but not always, noticeable. Under the microscope, the grays and maroons are characterized by particles of colored material suspended in a clear matrix. Usually, but not always, a freshly-flaked surface has a sandy appearance, although it is actually smooth.

To date, the writer is unaware of any systematic attempts to apply hydration dating to this material. One sample projectile point from the Mavrakis-Bentzen-Roberts buffalo trap east of Sheridan, Wyoming (Bentzen, 1962) was submitted to the University of Pennsylvania for analysis. The hydration thickness was greater than expected (6.49 microns) but the point was of a very poor quality of maroon-colored natural glass with many inclusions of slag.

More recently, however, projectile points of black translucent material believed to be non-volcanic natural glass, and another of the maroon material were obtained from the site. Hydration rims of these specimens were 3.6 microns thick (Irving Friedman, personal communication, 1973). If the hydration rate for obsidian is used, this thickness is not in line with two radiocarbon dates (2,460 + 140 years B.P.: 510 B.C., RL-160; and $\overline{2}$,600 $\underline{+}$ 200 years B.P.: 650 B.C., I-644) unless we accept an extremely high rate of hydration for this area. More work needs to be done with the material to determine whether hydration rates differ from those of other forms of natural glass and also to determine if these rates are constant for given sources and areas. Source data are not yet available for the samples tested.

Four glass samples were submitted for dating from the Kobold buffalo jump (Frison, 1970) near Kirby, Montana on Rosebud Creek. These were broken projectile points of

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materials resembling excellent quality obsidian. Unfortunately they were not returned, and source data could not be obtained. The writer believes that at least one of these samples was of natural glass from a local source, rather than obsidian. There seems little doubt that there are several sources of non-volcanic natural glass in this area of southern Montana and northern Wyoming for which source and hydration data remain to be collected.

In 1968, neutron activation analysis was applied to samples from a number of sites in north-central and northeastern Wyoming. All of these sites had in common pottery of a generalized Mandan tradition believed to be referable to the Crow (Frison and others, 1968), and obsidian and other natural glass samples. Samples from the top level of Daugherty Cave (east side of the Bighorn Basin), which yielded similar pottery, obsidian, and non-volcanic natural glass (Frison, 1968), were recently subjected to such analysis. Na/Mn ratios suggest the known natural glass sources in Montana (89.68 to 100 range in Na/Mn ratio). These samples can be separated chemically from obsidian sources in Yellowstone Park with similar Na/Mn ratios through measurement of iron (Fe), scandium (Sc), and rubidium (Rb) content. In the case of these samples, however, the appearance is distinctive enough for identification. One other glass sample from the site indicated an Obsidian Cliff (Yellowstone Park) origin (Na/Mn ratio 132.24).

OBSIDIAN STUDIES

Unpublished results of other true obsidian studies in the Bighorn Basin include five samples from Wedding of the Waters Cave (Frison, 1962) from a Late Middle Period level (1,620 ± 165 years B.P.: A.D. 330, radiocarbon date run in private laboratory by Don Grey in Sheridan, Wyoming, in 1961). Na/Mn ratios ranged from 133.74 to 147.70, almost certainly indicating an Obsidian Cliff origin. Hydration thickness measurements of three of the same specimens were 3.5, 3.6, and 3.7 microns (Clifford Evans, personal communication, 1962), which would place the age at about 247 B.C., the exact date depending upon the rate used.[2] It is believed that the radiocarbon date is too late, and that agreement between carbon-14 and hydration dating is reasonably close.

In addition to the above studies, an archaeological survey was made on property purchased by the National Girl Scout Organization in the area adjacent to Daugherty Cave. Most of the evidence from defined sites was of Late Archaic aspect, and six samples of obsidian were submitted for neutron activation analysis. Four of these were undoubtedly from Obsidian Cliff (Na/Mn range 159 to 160) and two were from another source in the Yellowstone Park area with Na/Mn ratios of 85 and 92. Lacking information on the ratios of other elements present, we could not determine the exact source. From appearance alone, the two samples do not seem to be from the non-volcanic natural glass sources mentioned earlier. There is, however, a group of obsidians referred to as the "90 group" with Na/Mn ratios between 83 and 95; and indications are that this source may be at Canyon Junction-Willow Park-Grassy Lake Reservoir, 1/4 mile south of Yellowstone Park (Wright and others, 1969).

In 1958, remains of log structures in front of a rockshelter in the Tensleep Canyon area, on the west side of the Bighorn Basin, were excavated. The materials indicated a Late Prehistoric date. Two samples of obsidian were submitted, both indicating an Obsidian Cliff source.

Other obsidian source studies have been centered in Jackson Hole, Yellowstone Park, and adjacent areas of Wyoming. Many sources are now known, with geologic evidence indicating that there are even more sources as yet unknown.

Obsidian Cliff in Yellowstone Park is apparently the source of the most widespread obsidian in Wyoming sites. A wide range in appearance has been noted in Obsidian Cliff samples, which range from opaque to translucent, and in color from black to mottled brown and maroon. All samples from this source have an Na/Mn ratio between 132 and 170 (Frison and others, 1968). The writer submitted from Obsidian Cliff eight samples covering the widest possible range of color, translucency, and different areas of the flow. The Na/Mn range was 141 to 167 in these samples, well within the known extremes of variation at the site.

Most obsidian sources in the Yellowstone-Teton area demonstrate conclusive evidence of quarrying. The writer collected samples from a source in the Teton Pass area west of Jackson, Wyoming. Two sources are actually present, about 100 yards apart, but these are probably part of the same vent. The maximum range in Na/Mn ratio for 15 samples is 73 to 82 with a mean of 77. In addition, ten samples were submitted from a site about 1/4 mile west of the quarry. The site was apparently a location of considerable workshop activity with large quantities of waste flakes and a number of broken bifaces and other forms. The debitage (flaking debris) was under 1 to 2 inches of soil. The submitted samples gave Na/Mn ratios ranging from 69 to 77.

The obsidian from both the source and the site is of excellent quality. Pieces of material 7 to 9 centimeters in diameter are abundant, and they show excellent flaking qualities. Many more samples should be submitted, so that we can determine the complete range of

[2]This date is based upon a very high rate of hydration. As the cave is in a locally very warm area, the rate may be valid. Use of a lower rate of hydration would push the date back further in time.

possible Na/Mn ratios; but the site and the quarry material appear to be the same. The isolated nature of the site, and the difficulty of access suggest that it was a location where material from the quarry was being manufactured into blanks of various shapes, probably to reduce the weight of materials to be transported. The site location presents no features that could in any way make it a desirable location for any other purpose; and it is one of the few available spots near the quarry that are level and protected.

Another source of obsidian that was apparently utilized aboriginally is close to the Teton Pass source but at the base of the mountains. The obsidian appears as cobbles of several sizes in gravel deposits, and shows indications of having been moved considerable distances through stream action. One cobble collected measured 14 centimeters in diameter, and larger ones have been found. Na/Mn ratios are within the range of the samples from the Teton Pass source (Na/Mn ratios of 71 to 80). The nearby area is literally covered with debitage and, as expected, Na/Mn ratios are similar to those of the material from the gravel source.

The ultimate source of this excellent obsidian in the gravels is not yet known. The drainage pattern is such that it is impossible that this material could have been derived from the known Teton Pass quarries, even though the Na/Mn ratios are similar. Attempts have not yet been made to compare the distribution of other elements in the samples, to distinguish the two groups.

Surface collections of obsidian have been gathered from various places such as campsites, and especially those areas where movements of prehistoric peoples would have been funneled. At Togwotee Pass east of Moran Junction a number of samples were collected, and six were submitted for analysis. Two were definitely of the "150 group" (Obsidian Cliff). One was of the 90 group (possibly the Grassy Lake source), and three were within the range of samples from the Teton Pass sources (Na/Mn ratios of 77 to 81).

Five samples from a campsite near Jackson, Wyoming were submitted. Three of these fall in the range of the Teton Pass sources (Na/Mn ratios of 74 to 79). One is within the 90 group range (Na/Mn ratio of 86) and one is within the range of what is known as the "110 group", the source of which is probably one of several in Yellowstone Park. Sources known with this Na/Mn ratio include Canyon Junction, Pelican Creek, Witch Creek, Falls River Basin, and Kepler Cascade (Wright and others, 1969), but careful study of other element distribution data is needed for their separation. Most likely the Jackson sample is from one of the above-mentioned Yellowstone Park sources.

A large number of obsidian samples were submitted from sites in the Upper Green River Basin area of Wyoming. The Eden-Farson site (Frison, 1971) is a Late Shoshonean campsite associated with an antelope trap. Seventeen samples from eight separate lodges were submitted. Results indicate that eight of these samples were of Obsidian Cliff origin and seven were in the 80 to 82 Na/Mn range, suggesting a Teton Pass source. One had an Na/Mn ratio of 85 and was very likely from the 90 group (Grassy Lake) source just south of Yellowstone Park. The radiocarbon age of the Eden-Farson site is 230 $\pm$ 100 years B.P. (A.D. 1720, RL-101).

The Wardell site near Big Piney (Frison, 1973) is a stratified Late Prehistoric Period buffalo trap with radiocarbon dates of 990 $\pm$ 100 years B.P. (A.D. 960, RL-103; top level of kill area), 1,170 $\pm$ 100 years B.P. (A.D. 780, RL-111; firepit in meat-processing area), and 1,580 $\pm$ 110 years B.P. (A.D. 370, RL-102; charred log in bottom of kill area). RL-102 may well be too early to properly date the lower kill level, as it was obtained from a large juniper log that may have been dead for as much as a century before its incorporation into the kill level; and in addition, the dated material included some of the central growth rings (ibid.:74).

Obsidian samples were submitted both for hydration dating and neutron activation analysis. Samples from the top level of the kill, and from the meat-processing area gave hydration rim thicknesses ranging from 1.5 to 1.9 microns, with a median close to 1.7 microns. Good agreement with the radiocarbon dates is obtained if a hydration rate of 2.5 to 2.8 microns^2 per 1,000 years is used, and such a rate is very plausible for the area (Irving Friedman, personal communication, 1973). Six samples from the meat-processing area and three samples from the kill area were submitted for neutron activation analysis. One sample each from the kill and meat-processing areas indicate an Obsidian Cliff source, while the remaining five from the meat-processing area and two from the kill area are in the 90 group, probably from the Grassy Lake source.

In 1968, samples were collected from a large surface site near Pinedale, Wyoming and ten were submitted for analysis. The results indicate two samples from Obsidian Cliff, two definitely in the 90 group, and six from Teton Pass sources. This site included components of Late Archaic and Late Prehistoric age.

Samples from the extreme southeastern area of Wyoming have also been tested. A single sample, apparently of Late Prehistoric cultural affiliation, from the south side of Medicine Bow Peak near Laramie is in the Obsidian Cliff range, as are three samples from a Late Prehistoric level at Willow Springs, also near Laramie. From this same level came two samples with Na/Mn ratios of 60 and 61. It is suggested that these may be from an as yet untested source in the Colorado Rockies. There have been reports of obsidian sources near the Wyoming border, but the writer has not visited these nor have any samples been collected.

Four samples were submitted from Late Prehistoric sites, all containing Upper Republican pottery, from near the Nebraska line between Cheyenne and Torrington, Wyoming. Three of these are from Obsidian Cliff (Na/Mn ratios of 150, 150, and 160) and one could be from the Teton Pass area (Na/Mn ratio of 81).

During the winter of 1970-71, Dr. Irving Friedman of the United States Geological Survey in Denver offered to provide both C^{14} and obsidian dates for a site in Sunlight Basin northwest of Cody, Wyoming. The site is an exceptionally large one with materials suggesting relationships with the McKean complex. The results (Irving Friedman, personal communication, 1972) were as follows: seven obsidian samples had a hydration thickness of 4.4 microns, one sample had a thickness of 4.5 microns, and one sample had a thickness of 4.6 microns. In addition, one fragment of a stemmed projectile point strongly suggesting an older type picked up and reused produced a hydration thickness of 7.1 microns. Results of two carbon samples were 4,180 ± 250 years B.P. (2,230 B.C., W-2597) and 4,430 ± 250 years B.P. (2,480 B.C., W-2599). If corrected, the C^{14} dates would indicate an antiquity of about 5,000 years for the site; and using a hydration rate of 3.8 $microns^2$ per 1,000 years, the two methods yield dates that are quite well in agreement.

Six samples were also submitted from this site for neutron activation. Two proved to be from Obsidian Cliff and the remaining four are in another group (Na/Mn ratio of 115). These may be part of the 110 group although 112 is the highest Na/Mn ratio so far recorded for this group. The samples could very easily be from an as yet unidentified source in the largely unexplored area in and around Yellowstone Park.

CONCLUSIONS

Both obsidian dating and neutron activation analysis are proving to be worthwhile tools for the archaeologist. Hydration dating is of course especially desirable because of its low cost, but the ideal situation is to obtain both C^{14} and obsidian dates. It is especially rewarding to see the two tests give comparable results.

Along with this, the source data are of value in the hypothesizing of population movements and possible trade routes and networks. One problem here is the difficulty in obtaining reasonably fast results from neutron activation testing. We are prepared to submit 5,000 samples but are unable to do so. There is still much to learn in terms of obsidian source data. Many known sources are untested and many sources remain undiscovered.

Especially needed in the area of southeastern Montana and northeastern Wyoming is an extensive survey to determine sources of non-volcanic natural glass. This unique material apparently can be treated similarly to obsidian with regard to source determination using the presence and amount of certain elements; but there are indications that some of this glass may behave erratically when hydration readings are attempted.

Wyoming, Montana, and Idaho are fortunately located for obsidian studies. The writer is not aware of attempts to trace the movements of Yellowstone, Teton, and Powder River area obsidians and non-volcanic glasses to the north and west beyond the immediately adjacent areas of Idaho and Montana, and to the north, southern Alberta. Until the total picture of these movements is known our efforts lack an adequate frame of reference, and a large body of culturally significant data remains ignored by many researchers.

REFERENCES

Bentzen, Raymond C.
1962 The Mavrakis-Bentzen-Roberts Bison Trap, 48SH311. A Report of an Investigation by members of the Sheridan Chapter, Wyoming Archaeological Society: 15 p. Sheridan, Wyoming: printed by the Society.

Frison, George C.
1962 Wedding of the Waters Cave, a stratified site in the Big Horn Basin of Wyoming. Plains Anthropologist, 7(18): 246-265. Lincoln, Nebraska.
1968 Daugherty Cave, Wyoming. Plains Anthropologist, 13(42):253-295. Topeka, Kansas.
1970 The Kobold Site, 24BH406: A post-Altithermal record of buffalo jumping for the Northwestern Plains. Plains Anthropologist, 15(47):1-35. Topeka, Kansas.
1971 Shoshonean antelope procurement in the Upper Green River Basin, Wyoming. Plains Anthropologist, 16(54):258-284. Topeka, Kansas.
1973 The Wardell Buffalo Trap, 48SU301: Communal procurement in the Upper Green River Basin, Wyoming. Museum of Anthropology, University of Michigan, Anthropological Papers, 48:1-111. Ann Arbor, Michigan.

Frison, G. C., G. A. Wright, J. B. Griffin, and A. A. Gordus
1968 Neutron activation of obsidian: an example of its relevance to Northwestern Plains archaeology. Plains Anthropologist, 13(41):209-217. Lincoln, Nebraska.

Gordus, A. A., G. A. Wright, and J. B. Griffin
1968 Obsidian sources characterized by neutron activation analysis. Science, 161:382-384. Washington, D. C.

Wright, G. A., J. B. Griffin, and A. A. Gordus
1969 Preliminary report on obsidian samples from Veratic Rockshelter, Idaho. Tebiwa, 12(1):27-30. Pocatello, Idaho.

A REVIEW OF LICHENOMETRY AND THE DATING OF WEATHERED ROCK SURFACES IN THE HIGH CORDILLERA

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ABSTRACT

A brief review is given of the method of lichenometry for the relative and absolute dating of rock surfaces. The method can be used successfully over a time period of 0 to 9,000 years with actual limits being a function of local climate and the speed of rock weathering. In the area of the Rocky Mountains a growth rate of 15 mm/100 yrs for the first 300 years and then 3 mm/100 yrs until senescence may apply. It is recommended, however, that individual growth curves should be constructed wherever possible.

The surface weathering of boulders and the development of soil profiles are also being increasingly used as a relative dating technique. Calibration of the weathering curves has, however, rarely been attempted.

INTRODUCTION

The dating of both geological and archaeological materials is central to an understanding of the changing natural and human environments that characterized the latter part of the Quaternary. The advent of radiocarbon dating greatly accelerated our awareness of the timing of events, but unfortunately, the high alpine regions of western North America are commonly devoid of datable materials within stratigraphic sections. In fact, good vertical exposures are rare and most of the Quaternary geology is concerned with the recognition of glacial deposits by morphostratigraphic criteria. Dating of these deposits can be done on a relative basis by position within a stratigraphic record but it is possible to gain an "absolute" or semi-quantitative concept of the age difference between deposits by considering the dual methods of lichenometry and surficial rock weathering. Soil development is being used increasingly as an age-dependent criterion. Lichenometry can, according to region, date substrates from a maximum of 300 to nearly 10,000 years B.P. (Miller and Andrews, 1972; Denton and Karlén, 1973).

It is the purpose of our short paper to review briefly the various methods that we and others have used, and to point out some of the advantages and disadvantages of each.

LICHENOMETRY

Lichenometry is defined as the use of lichen size to measure various aspects of the relative and "absolute" age of substrates. The most commonly dated substrate is rock although this need not be the case as soil, wood, and other lichen substrates can be used. Biologists have commented on the size/age relationship for a considerable time but the modern development of lichenometry was largely the responsibility of Roland Beschel (1950, 1961). The fundamental assumption behind Beschel's method is that it is the lichen thallus with the maximum diameter that is the best indicator of surface age. Others (Stork, 1963; Rampton, 1970) have used averages of large thalli or best-fit regression techniques; such methods might have utility for relative dating but are unsatisfactory for estimation of the absolute age of a substrate. Platt and Amsler (1955) independently introduced and defended the concept of using only the maximum lichen diameter for dating purposes.

Basic references

In this short note we do not intend to comment exhaustively on lichenometry. The following list of references will provide the reader with, in our opinion, the most comprehensive introduction: Beschel (1961; 1973); Andrews and Webber (1964); Benedict (1967); Jochimsen (1973); Orwin (1970); and Platt and Amsler (1955). We would like to point out that the journal Arctic and Alpine Research, Vol. 5, No. 4 (1973) is devoted entirely to papers on all facets of lichenometry. Several of the papers in that volume are concerned specifically with the use of lichenometry in the high Cordillera of North America (G. H. Miller, 1973; Birkeland, 1973; Carrara and Andrews, 1973).

Identification of lichens

Field identification of lichens is not easy and, unfortunately, there is some danger that the most commonly used species (Rhizocarpon geographicum in its widest sense) may be confused with other yellow-green Rhizocarpons. It is recommended strongly that geologists or archaeologists about to use lichenometry for the first time spend a period examining specimens in a herbarium under the direction of a competent botanist. It is good practice (Benedict, 1967) to send voucher specimens of

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the main lichens you use to a herbarium or museum so that they can be retained and used by others for verification.

Problems may be encountered if the study includes a wide range of rock types, especially if there are limestones or dolostones. R. geographicum is found particularly on granites and other siliceous rocks whereas other lichens are dominant in limestone/dolostone terrain.

Sampling procedures

Sampling a substrate for lichen sizes entails three main procedures that vary according to the purpose of the study. If the research is aimed at dating of a particular till unit, then a search of the entire deposit for maximum thalli is best (Benedict, 1967; Denton and Karlén, 1973), although wet sites should be avoided. However, this procedure is really feasible only on rather small Neoglacial moraines, and becomes inefficient as the size of the unit increases.

If a valley once contained a large glacier that has retreated relatively rapidly, then selected sampling at certain specified horizontal or vertical distances is recommended. In this case, the size of the sample area may be restricted to a circle of 10 m radius or a square of 10 m^2 (Andrews and Webber, 1964; 1969). By sampling in this fashion, lines of equal lichen diameter can be drawn, and these represent isochronous surfaces that may be used to reconstruct the retreat of a glacier (Andrews and Webber, 1969). The same rationale would dictate this method of sampling if a researcher were concerned with the history of a large rock glacier; this general sampling plan has been used for this purpose by Potter (1972) and G. H. Miller (1973).

Finally, the researcher might wish to determine if there are distinct lichen populations present within a sampling unit -- for example, large boulders lying on a surface exposed for much of the Holocene might have been used to construct an Indian game-drive (cf. Benedict, 1967). Thus boulders would have surfaces of essentially two ages. In this example, or others of a similar nature, the measurement of the maximum lichen thallus is not the purpose of the study, rather the need is for methods to recognize the presence of two distinct populations of lichen sizes. This aim can be realized through plotting of size/frequency data for a species (Lindsay, 1973; Matthews, 1973; Andersen and Sollid, 1971).

Relative and absolute age determinations

Substrates of similar age can be correlated in relative terms purely on the basis of similar maximum diameters. Thus we could talk about the 40 mm R. geographicum moraines without any reference to their absolute age. This approach is common in many sciences and might be compared to correlations of archaeological sites on the basis of artifact typology. Little more can be said about this aspect other than that correlations over wide geographic and thus climatic areas should be considered carefully.

However, it is much more meaningful if a study can be set in an actual temporal framework. This necessitates the development of a relationship between lichen thallus size and age. Early studies (Andrews and Webber, 1964) had to assume that lichen growth rates were a linear function of time; but in 1967 Benedict was able to show that the growth curve of R. geographicum had an initial rapid growth rate (15 mm/100 yrs) which reduced rapidly to a long linear period of growth on the order of 3 mm/100 yrs. Beschel had in several of his earlier publications (e.g. 1961) discussed the presence of the so-called "great period" in lichen growth rates but Benedict's contribution was to indicate the actual shape of the growth curve over a period of 3,000 years or so.

There are two principal methods for developing a curve showing lichen thallus size as a function of age [note: Benedict's plot (Fig. 9, p. 830, 1967) shows age as a function of lichen size; we would recommend interchanging the axes]. These methods may be listed as (1) indirect methods and (2) direct methods. Indirect methods have been used most commonly. They consist of determining the age of a substrate by some method other than lichenometry and then measuring the lichen thalli on this substrate. Methods of dating vary between the use of substrates of known age, such as gravestones (Beschel, 1958; Carrara and Andrews, 1973), survey cairns (Benedict, 1967) or radiocarbon-dated substrates (Benedict, 1967; Miller and Andrews, 1972; Denton and Karlén, 1973). Authors plot the size of lichens as a function of age as a single line. However, it must be noted that because of sampling errors in determining the maximum lichen thallus, as well as the standard deviation of the C-14 date, a more reasonable approach would be to plot the function as a band of increasing width. Miller and Andrews (1972, Fig. 5) attempted to illustrate at least the sense of this by plotting the curve on log-log paper with the error term a circle of constant size (and hence, on log-log paper of increasing magnitude the larger the error). Thus, at an estimated age of 100 years the estimated error is $\pm$15 years; but this increases to $\pm$1,000 years beyond an age of 10,000 years.

An alternative method for computing the growth curve of a lichen species is to measure directly the growth of a number of individual thalli over a period of one or more years. If lichens of different sizes are measured, then the growth rate as a function of lichen diameter can be determined (Andrews and Webber, 1969; Miller and Andrews, 1972; Ten Brink, 1973; G.H. Miller, 1973; Armstrong, 1973). This approach is most suitable for the faster growing lichen species. Results can be obtained in the space of one to two years. Over a longer period even the growth of R. geographicum can be measured (Ten Brink, 1973). The

TABLE I. GROWTH RATES OF R. geographicum FROM THE HIGH CORDILLERA OF NORTH AMERICA (FROM WEBBER AND ANDREWS, 1973)

Area	Great Period Rate mm/100 yrs	Length yrs	Linear Phase mm/100 yrs	Length yrs	Author
Colorado Front Range	14	100	3	3,000	Benedict, 1967
Sierra Nevada	14	300	4	3,000	Curry, 1969
St. Elias & Wrangell Mountains, Alaska	17	300	3	2,800	Denton and Karlén, 1973
North St. Elias, Yukon	15	500	–	———	Rampton, 1970
San Juan Mountains, Colorado	*30	100	–	———	Carrara and Andrews, 1973
North Cascades, Washington	50	100	8	700	Miller, 1969
Central Alaska Range	50	300	–	———	Reger and Péwé, 1969

*This rate applies to elevations well below timberline and thus it is undoubtedly a maximum value for growth rate in the San Juan Mountains above timberline.

actual procedures involved in this method require lichen thalli either to be photographed or traced onto a plastic film, and then to be remeasured after a suitable interval of time. Optical measurement has been tried successfully in Wales (Armstrong, 1973).

In another indirect method, information on the growth rate of slower growing species can be derived if the ratios of lichen sizes are known (Miller and Andrews, 1972). For example, if the size ratio of Alectoria minuscula : R. geographicum is 5:1 and the growth of A. minuscula is 0.7 mm/yr, then an estimate of growth rate of R. geographicum would be 0.14 mm/yr.

Plots of lichen maximum size versus the percentage cover of lichens on boulders indicate that in broad terms lichen cover is also a function of the age of the substrate. We think that the main application of the degree of lichen cover is in large-scale mapping from air photographs, because the differences in lichen cover are quite noticeable on conventional black and white imagery.

Absolute growth curves have now been determined for a number of ranges in the high Cordillera of North America (Table I, compiled from Webber and Andrews, 1973). Perhaps the most surprising result evident in Table I is the consistency of growth rates at many widely separated geographical regions, with a great period growth rate of ca. 15 mm/100 yrs for a period of 100-500 years followed by a long linear period of growth of ca. 3 mm/100 yrs. This statement applies to four of the seven areas (Table I). As noted on that table the growth rate for the San Juan Mountains of Colorado is from below treeline and, therefore, might be expected to reflect more favorable growing conditions near the lower limit (altitudinally) of R. geographicum. The growth rate in the Northern Cascades (C. D. Miller, 1969) is similar to several from maritime areas in Northern Europe (see Table 2, Webber and Andrews, 1973) but it is difficult to explain the high growth rate of R. geographicum from Central Alaska (Reger and Péwé, 1969).

Although our judgment is not soundly based we do suggest that a growth rate of 15 mm/100 yrs for this first 300 years and a linear phase of 3 mm/100 yrs for between 300 and 9,000 years might apply to many of the drier parts of the American Rocky Mountains. Certainly this verdict should be subjected to repeated testing but if a coarse, crude age determination is required from lichenometry (in an area where a growth rate curve is not available), then these values might have some merit. Certainly there will be no problem in differentiating deposits 100 to 1,000 years old from those around 3,000 years or older.

WEATHERING STUDIES

Quaternary geologists have long recognized that various physical and chemical processes result in a noticeable differentiation of surficial units, based on the variations in degree of weathering of surface boulders and on the depth and degree of soil development. At the same time many workers have commented on the difficulties of using weathering as a relative or absolute dating tool (Birkeland, 1973; Mahaney, 1973; Williams, 1973; Madole, 1969). These difficulties appear to be caused primarily by (1) regional variations in macro-, meso-, and microclimates that control the rate and nature of the weathering processes; (2) the general absence of datable material with which to develop an initial weathering-curve time calibration; and (3) a lack of standardization of what and how to measure, so that the results of one worker are not easily compared to those of another.

Despite these problems, it appears from our own cursory field studies and those of others (e.g. Birkeland, 1973) that weathering studies can, in a relative sense, delimit surficial rock units that are (1) late Neoglacial in age ($\leq$ 2,000 B.P.); (2) Pinedale in age (7,000 to 20,000 B.P.); and (3) Bull Lake in age ($\geq$ 70,000 B.P.). There are problems in differentiating between the various possible Pinedale stades; it will be difficult to separate the late Pinedale from the early Neoglacial; and finally, it will probably be hard to separate "late Bull Lake" deposits from those of earlier glaciations because the weathering products apparently reach a pseudo-steady state condition after approximately 100,000 years in many parts of the mountains of the western United States.

There is an increasing move to develop quantitative methods for analyzing these various weathering differences. Because of the various mathematical measurement scales used in such studies [e.g. nominal scale (soil color); ordinal scale (fresh to weathered); ratio scale (depth and width of pitting); and closed number scale (percentage data)] appropriate statistical methods are not readily available. Information and graph theory offer a useful approach and have been used to examine weathering data (Andrews and Estabrook, 1971; C. D. Miller, 1973b). One of the more useful aspects of the quantitative approach will be to provide guidelines indicating which are the most powerful field measurements in terms of discriminating between deposits of different ages. Such an approach is contained in the paper by Boyer and Pheasant (1974, in press) which examines the usefulness of weathering studies in the eastern Canadian Arctic as a relative chronological tool.

Soil properties can be a function of time (Richmond, 1962; Birkeland, 1973; Mahaney, 1970). In the high alpine areas of the North American Cordillera, researchers are noting that the following properties of the soil profile appear to be more or less age-dependent: (1) thickness and organic content of the A horizon: (2) thickness of the Cox horizon (for Neoglacial soils); (3) color and thickness of the B horizon. Birkeland (1973 and personal communication, 1973) is finding that a useful age indicator is the presence and thickness of loess which is frequently present in the high country. Its development has been tentatively assigned to the climatic optimum.

We urgently require working graphs showing the development of weathering rind thickness, the decrease in fresh rocks, and the development of a color and textural (clay-rich) B as functions of time[3]. However, we have to bear in mind that these rate curves will also be expressing other factors that influence weathering. A measure of the disagreement that can exist between workers looking at the same alpine deposits is the recent discussion by Williams (1973) and Mahaney (1973) of the Fourth of July cirque, Colorado Front Range. Williams (1973) gives good reasons why a unit that Mahaney (1973) called Temple Lake (possibly 2,500 years old) should be assigned to late Bull Lake time (ca. 100,000 years old). The age assignments differ by an order of magnitude!

SUMMARY

Lichenometry and weathering studies can provide a relative age and even good estimates of the absolute age of a deposit. However, there is a need to consider the biological and geological processes that govern the rates of change (of lichen size, weathering rinds, etc.) with time. This can be approached experimentally or by developing a series of curves based on deposits of known age. In the alpine areas the finding of rock units that can be radiocarbon-dated or dated by fission-track methods are extremely rare.

REFERENCES

Andersen, J. L., and J. L. Sollid
1971 Glacial chronology and glacial geomorphology in the margin zones of the glaciers Midtalsbreen and Nigardsbreen, south Norway. Norsk Geografisk Tidsskrift, 25: 1-38. Oslo, Norway.

Andrews, J. T., and G. Estabrook
1971 Applications of information and graph theory to multi-variate geomorphological analysis. Journal of Geology, 79:207-221. Chicago, Illinois.

Andrews, J. T., and P. J. Webber
1964 A lichenometrical study of the northwestern margin of the Barnes Ice Cap: a geomorphological technique. Geographical Bulletin, 6(22):80-104. Geographical Branch, Department of Mines and Technical Surveys, Ottawa, Canada.
1969 Lichenometry to evaluate changes in glacial mass budgets: as illustrated from north-central Baffin Island, N.W.T. Arctic and Alpine Research, 1:181-194. Boulder, Colorado.

Armstrong, R. L.
1973 Seasonal growth and growth rate -- colony size relationships in six species of Saxicolous lichens. New Phytologist, 72:1023-1030. Oxford, England.

Benedict, J. B.
1967 Recent glacial history of an alpine area in the Colorado Front Range, U.S.A. I. Establishing a lichen-growth curve. Journal of Glaciology, 6:817-832. Cambridge, England.

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[3]Editor's note: the relative development of color and textural B horizons at slightly lower altitudes is discussed in this volume by Reider et al.

Beschel, R. E.
1950 Flechten als Altersmasstab rezenter Moränen. Zeitschrift für Gletscherkunde und Glazialgeologie, 1:152-161. Innsbruck, Austria.
1958 Flechtenvereine der Städte, Stadtflechten und ihr Wachstum. Berichte des Naturwissenschaftlich-medizin-ischen Vereins in Innsbruck, 52:1-158. Innsbruck, Austria.
1961 Dating rock surfaces by lichen growth and its application to glaciology and physiography (lichenometry). In G. O. Raasch (ed.), Geology of the Arctic, v. 2:1044-1062. University of Toronto Press, Toronto, Canada.
1973 Lichens as a measure of the age of recent moraines. Arctic and Alpine Research, 5(4):303-309. Boulder, Colorado.

Birkeland, P. W.
1973 Use of relative age-dating methods in a stratigraphic study of rock-glacier deposits, Mt. Sopris, Colorado. Arctic and Alpine Research, 5(4):401-416. Boulder, Colorado.

Boyer, S., and D. R. Pheasant
1974 Delimitation of weathering zones in the fiord area of eastern Baffin Island, Canada. Geological Society of America Bulletin, in press. Boulder, Colorado.

Carrara, P. E., and J. T. Andrews
1973 Problems and application of lichenometry to geomorphic studies, San Juan Mountains, Colorado. Arctic and Alpine Research, 5(4):373-384. Boulder, Colorado.

Curry, R. R.
1969 Holocene climatic and glacial history of the central Sierra Nevada, California. Geological Society of America Special Paper, 123:1-47. Boulder, Colorado.

Denton, G. H., and W. Karlén
1973 Lichenometry: its application to Holocene moraine studies in southern Alaska and Swedish Lapland. Arctic and Alpine Research, 5(4):347-372. Boulder, Colorado.

Jochimson, M.
1973 Does the size of lichen thalli really constitute a valid measure for dating glacial deposits? Arctic and Alpine Research, 5(4):417-424. Boulder, Colorado.

Lindsay, D. C.
1973 Estimates of lichen growth rates in the maritime Antarctic. Arctic and Alpine Research, 5(4):341-346. Boulder, Colorado.

Madole, R. F.
1969 Pinedale and Bull Lake glaciation in upper St. Vrain drainage basin, Boulder County, Colorado. Arctic and Alpine Research, 1:279-287. Boulder, Colorado.

Mahaney, W. C.
1970 Soil genesis on deposits of Neoglacial and late Pleistocene age in the Indian Peaks of the Colorado Front Range. Ph.D. Dissertation, University of Colorado, Boulder, Colorado. 246 p.
1973 Neoglacial chronology in the Fourth of July cirque, central Colorado Front Range. Geological Society of America Bulletin, 84:161-170. Boulder, Colorado.

Matthews, J. A.
1973 Lichen growth on an active medial moraine, Jotunheimen, Norway. Journal of Glaciology, 12(65):305-313. Cambridge, England.

Miller, C. D.
1969 Chronology of Neoglacial moraines in the Dome Peak area, North Cascade Range, Washington. Arctic and Alpine Research, 1(1): 49-66. Boulder, Colorado.
1973a Chronology of Neoglacial deposits in the Northern Sawatch Range, Colorado. Arctic and Alpine Research, 5(4):385-400. Boulder, Colorado.
1973b Evaluation of late-Pleistocene glacial succession in the northern Sawatch Range, Colorado, by information- and graph-theoretic methods. Geological Society of America Abstracts with Programs, 5(6):496-497. Boulder, Colorado.

Miller, G. H.
1973 Variations in lichen growth from direct measurements: Preliminary curves for Alectoria minuscula from eastern Baffin Island, N.W.T., Canada. Arctic and Alpine Research, 5(4):333-339. Boulder, Colorado.

Miller, G. H., and J. T. Andrews
1972 Quaternary history of northern Cumberland Peninsula, east Baffin Island, N.W.T., Canada. Part VI: Preliminary lichen growth curve for Rhizocarpon geographicum. Geological Society of America Bulletin, 83:1133-1138. Boulder, Colorado.

Orwin, J.
1970 Lichen succession on recently deposited rock surfaces. New Zealand Journal of Botany, 8(4):452-477. Wellington, New Zealand.

Platt, R. B., and F. P. Amsler
1955 A basic method for the immediate study of lichen growth rates and succession. Journal of the Tennessee Academy of Science, 30:177-183. Nashville, Tennessee.

Potter, N.
1972 Ice-cored rock glacier, Galena Creek, Northern Absaroka Mountains, Wyoming. Geological Society of America Bulletin, 83:3025-3058. Boulder, Colorado.

Rampton, V.
1970 Neoglacial fluctuations of the Nataxhat and Klutlan glaciers, Yukon Territory, Canada. Canadian Journal of Earth Sciences, 7:1236-1263. Ottawa, Canada.

Reger, R. D., and T. L. Péwé
1969 Lichenometric dating in the central Alaska Range. In T. L. Péwé (ed.), The Periglacial Environment: Past and Present: 223-247. McGill-Queen's University Press, and Arctic Institute of North America, Montreal, Canada.

Richmond, G. M.
1962 Quaternary stratigraphy of the La Sal Mountains, Utah. United States Geological Survey Professional Paper, 324:1-135. Washington, D.C.

Stork, Adelaide
1963 Plant immigration in front of retreating glaciers with examples from Kebnekajse area, northern Sweden. Geografiska Annaler, 45(1):1-22. Stockholm, Sweden.

Ten Brink, N. W.
1973 Lichen growth rates in West Greenland. Arctic and Alpine Research, 5(4):323-331. Boulder, Colorado.

Webber, P. J., and J. T. Andrews
1973 Lichenometry: a commentary. Arctic and Alpine Research, 5(4):295-302. Boulder, Colorado.

Williams, J.
1973 Neo-glacial chronology of the Fourth of July cirque, central Colorado Front Range. Geological Society of America Bulletin, 84:3761-3766. Boulder, Colorado.

HOLOCENE CHANGES IN WYOMING VEGETATION

ALAN A. BEETLE[1,2]

ABSTRACT

During the Holocene, Wyoming has experienced both grassland and temperate forest climates in varying degrees. Wyoming vegetation has faithfully reflected these climates and their changes through migrations of plant species and plant communities. The existence of a certain range of physical or biotic factors is not sufficient to explain the presence or absence of species as there are greater problems of barriers, evolution and genetic plasticity.

INTRODUCTION

Physical evidence indicates that the Holocene has witnessed changes in plant life, animal life, and climate. The extent to which the three are correlated is not always obvious. The greatest variations in animal numbers have not coincided with the strongest changes in climate. These peak changes in climate may not have been great enough to cause any significant realignment of plant communities.

Holocene changes have been cyclic. The order and duration of each cycle may never be known, nor may it be important to know as long as all the parts were able to survive the extremes of climatic factors (sometimes acting jointly with other factors) which function to circumscribe and limit the area that any species can occupy.

Fitting together all the evidence is essential. Patterns of change based on one line of evidence will only be questioned, but patterns which integrate all the lines of evidence will be difficult to assail. Evidence is to be found in distributions, both living and fossil, of all life. The past has been resourcefully studied through pollen profiles, radiocarbon dating, edaphic phytoliths, and fossil excavation. Present-day distribution of plants and animals is a geologic feature which, when properly interpreted, may elucidate the history of communities back to the earliest Cretaceous.

Ungulates, the largest Wyoming animals and those most closely associated with man, traditionally have been associated with the plains, foothills and forest margin. Fire, whether natural or cultural has been associated with both prairies and forests (but not with the shrub transition); although it perhaps limited only the distribution of the forest. Climate in Wyoming seems to have supported not only marginal grasslands and temperate forests but also a broad transition dominated by a rich shrub flora.

Viewed today, the Wyoming vegetation is a blurred reflection of the past. Perhaps the focus on any particular prehistoric moment can never be sharpened completely, but it is possible to trace backward the various plant communities and to reconstruct models consistent with both the known climatic change and evident variations in animal and human populations.

FORESTS AND FIRE

While the three Wyoming vegetation zones -- coniferous forest, shrub transition, and grassland -- are all ancient, there is greater evidence of the antiquity of the forest in the fossil record. There is also great variety in the understory cover, a more readily predictable sequence of seral stages, and generally in the literature a greater acceptance of climax status than is the case with grasslands.

Plants are part of the total environment. They respond sensitively to climatic and edaphic changes.

Both the kinds and rates of these changes have been studied. One source of error in the interpretations made of Holocene landscapes is the failure to differentiate between developmental changes wherein the climate maintains a status quo, and those changes due to a significant shift in the macroclimate.

Basic lines of evidence center around climate (varved clays, tree rings, melting glaciers), soils (parent material -- whether alluvial or eolian, depth, maturity, phytoliths), fire (charcoal), geology (dry lake beds, erosional patterns), plants (extinction, migration, pollen, distribution) and animals (extinction, migration, morphologic change).

There is evidence in the soil (charcoal layers) and in the plants (genetic adaptation) of the long association of fire with the temperate coniferous forest. Long before man was able to set fires, mature woods were reduced to the seral stages of a pyric disclimax by lightning.

In the fragmentary state of our knowledge, it is not really known to what extent the forest margins have been determined by the habitat confinement of climatic climax or to what extent they are held back by fires. There is some literature that implies that fires (especially those set by man) sweep off the grasslands and threaten

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[2]Published with the approval of the director, Wyoming Agricultural Experiment Station, as Journal Article No. 658.

the forest. Actually, historical evidence suggests that fires have probably swept out of the forests onto the shrub transitions and grasslands.

Within the forest zone, fire has heightened in importance the lodgepole pine by giving the tree a prominent role in seral stages of climax, but burned, spruce forest. Fire does not seem to be the determinant of climax lodgepole pine forest -- rather, this climax is due to a coincidence of site and wind.

Limber pine savannah and spruce islands are here conspicuous features of the subalpine zone. World-wide savannahs are related to two situations: (1) fire frequency, and (2) transitions between major climates, either grassland and temperate forest or grassland and tropical forest. The limber pine savannah fits into the first. Man's control of fire in Yellowstone National Park is gradually eliminating the extent of this vegetation type.

TRANSITIONS AND CLIMATE

Grassland is a major response by vegetation to a major climatic zone. Temperate forest is another major response by vegetation to another major climatic zone. In Wyoming, where both grasslands and temperate forest occur, the transition between the two finds expression in the highly variable shrub savannah which characterizes most of the Great Basin, of which the Red Desert and associated Wyoming basins are a part.

It seems likely that past climatic fluctuations may have expanded or constricted this shrub savannah. Colder, wetter climates would have expanded the forests and contracted the transition west of the Continental Divide. Eastward, the same climates would have sharpened the contrast between grassland and forest, squeezing out the transition. Extended periods of hot, dry climates would have expanded and diversified the transition both east and west of the Continental Divide.

Sagebrush savannahs are the hardest vegetation to characterize. They exhibit the extreme variability so characteristic of youthfulness, quite in contrast with the predictable stability found in the shortgrass plant association or the lodgepole pine forest. Where tree savannahs can be demonstrated, they represent a transition between temperate forest and grassland. However, the sagebrush savannahs seem to be a transition between desert vegetation and grassland.

GRASSLANDS AND ANIMALS

Grasslands in Wyoming are marginal, but the shortgrass ranges dominated by blue grama and buffalograss fall within the grassland climatic zone. Various types of bison were the major grassland ungulate species. Prehistoric man was closely associated with this animal.

To what extent animal populations varied with the climate is problematic. If cold, wet climates expanded the forests and limited the game range, the same conditions would have increased the forage and therefore the carrying capacity of neighboring grasslands. The animal population may thus have remained within the same fluctuating limits regardless of long range change in the macroclimate.

The fact that there are true grassland species, both plant and animal, testifies to the continuous existence of a true prairie and therefore of a grassland climate. Either the boreal spruce forest which some imagine covered the continent from the Appalachian Mountains westward to Missouri and Kansas was greatly fragmented, or an area of true grassland was present somewhere south of the forest front.

Man in Wyoming has been a hunter. Since many Wyoming archaeological sites are older than those farther north, it appears that man was present at the end of the Pinedale glacial period to take advantage of the following amelioration in climate and migrate northward, or adjust in Wyoming to such climatic fluctuations as were to follow. Studies of plant distribution support such a generalized hypothesis.

REFERENCES

Axelrod, Daniel I.
1948 Climate and evolution in western North America during middle Pliocene time. Evolution, 2:127-144. Lawrence, Kansas.

Beetle, A. A.
1957 Grassland climax, evolution, and Wyoming. University of Wyoming Publications, 21:64-70. Laramie, Wyoming.
1960 Distribution as a key to the age and origin of grasses. University of Wyoming Publications, 24:1-8. Laramie, Wyoming.
1963 American prehistory and range management. University of Wyoming Publications, 28:1-6. Laramie, Wyoming.

Chaney, R. W. and M. K. Elias
1936 Late Tertiary floras from the High Plains. Carnegie Institute Washington Publication, 476:1-72. Washington, D. C.

Dort, W. and J. K. Jones
1970 Pleistocene and recent environments of the Central Great Plains. University Press of Kansas, Lawrence, Kansas. 433 p.

Elias, M. K.
1942 Tertiary prairie grasses and other herbs from the High Plains. Geological Society of America Special Papers, 41:1-176. New York, N. Y.

Ferguson, C. W.
1969 A 7,104-year annual tree ring chronology for bristle-cone pine, Pinus aristata, from the White Mountains. California Tree Ring Bulletin, 29:1-29.

Heusser, C. J.
1960 Late Pleistocene environments of North Pacific North America. American Geographical Society Special Publication, 35:1-308. New York, N. Y.

Stuiver, M.
1970 Tree ring, varve, and carbon 14 chronologies. Nature, 228:454-455. London, England.

MINOR ELEMENTS IN FOSSIL BONE: APPLICATION TO QUATERNARY SAMPLES

RONALD B. PARKER[1] AND HEINRICH TOOTS[2]

ABSTRACT

Minor element content of fossil bone has provided much useful information about Tertiary fossil vertebrates. Insights have been gained into diet, life habitat, climate after burial, type of diagenetic change, and relative age of samples. Recent studies of pre-Nebraskan and Sangamon material show that introduction of elements is very rapid and makes application to Quaternary material appear very promising.

INTRODUCTION

Fossil bones and teeth are composed mostly of the mineral hydroxylapatite (McConnell, 1973). They are far from chemically pure $Ca_5(PO_4)_3(OH)$, but rather, regularly contain fluorine as an essential constituent and varying amounts of minor elements as "trace constituents". Na, Mg, K, Mn, Fe, Sr, and Y are almost invariably present; with Al, Si, S, Cu, Zn, As, Ba, Pb, V, and rare earths locally important.

For the purposes of the following discussion it is convenient to group minor elements into those which have entered the bone during the life of the animal (premortal) and those which have been added to the bone after death and subsequent burial of the remains (postmortal). This distinction is a useful one because the conclusions which may be drawn from minor element content are quite different in the two cases. Premortally introduced elements tell us about such factors as diet, food chains, and the chemical properties of the animal's environment during life. Postmortally introduced (or removed) elements indicate conditions immediately following the death of the animal, during subsequent diagenesis of the enclosing sediment, and during fossilization of the bone. These conditions include climate, ground-water movement, and both physical and chemical character of the burial environment.

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PREMORTALLY ACQUIRED ELEMENTS

Minor elements which become included in bones and teeth during the life of the animal are of two kinds: 1) elements which are part of the crystal structure of the apatite (such as fluorine, which occupies the (OH) site in the structure, or strontium, which freely replaces calcium in the apatite), or 2) elements which are held as adsorbed ions on the apatite crystallite surfaces, and as exchangeable ions in both the mineral and non-mineral portions of the bone tissues. We believe that most of the sodium, magnesium, and potassium is of the latter sort.

Elements of the first sort are, as it were, locked into the apatite structure during the life of the animal, and apparently are not removed during normal diagenesis. This contention is supported by the data of Table I wherein strontium is essentially constant in bone, dentine, and enamel from the same specimens; while sodium is depleted in the more porous and permeable bone and dentine through leaching from exchangeable sites. This is not to say that some elements are not enriched beyond life values. The fluorine content of the same samples shows the more porous and permeable tissues to be enriched in fluorine.

Strontium content appears to undergo no change during fossilization and is a valuable clue to diet and food chains in vertebrates. Strontium is much more abundant in plants than in animal flesh, and this difference is reflected in the strontium content of the bones of herbivores as compared with those of carnivores.

TABLE I. STRONTIUM, SODIUM AND FLUORINE IN BONE, DENTINE, AND ENAMEL (wt. %).

	Sr			Na			F		
Sample	bone	dentine	enamel	bone	dentine	enamel	bone	dentine	enamel
HT162[1]	0.04	0.04	0.04	0.31	0.27	0.57	2.15	2.32	1.02
HT161[2]	0.10	0.10	0.07	0.41	0.37	0.74	2.37	2.63	0.63
HT154[3]	0.08	0.07	0.06	0.39	0.39	0.59	2.95	2.67	0.45

[1]HT162, Coryphodon, lower Eocene, Bighorn Basin, Wyoming.
[2]HT161, titanothere, lower Oligocene, near Lance Creek, Wyoming.
[3]HT154, Subhyracodon, Oligocene, South Torrington, Wyoming.

TABLE II. SODIUM IN RECENT AND PLEISTOCENE *Bison* sp. DENTINE AND ENAMEL (wt. %).

Recent[1]			Pleistocene[2]		
Sample	dentine	enamel	Sample	dentine	enamel
L-1	0.83	0.56	MH-12	0.19	0.51
L-2	0.72	0.53	MH-13	0.19	0.51
L-5	0.72	0.50	MH-14	0.22	0.48
L-8	0.72	0.53	MH-15	0.20	0.49

[1]Recent specimens, Yellowstone National Park.
[2]Pleistocene (Sangamon) specimens, Las Animas Co., Colorado (see Hager, 1973 for location).

In fact, on a less inclusive level, grazers can be distinguished from browsers among the herbivores (Toots and Voorhies, 1965). We have not yet applied this technique to human remains, but the same principles apply. Ancient man's diet can be so investigated both in relation to geographic and cultural factors, and to the age of individuals in the population.

Sodium, which is probably not part of the apatite structure in most fossils, offers promise as a dietary or other environmental indicator. We have recently found (Parker, Toots, and Murphy, 1974) that because of the relative impermeability of tooth enamel the sodium content of the enamel appears to be unaffected by postmortal leaching (Table II). Thus, even though sodium is not an essential part of the apatite structure, it is preserved at life levels and presumably will lend itself to interpretations like those based on strontium. Hopefully, sodium will complement strontium as an environmental and dietary indicator inasmuch as its geochemical and biochemical behavior is altogether different from that of strontium.

Our studies of the behavior of magnesium and potassium are so incomplete at this stage that we will not engage in unsupported predictions.

POSTMORTALLY ACQUIRED ELEMENTS

Bones and teeth are particularly susceptible to diagenetic alteration because of the presence of organic (non-mineral) matter which catalyzes some reactions, and because of the very small size of the apatite crystallites, resulting in a very large surface area per unit volume. As with the premortally acquired elements, those which enter the skeletal tissues after death are of two types: 1) those which replace apatite elements (such as fluorine for (OH) or yttrium for calcium); and 2) those which occupy voids in the bone or tooth as parts of separate and distinct mineral phases (as is the case for Al, Si, S, Mn, Fe, Ba, Pb, V, and at least part of the Mg and K).

The addition of fluorine to fossil bone during fossilization is well known to archaeologists (Oakley, 1950; Oakley and Hoskins, 1950). The utility of the fluorine dating method for other than the coarsest age distinctions is most limited, however. We have recently shown that fluorine content of bones and teeth of the same individual is highly variable (Table I), depending more on the physical and chemical properties of the tissue than on the geologic age of the sample (Parker, Murphy, and Toots, 1973).

Yttrium is a surprisingly common postmortal element in vertebrate fossils, replacing calcium in the apatite structure. It is present in appreciable amounts (up to more than one weight percent) in samples of Tertiary and early Quaternary age, and appears to enter the bone readily and rapidly. Its presence suggests extensive ground-water circulation because yttrium, like fluorine, is a very minor trace element in normal ground water. Many yttrium-rich bones and teeth also contain appreciable amounts of one or more of the chemically similar rare earth elements (see also Wyckoff, 1972). Because yttrium enters vertebrate fossils fairly rapidly, it offers promise for comparative studies of material of early Quaternary age, especially as to early burial history. We are currently investigating a series of Quaternary horse samples supplied by the late C. W. Hibbard, University of Michigan, in order to more fully understand the significance of yttrium. Hager(1973) has used the presence or absence of yttrium as a supporting criterion for separation of two faunal assemblages in a Colorado Pleistocene site.

The remaining postmortally introduced elements occupy voids such as those previously occupied by the living, non-mineral parts of the bone and postmortal fractures. Iron minerals commonly occupy such voids and bulk iron content, once thought to be

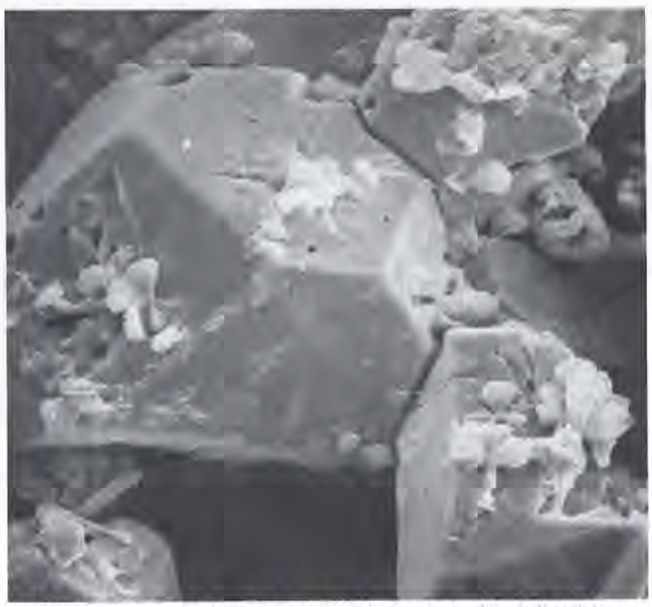

FIGURE 1. Pyritohedrons of pyrite (FeS_2) with a later Va mineral in sheaf-like aggregates on the crystal faces (750x). Lower Eocene, Shirley Basin, Wyoming.

time-dependent (Houston, 1962), was later shown to have correlations with climate (Houston, Toots, and Kelley, 1966). Humid and tropical environments favor retention of iron minerals by the bone. Were this relationship proven to be the case in all examples, its applications to archaeology are obvious. Current studies using a scanning electron microscope (SEM) and X-ray energy dispersive spectrometer (XES) have revealed that the iron is present in more than one mineral in the voids (Fig. 1) and the conclusions from bulk analyses should be approached with caution until more is known about iron's significance.

Manganese content of vertebrate fossils is apparently affected by chemical reactions controlled or strongly influenced by the non-mineral organic constituents of the bone, as well as the bacterial population of the buried skeleton (Parker and Toots, 1972). These factors may in themselves be affected by climate. Again, recent SEM-XES studies show that manganese deposition is part of a sequential filling of the voids (Fig. 2), and is not as simple as it might at first appear.

Barium and lead are common associates of manganese in bone and tooth, at least in part as minerals of the hollandite-coronadite series (Parker and Toots, 1972). SEM-

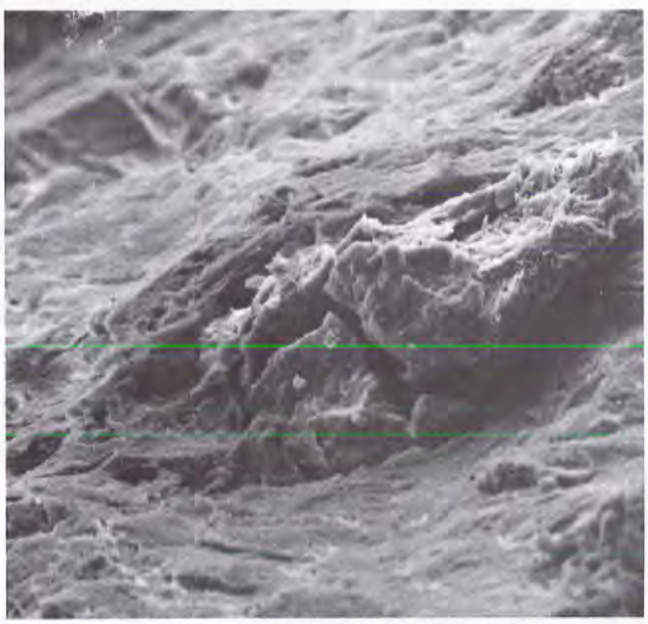

FIGURE 2. Pore in bone filled with a K, Mn, Fe silicate with subsequent crack filled by a Mn (500x). Lower Oligocene, Shirley Basin, Wyoming.

XES investigations have demonstrated presence of a parallel iron-barium association in the form of a presently unknown mineral (Fig. 1). It appears at present that barium and lead follow the transition metals.

Aluminum, silicon, and potassium are present in voids as clay minerals, silica, and potassium feldspar (Fig. 3). As in the cases of iron and manganese, our work with the SEM-XES has just begun and perhaps silence is the course of wisdom at this stage

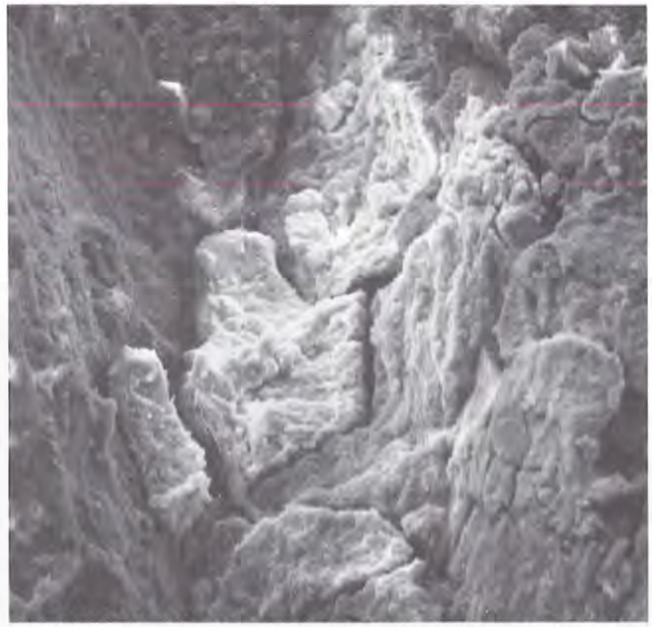

FIGURE 3. Potassium feldspar coating interior of pore (350x). Same specimen as Figure 2.

of our investigations. We can state that the minerals occupying voids were deposited in a complicated sequence, probably in response to a range of changing geochemical conditions with time. We are encouraged to believe that the sequence of minerals will give us a firm basis for estimating a sequence of geochemical environments from death and burial to final fossilization.

CONCLUSIONS

Minor elements in vertebrate fossils

FIGURE 4. Spherical aggregates (framboids) of pyrite filling void of mammoth bone dated by C^{14} as 11,300 years B.P. (1000x).

reflect features of diet, geochemical life environment, climate, conditions of burial, and diagenetic history during fossilization. Our current studies with the SEM-XES have shown that postmortal introduction of certain elements is very rapid indeed, with extensive mineralization present in bones as young as 11,300 years B.P. (Fig. 4). Thus applications to Quaternary materials would seem very promising. Until recently, application to human remains has been, except for fluorine, nonexistent to our knowledge. Brown (1973) has just published an abstract describing the use of Sr content of human bones to infer dietary habits. It is to be hoped that more anthropologists will do such studies, as the reward/effort ratio is very large.

We have included in the reference list some citations which were not referred to in the text, to provide the interested reader with additional background leads.

REFERENCES

Brown, Antoinette
1973 Bone strontium analysis and social patterns. American Anthropological Association, Abstracts of the 72nd Annual Meeting, New Orleans, 28 November - 2 December 1973: 30. Washington, D.C.

Hager, Michael W.
1973 Late Pliocene and Pleistocene History of the Donnelly Ranch Vertebrate Site, Southeastern Colorado. Ph.D Dissertation (Geology), University of Wyoming, Laramie, Wyoming. 140 p.

Houston, R. S.
1962 Non-paleontological methods of correlation of rocks of Tertiary age in Wyoming: Part I -- Heavy elements in bone fragments. Contributions to Geology, 1:3-6. Laramie, Wyoming.

Houston, R. S., Heinrich Toots, and J. C. Kelley
1966 Iron content of fossil bone of Tertiary age in Wyoming correlated with climatic change. Contributions to Geology, 5:1-18. Laramie, Wyoming.

McConnell, Duncan
1962 Dating of fossil bones by the fluorine method. Science, 136:241-244. Washington, D.C.
1973 Apatite. Springer-Verlag, New York, N.Y. 111 p.

Oakley, Kenneth P.
1950 The fluorine dating method. Yearbook of Physical Anthropology (1949), 5:44-52.

Oakley, Kenneth P., and C. Randall Hoskins
1950 New evidence on the antiquity of Piltdown man. Nature, 165:379-382. London, England.

Parker, Ronald B., J. W. Murphy, and Heinrich Toots
1973 Fluorine in fossilized bone and tooth: distribution among skeletal tissues. Archaeometry, 16: in press. Cambridge, England.

Parker, Ronald B., and Heinrich Toots
1970 Minor elements in fossil bones. Geological Society of America Bulletin, 81:925-932. Boulder, Colorado.
1972 Hollandite-coronadite in fossil bone. American Mineralogist, 57:1527-1530.

Parker, Ronald B., Heinrich Toots, and J. W. Murphy
1974 Leaching of sodium from skeletal parts during fossilization. Geochemica et Cosmochemica Acta, in press.

Toots, Heinrich
1963 The chemistry of fossil bones from Wyoming and adjacent states. Contributions to Geology, 2:69-80. Laramie, Wyoming.

Toots, Heinrich, and M. R. Voorhies
1965 Strontium in fossil bones and the reconstruction of food chains. Science, 149: 854-855. Washington, D.C.

Wyckoff, Ralph W. G.
1972 The Biochemistry of Animal Fossils. Scientechnica, Williams and Wilkins, Baltimore, Maryland.

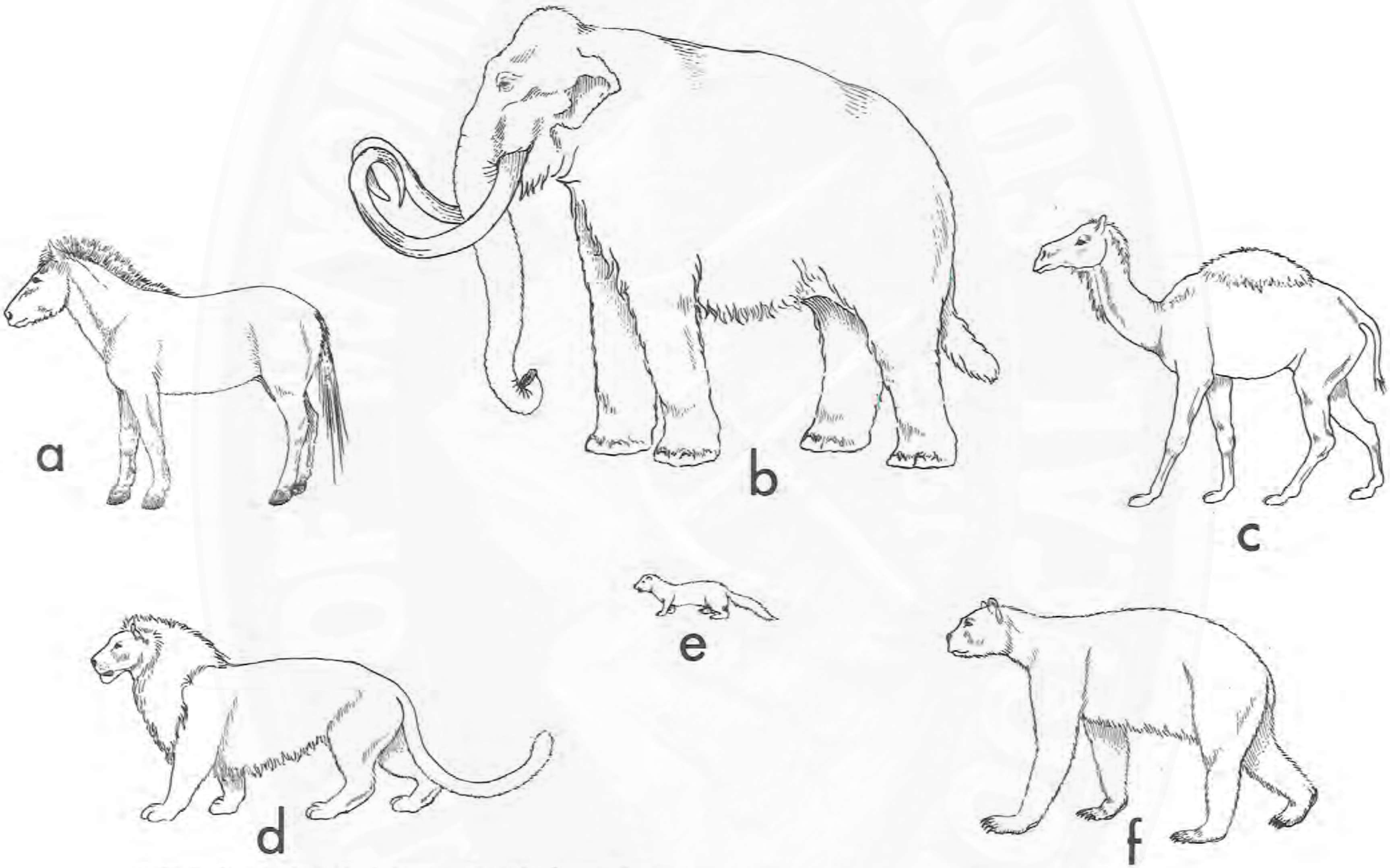

FIGURE 1. Extinct Pleistocene mammals of Wyoming:

a. horse, Equus sp.
b. mammoth, Mammuthus sp.
c. camel, Camelops hesternus
d. lion, Panthera leo atrox
e. marten, Martes nobilis
f. short-faced bear, Arctodus simus

A SURVEY OF THE LATE PLEISTOCENE AND HOLOCENE MAMMAL FAUNA OF WYOMING

ELAINE ANDERSON[1]

ABSTRACT

The late Pleistocene mammal fauna of Wyoming is made up of three components: extinct forms, species no longer found in Wyoming today, and extant species. The extinct forms include Arctodus simus, Martes nobilis, Panthera leo atrox, Mammuthus sp., Equus conversidens, Equus sp., Camelops hesternus, Hemiauchenia sp., and an ovibovine. Microsorex hoyi, Myotis thysanodes, Cynomys gunnisoni, Spermophilus variegatus and Dicrostonyx torquatus, although reported from late Pleistocene sites do not occur in Wyoming today.

Three late Pleistocene-early postglacial faunas, Little Box Elder Cave, Horned Owl Cave and Bell Cave, are discussed and compared with faunas of the same age in northern Colorado (Chimney Rock Animal Trap) and Idaho (Jaguar and Moonshiner caves). Isolated finds of extinct mammals in Wyoming are mapped. Paleontological, zoogeographical, and climatic evidence are used to explain changes in the mammalian fauna from the late Pleistocene to the present day.

INTRODUCTION

During the late Pleistocene, herds of horses (Equus conversidens and Equus sp.), camels (Camelops hesternus and Hemiauchenia sp.), bison (Bison sp.) and mammoths (Mammuthus sp.) roamed across the plains of Wyoming (Fig. 1). They were hunted, perhaps, by the Pleistocene lion (Panthera leo atrox), the great short-faced bear (Arctodus simus), and man (Homo sapiens). At the same time, martens (Martes sp.), wolverines (Gulo gulo), pikas (Ochotona princeps), and lemmings (Dicrostonyx torquatus) -- animals that today are found in coniferous forests, the tundra, or the Far North -- inhabited southeastern Wyoming.

Along with these unusual forms were other components of the late Pleistocene fauna still extant in the same area. A few others like the wolf (Canis lupus), grizzly bear (Ursus arctos), black-footed ferret (Mustela nigripes), and bison (Bison bison) have been nearly extirpated by man. Although found in late Pleistocene sites, pygmy shrews (Microsorex hoyi), fringed myotis (Myotis thysanodes), rock squirrels (Spermophilus variegatus), Gunnison prairie dog (Cynomys gunnisoni) and lemmings are no longer found in Wyoming. Others, like the raccoon (Procyon lotor), black bear (Ursus americanus), gray fox (Urocyon cinereoargenteus), tree squirrel (Tamasciurus hudsonicus), kangaroo rat (Dipodomys ordii), grasshopper mouse (Onychomys leucogaster), and jumping mouse (Zapus spp.), though absent from the late Pleistocene record, occur in Wyoming today.

LATE PLEISTOCENE LOCAL FAUNAS

To examine in detail changes in the mammalian fauna of Wyoming, a study of late Pleistocene local faunas (Fig. 2) and isolated finds of extinct species (Fig. 3) was undertaken. Three local faunas in Wyoming -- Little Box Elder Cave, Converse County (Anderson, 1968); Horned Owl Cave, Albany County (Guilday, Hamilton and Adam, 1967); and Bell Cave, Albany County (Zeimens and Walker, this volume) -- were compared with three sites in neighboring states -- Chimney Rock Animal Trap, Larimer County, Colorado (Hager, 1972a, 1972b); Jaguar Cave, Lemhi County, Idaho (Kurtén and Anderson, 1972); and Moonshiner Cave, Bingham County, Idaho. All of these sites are late Pleistocene-Holocene in age. Table I compares the faunas of these six sites.

FIGURE 2. Location of late Pleistocene local faunas in Wyoming, Colorado, and Idaho:
1. Little Box Elder Cave, Wyoming
2. Bell Cave, Wyoming
3. Horned Owl Cave, Wyoming
4. Chimney Rock Animal Trap, Colorado
5. Jaguar Cave, Idaho
6. Moonshiner Cave, Idaho

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	Little Box Elder Cave Converse Co. Wyo.	Horned Owl Cave Albany Co. Wyo.	Bell Cave Albany Co. Wyo.	Chimney Rock Animal Trap Larimer Co. Colo.	Jaguar Cave Lemhi Co. Ida.	Moonshiner Cave Bingham Co. Ida.	Historic, Wyo.	Extant, Converse Co. Wyo.	Extant, Albany Co. Wyo.
Sorex cinereus			●			●	●	●	●
Sorex palustris	●		●				●	●	●
Sorex sp.	●			●					
Microsorex hoyi	●								
Cryptotis sp	●								
Myotis evotis	●						●	●	●
Myotis volans	●						●	●	●
Myotis subulatus	●						●	●	●
Myotis thysanodes	●								
Myotis lucifugus			●				●	●	●
Myotis sp.						●			
Lasionycteris noctivagens	●		●				●		●
Eptesicus fuscus	●		●				●	●	●
Homo sapiens	●		●				●	●	●
Ochotona princeps	●	●	●	●	●	?●	●		●
Lepus cf. townsendii	●	●			●		●	●	●
Lepus californicus		●					●	●	●
Lepus americanus					●		●	●	●
Lepus sp.			●			●			
Sylvilagus nuttalli					●		●	●	●
Sylvilagus sp.	●	●	●	●		●			
Brachylagus idahoensis					●	●			
Marmota flaviventris	●	●	●	●	●	●	●	●	●
Tamiascurius hudsonicus							●	●	●
Cynomys leucurus		●					●	●	●
Cynomys ludovicianus							●	●	●
Cynomys cf. gunnisoni			●						
Cynomys sp.	●			●					
Spermophilus lateralis	●	●	●	●	●	●	●	●	●
Spermophilus variegatus	●								
Spermophilus tridecemlineatus	●		●				●	●	●
Spermophilus richardsonii			●	●	●	●	●	●	●
Spermophilus townsendii					●	●			
Spermophilus sp.		●							
Eutamias minimus	●					●	●	●	●
Eutamias sp.		●			●				
Thomomys talpoides			●		●		●	●	●
Thomomys sp.	●			●		●			
Zapus hudsonius							●	●	●
Perognathus cf. parvus						●	●	●	●

TABLE I. Species of mammals found in late Pleistocene local faunas, and those extant in Wyoming today.

	Little Box Elder Cave Converse Co. Wyo.	Horned Owl Cave Albany Co. Wyo.	Bell Cave Albany Co. Wyo.	Chimney Rock Animal Trap Larimer Co. Colo.	Jaguar Cave Lemhi Co. Ida.	Moonshiner Cave Bingham Co. Ida.	Historic, Wyo.	Extant, Converse Co. Wyo.	Extant Albany Co. Wyo.
Perognathus sp.	●								
Dipodomys ordii						●	●	●	●
Castor canadensis	●				●	●	●	●	●
Peromyscus maniculatus			●			●	●	●	●
Peromyscus leucopus						●			
Peromyscus sp.	●	●		●	●				
Reithrodontomys megalotis							●	●	●
Neotoma cinerea	●	●	●	●	●	●	●	●	●
Dicrostonyx torquatus	●		●		●				
Clethrionomys gapperi	●						●	●	●
Ondatra zibethicus	●	●	●				●	●	●
Phenacomys intermedius	●	●	●				●		●
Phenacomys sp.						●			
Onychomys leucogaster							●	●	●
Microtus ochrogaster	●		●				●	●	●
Microtus pennsylvanicus	●						●	●	
Microtus longicaudus	●			●		●	●	●	●
Microtus montanus	●		●	●	●	●	●	●	●
Lagurus curtatus	●	●	●		●	●	●	●	●
Erethizon dorsatum	●		●	●	●	●	●	●	●
Canis latrans	●		●	●	●	●	●	●	●
Canis lupus	●		●	●	●	●	●		
Canis familiaris					●		●	●	●
*Canis dirus					●				
Vulpes vulpes	●	●	●	●	●	●	●	●	●
Vulpes velox			●	●		●	●	●	●
Ursus arctos	●			●	●	●	●		
Urocyon cinereoargenteus							●	●	●
Ursus americanus							●		●
+Arctodus simus	●								
Procyon lotor							●	●	●
Mustela frenata	●	●	●	●	●	●	●	●	●
Mustela erminea				●		●	●	●	●
Mustela rixosa						●			
Mustela vison		●	●	●		●	●	●	●
Mustela nigripes	●			●	●	●	●	●	●
Martes americana			●	●			●		●
*Martes nobilis	●		●	●	●	●			
Gulo gulo	●			●	●	●	●		

TABLE I. Continued.

	Little Box Elder Cave Converse Co. Wyo.	Horned Owl Cave Albany Co. Wyo.	Bell Cave Albany Co. Wyo.	Chimney Rock Animal Trap Larimer Co. Colo.	Jaguar Cave Lemhi Co. Ida.	Moonshiner Cave Bingham Co. Ida.	Historic, Wyo.	Extant, Converse Co. Wyo.	Extant, Albany Co. Wyo.
Taxidea taxus	●	●	●		●	●	●	●	●
Mephitis mephitis	●		●	●	●	●	●	●	●
Spilogale putorius	●				●	●	●	●	●
Lynx rufus	●		●	●	●	●	●	●	●
Lynx canadensis					●	●	●		●
Felis concolor	●			●	●		●		
* Panthera leo atrox	●			●	●				
* Equus conversidens	●		●		●				
* Equus sp. (large)	●	●	●		●				
Equus caballus			?●				●	●	●
+ Camelops cf. hesternus	●	●	●		●				
+ Hemiauchenia sp.	?●								
Cervus elaphus	●		●		●	●	●		
Odocoileus hemionus	●	●	●			●	●	●	●
Odocoileus virginianus							●	●	●
Odocoileus sp.				●	●				
Alces alces	?●						●		
Rangifer tarandus					●				
Antilocapra americana	●	●	●	●	●	●	●	●	●
Bison bison	●		●			●	●		
Bison sp.				●	●				
+ Ovibovini indet.	●								
Oreamnos americanus		●	●				intro		
Oreamnos sp.	●								
Ovis canadensis	●	●	●	●	●		●		
Ovis aries			●			●	●	●	●

+ Extinct genus
* Extinct species

TABLE I. Continued.

Little Box Elder Cave is situated at the eastern edge of the Rocky Mountains and the western border of the Great Plains. Eight of the reported species are extinct. Since Anderson's paper (1968), Martes nobilis (Anderson, 1970) and Arctodus simus (Kurtén and Anderson, MS) have been recorded. This is the first record of Arctodus and Ursus arctos occurring together. Recent re-examination of the mustelid material revealed the presence of Spilogale putorius.

Horned Owl Cave and Bell Cave are located on the western slope of the Laramie Mountains at an elevation of 8,000 feet. Both caves contain the remains of Camelops and a large Equus, and Martes nobilis is found in Bell Cave. Ochotona, Phenacomys, and Oreamnos are reported from the caves, but are not found in the region today. Contrary to Long's statement (1965:720) that Oreamnos is not native to Wyoming, but has been introduced in the northwestern part of the state, there are three late Pleistocene records. The Oreamnos remains from Horned Owl, Bell, and Little Box Elder caves compare favorably in size and morphology with O. americanus rather than with O. harringtoni, a smaller extinct species known from caves in Nevada and Arizona.

Carbon-14 dates of 10,370 $\pm$ 350 years B.P. (8420 B.C.; I-??) and 11,580 $\pm$ 250 years B.P. (9630 B.C.; Gx-??) were obtained from two hearths in Jaguar Cave, Lemhi County, Idaho (Kurtén and Anderson, 1972). The mammal assemblage shows many similarities to those of the Wyoming cave faunas. However, Rangifer tarandus and Lynx canadensis are present, and remains of domestic dog have been identified.

Lynx rufus, the more abundant species of medium-sized cat in the late Pleistocene fossil record, is found in the Casper Local Fauna, near Casper, Wyoming, dated near 10,000 years B.P. (Wilson, in press), as well as Little Box Elder Cave, Bell Cave, and Chimney Rock Animal Trap. It is possible that L. canadensis also occurred in Wyoming at this time, but that its remains have not yet been recognized. The two species co-occur at the two Idaho sites. Distinctive characters separating the species are given by Kurtén and Anderson (1972).

The four caves show a mixture of plains, coniferous forest, and tundra inhabitants. The caves were probably used as carnivore dens, as indicated by the presence of fairly complete postcranial material of both predator and prey. The presence of artifacts and hearths in the caves indicates their use by Indians.

Chimney Rock Animal Trap in northeastern Colorado and Moonshiner Cave in southeastern Idaho are natural traps, where animals fell in and could not escape. Both sites contain remains of a large number of carnivores that were presumably attracted to the holes by the cries, odors, and struggles of entrapped animals. John A. White (Biology Department, Idaho State University) and I believe that a functional animal trap should have a minimum depth of 8-10 feet and no low overhangs or other means by which an animal could escape. Both Chimney Rock Animal Trap and Moonshiner Cave have been in existence for a long time; remains of extinct animals and animals no longer found in the region have been identified from them, and animals are still falling in.

OCCURRENCES OF EXTINCT SPECIES

Additional records of extinct Pleistocene mammals from collections in the Geology Department, University of Wyoming, the collections of the U.S. National Museum of Natural History, the early records of Hay (1924; 1927), and private collections in Wyoming were plotted (Fig. 3). Only the genus Mammuthus is not represented in the cave faunas. Finds of mammoths from Wyoming are summarized in Table II. A nearly complete mammoth skeleton was recovered from the Union Pacific (U.P.) Mammoth Site in Carbon County (Irwin, Irwin, and Agogino, 1962; Irwin, 1970) in association with non-diagnostic artifacts. The site was radiocarbon-dated to 11,280 $\pm$ 350 years B.P. (9330 B.C., I-449; Haynes, 1967). Excavations under the direction of George C. Frison at a Clovis mammoth kill site east of Worland, Washakie County, are currently in progress. Two Clovis-like projectile points and remains of at least three young mammoths have been recovered (Michael Wilson, personal communication, 1974).

Remains of bison, horse and camel are fairly common throughout the state (Table III and Wilson, this volume). Undoubtedly, there are many more records, unknown to us, that would make this map more complete. So far, there are no records of ground sloths, mastodonts, dire wolves, or saber-toothed cats in Wyoming although they have been reported from neighboring states.

Using Anderson's data on Little Box Elder Cave, Long (1971) pointed out the importance of analyzing late Pleistocene and Recent faunas together in order to interpret climatic and zoogeographic changes. Changes in the distribution of bears provide a good example of this kind of study. Only Ursus arctos, the grizzly bear, is present at the six late Pleistocene sites studied; there is no trace of Ursus americanus, the black bear, an animal common in eastern and southern deposits of the same age. The maxilla of a black bear was recovered from Middle Period archaeological deposits at the Dead Indian Site in Park County, Wyoming (Wilson, personal communication, 1974). These deposits were dated to 4,180 $\pm$ 250 years B.P. (2230 B.C., W-2597) and 4,430 $\pm$ 250 years B.P. (2480 B.C., W-2599), with a corrected age of approximately 5,000 years (Frison, this volume). Mandibles and limb bones from two black bears were recovered at the Piney Creek sites, of Late Prehistoric age (Frison, 1967). Today Ursus americanus is common in the state, as it is over most of the United States. Ursus arctos has been extirpated by man from most of its former range, and is found in Wyoming only in Yellowstone National Park.

TABLE II. FINDS OF Mammuthus sp. FROM WYOMING*

	Locality	Material	Age	Source and notes
1.	Careyhurst, Converse Co.	2 molars, 2 vertebrae (USNM 8080). Rest of skeleton present	unknown	Hay, 1924:81. Identified as M. columbi. U.S. National Museum collections.
2.	?, Converse Co.	1 molar	unknown	Hay, 1924:82. Identified as M. columbi. Private collection.
3.	Buffalo, Johnson Co.	1 molar	unknown	Hay, 1924:82. Identified as M. columbi. State Historical and Natural History Society, Denver, Colorado, collection.
4.	Powder River, Johnson? Co.	1 molar	unknown	Hay, 1924:101. Identified as M. imperator. American Museum of Natural History collections.
5.	Rawhide Butte area, Goshen or Niobrara Counties	fragments	unknown	Hay, 1924:118. Collected by F. B. Loomis, Amherst College.
6.	Casper, Natrona Co.	1 molar	unknown	Hay, 1924:118; Knight, 1903:828. Found in area by a stockman.
7.	Dover, Albany Co.	mandible	unknown	Hay, 1924:118; Knight, 1903: 828. Possibly in Univ. of Wyoming collections.
8.	Lingle, Goshen Co.	skeleton	unknown	Hay, 1927:299-300. Large skull with 7-foot tusks. Destroyed by construction activity.
9.	Indian Creek, ? Co.	1 molar	unknown	Hay, 1927:300. Sold to a dealer.
10.	Union Pacific Mammoth Site, SW of Rawlins, Carbon Co.	skeleton with skull	11,280 ± 350 B.P. (I-449)	Irwin, Irwin and Agogino, 1962; Haynes, 1967. Univ. of Wyoming collections
11.	Bosler Gravel Pit, N. of Laramie, Albany Co.	1 molar (UW 3384)	unknown	unpublished. Univ. of Wyoming collection.
12.	Gravel pit near site of Fort Steele, along North Platte River, Carbon Co.	skull?	unknown; likely late Pleistocene	unpublished. Private collection.
13.	Mammoth kill site, 4 miles E. of Worland, Washakie Co. (Colby Site)	parts of at least 3 skeletons	11,200 ± 220 B.P. (RL-393)	unpublished. Work in progress under direction of Dr. George C. Frison, Univ. of Wyoming.
14.	N. of Sheridan, Sheridan Co.	scapula	unknown	anonymous, 1960. Disposition not known.
15.	W. of Sheridan, Sheridan Co.	mandible	unknown	anonymous, 1960. Private collection.
16.	Mahogany Buttes, near Big Trails, Washakie Co.	molar and associated fragments	unknown	unpublished. Private collection.
17.	Independence Rock (gravel pit), Natrona Co.	tusk fragments and associated material	unknown	unpublished. Retained by contractor.
18.	Loess near Hell Gap Site, N. of Guernsey, Platte Co.	"mammoth remains"	less than 11,000 B.P.	Greene, 1967. Disposition not known.
19.	NE foothills of Rawhide Buttes, Niobrara Co.	articulated skeleton	greater than 10,550 ± 350 B.P.	Damon, Haynes and Long, 1964. Date taken on overlying deposit. Vertebrae charred but no artifacts recovered.
20.	Bentzen-Kaufmann Cave, 48SH301, Sheridan Co.	fragment of scapula	greater than 6,975 ± 275 B.P. (Don Grey date)	Grey, 1962. Dated in private laboratory. Bone recovered from bottom of lower level, below dated material.

*Table prepared by Michael Wilson, Department of Anthropology, University of Wyoming. We are aware of a number of additional reports that are not yet fully substantiated through observation of specimens.

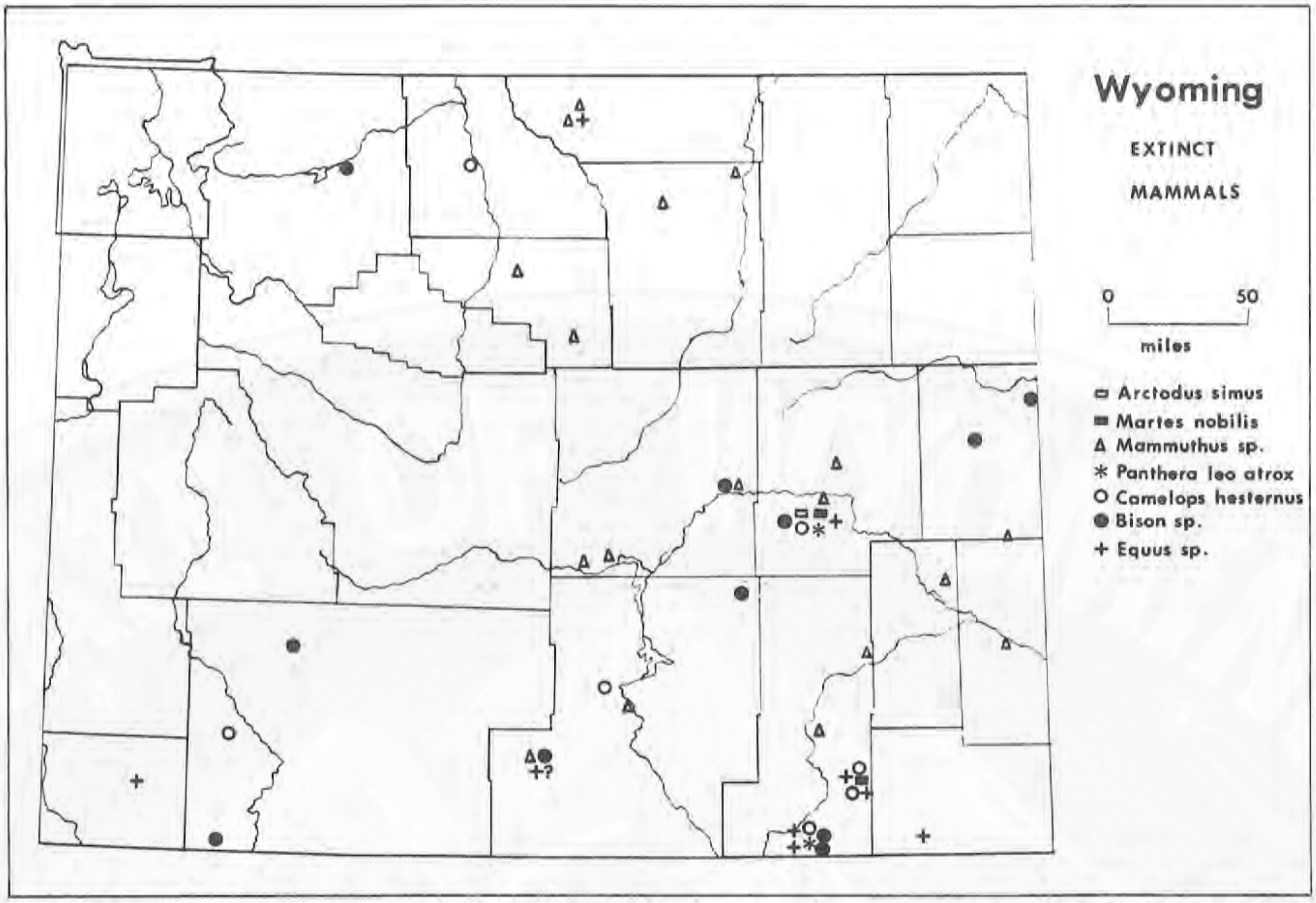

FIGURE 3. Isolated finds of extinct Wyoming mammals. Included are archaeological bison finds of Paleo-Indian age. A number of the plotted finds are unpublished, and are based upon specimens in the University of Wyoming (Geology and Anthropology) collections, and the collections of the United States National Museum of Natural History.

Another example involving late Pleistocene and Recent faunal changes is the replacement of the large extinct Martes nobilis by the living species of marten, Martes americana. At Bell Cave and Chimney Rock Animal Trap the extinct species is found in the lower levels of the deposits, and the living species in the upper levels.

Climatic changes in Wyoming during and since the late Pleistocene have influenced mammal distribution. Temperatures, glaciers, and aridity proved to be effective barriers to mammal migrations. Long (1965:730) believes that most extant Wyoming mammals immigrated into the state after the height of the Wisconsin glaciation. Although the life zone concept has its limitations (Long, 1965:723-725), it is useful in dicussing broad changes in distribution. During the late Pleistocene, life zones were lowered so that the spruce-fir forest probably extended down to 5,500 feet (the elevation of Little Box Elder Cave), and tundra conditions may have existed at the 8,000-foot level in some areas. These conditions permitted boreal mammals to expand their range away from the glaciated Rocky Mountain chain. During the interglacials and the climatic optimum (10,000-11,000 years ago), the montane mammals followed the rising life zones upward or northward and were replaced by warmth-adapted species. Throughout this period of time the Rocky Mountains served as an effective isolating barrier and were responsible for much of the speciation and subspeciation of Wyoming mammals.

At the end of the Pleistocene many of the large mammals became extinct. Martin (1967) believed that man's "Pleistocene overkill" was the sole agent of late Pleistocene extinction. However, it is more likely that a combination of factors -- changes in climate, changes in vegetation, increased competition, overspecialization, and man's activities, were responsible.

Throughout Historic time, man and his activities have had an increasingly deleterious effect on the native mammal population: these activities include exploitation of fur-bearers; hunting of big game animals; destruction of habitat by farming and overgrazing of lands; construction of subdivisions; poisoning of rodents and, as a result, poisoning of valuable predators; and introduction of non-native mammals often to the detriment of endemic species.

CONCLUSION

In closing, I would like to mention

TABLE III. FINDS OF EXTINCT Panthera, Camelops, AND Equus FROM WYOMING (EXCLUSIVE OF CAVE SITES)*

	Species	Locality	Material	Source and notes
1.	*Panthera leo atrox*	Monolith Gravel Quarry, SW of Laramie, Albany Co.	rt. metacarpal IV (UW 3906)	unpublished. Univ. of Wyoming collections.
2.	*Camelops hesternus*	Monolith Gravel Quarry, SW of Laramie, Albany Co.	several postcranial elements (UW 3889, 3890)	unpublished. Univ. of Wyoming collections.
3.	"	N. outskirts of Rawlins, Carbon Co.	rt. M_3 (UW 1304)	unpublished. Univ. of Wyoming collections.
4.	"	bentonite pit near Greybull, Big Horn Co.	distal end of metacarpal (UW 1942)	unpublished. Univ. of Wyoming collections.
5.	"	Stauffer Chemical Plant, NW of Rock Springs, Sweetwater Co.	metapodial	unpublished. Univ. of Wyoming (Anthropology) collections.
6.	*Equus* sp.	Monolith Gravel Quarry, SW of Laramie, Albany Co.	teeth and postcranial material (UW 2398, 3889, 3890, 3891, 3892)	unpublished. Univ. of Wyoming collections.
7.	"	7 miles W. of Sheridan, Sheridan Co.	tooth and postcranial material	unpublished. Univ. of Wyoming (Anthropology) collections.
8.	"	2 miles W. of Cheyenne, Laramie Co.	teeth	unpublished. U.S. National Museum collections.
9.	"	Bridger, Uinta Co.	1 molar	Hay, 1924:152. U.S. National Museum collections.
10.	"	Union Pacific Mammoth site, SW of Rawlins, Carbon Co.	not specified	Irwin, 1970:125. Disposition of material not indicated.

*Table prepared by Michael Wilson, Department of Anthropology, University of Wyoming.

some of the problems that still remain for the Pleistocene mammologist:

1. location and study of local faunas and isolated finds in other parts of the state;
2. determination of valid species through detailed studies of all available material. This is especially important for the genera *Equus*, *Bison* (see Wilson, this volume), *Mammuthus*, and *Camelops*;
3. use of the knowledge of Pleistocene local faunas to better understand the extant mammals.

The study of Pleistocene mammals is just one facet of Quaternary studies, an interdisciplinary field. Close cooperation with biologists, geologists, and archaeologists is necessary for a more complete understanding of the Pleistocene and Holocene time periods.

ACKNOWLEDGEMENTS

I would like to thank Michael Wilson, Michael W. Hager, and Danny N. Walker for their assistance with this project. Erica Hansen, Michael Wilson and Diane J. Wilson drafted the illustrations. Dr. Clayton E. Ray and Robert Purdy, United States National Museum of Natural History, read the manuscript.

REFERENCES

Anderson, E.
1968 Fauna of the Little Box Elder Cave, Converse County, Wyoming. I. The Carnivora. *University of Colorado Studies, Series in Earth Sciences*, 6:1-59. Boulder, Colorado.
1970 Quaternary evolution of the genus *Martes* (Carnivora, Mustelidae). *Acta Zoologica Fennica*, 130:1-132. Helsinki, Finland.

Anonymous
1960 Extinct elephant bones found. *The Wyoming Archaeologist*, 3(1):2. Sheridan, Wyoming.

Damon, P. E., C. V. Haynes, Jr., and A. Long
1964 Arizona radiocarbon dates V. *Radiocarbon*, 6:91-107. New Haven, Connecticut.

Frison, George C.
1967 The Piney Creek sites, Wyoming. *University of Wyoming Publications*, 33(1):1-92. Laramie, Wyoming.
n.d. The application of volcanic and non-volcanic natural glass studies to archaeology in Wyoming. *This volume*: 61-64.

Greene, Ann M.
1967 *The Betty Greene Site: A Late Paleo-Indian Site in Eastern Wyoming*. M.A. Thesis (Anthropology), University of Pennsylvania, Philadelphia, Pennsylvania. 75 p.

Grey, Donald C.
1962 *Radiocarbon date list number one*. Mimeographed, 3 p. Sheridan, Wyoming: Issued by author.

Guilday, J. E., H. Hamilton, and E. K. Adam
1967 Animal remains from Horned Owl Cave, Albany County, Wyoming. *Contributions to Geology*, 6(2):97-99. Laramie, Wyoming.

Hager, Michael W.
1972a A late Pleistocene-Recent animal trap

fauna from northeast Colorado. (Abstract). Geological Society of America Abstracts with Programs, Rocky Mountain Section, 4(6):379. Boulder, Colorado.

1972b A late Wisconsin-Recent vertebrate fauna from the Chimney Rock Animal Trap, Larimer County, Colorado. Contributions to Geology, 11(2):63-71. Laramie, Wyoming.

Hay, O. P.

1924 The Pleistocene of the middle region of North America and its vertebrated animals. Carnegie Institute of Washington, Publication, 322A:1-385. Washington, D.C.

1927 The Pleistocene of the western region of North America and its vertebrated animals. Carnegie Institute of Washington, Publication, 322B:1-346. Washington, D.C.

Haynes, C. Vance, Jr.

1967 Carbon-14 dates and early man in the New World. In P. S. Martin and H. E. Wright, Jr. (Eds.), Pleistocene Extinctions: the Search for a Cause: 267-286. Yale University Press, New Haven, Connecticut.

Irwin, C., H. Irwin, and G. Agogino

1962 Ice Age Man vs. mammoth in Wyoming. National Geographic Magazine, 121(6):828-837. Washington, D.C.

Irwin, H.

1970 Archaeological investigations at the Union Pacific Mammoth Kill site, Wyoming, 1961. National Geographic Society Research Reports, 1961-1962: 123-125. Washington, D.C.

Knight, W. C.

1903 Remains of elephants in Wyoming. Science, n.s., 17(438)828-829. Washington, D.C.

Kurtén, B., and E. Anderson

1972 The sediments and fauna of Jaguar Cave. II. The Fauna. Tebiwa, 15(1):21-46. Pocatello, Idaho.

MS [Arctodus simus at Little Box Elder Cave]. Manuscript in possession of author.

Long, C. A.

1965 The mammals of Wyoming. University of Kansas Publications, Museum of Natural History, 14(18):493-758. Lawrence, Kansas.

1971 Significance of the late Pleistocene fauna from the Little Box Elder Cave, Wyoming, to studies of zoogeography of Recent mammals. Great Basin Naturalist, 31(2):93-105. Provo, Utah.

Martin, P. S.

1967 Prehistoric overkill. In P. S. Martin and H. E. Wright, Jr. (Eds.), Pleistocene Extinctions: the Search for a Cause: 75-120. Yale University Press, New Haven, Connecticut.

Wilson, Michael

in press The Casper Local Fauna and its fossil bison. In George C. Frison (Ed.), The Casper Site: a Hell Gap Bison Kill on the High Plains: 125-171. Academic Press, New York, N.Y.

n.d. History of the Bison in Wyoming, with particular reference to early Holocene forms. This volume: 91-99.

Zeimens, George, and D. N. Walker

n.d. Bell Cave, Wyoming: preliminary archaeological and paleontological investigations. This volume: 88-90.

BELL CAVE, WYOMING: PRELIMINARY ARCHAEOLOGICAL AND PALEONTOLOGICAL INVESTIGATIONS

GEORGE ZEIMENS AND DANNY N. WALKER[1]

Bell Cave is located in Wall Rock Canyon on the western slope of the Laramie Mountains, 18 miles north of Laramie, Wyoming. The cave is at an elevation of 7,800 feet, 100 feet below the rim of the canyon and 400 feet above the floor. The cave was formed in the Casper Limestone, a resistant unit which forms the caprock of caves in the area. Wall Rock Creek is an intermittent stream with drainage into the Laramie River north of Bosler, Wyoming.

Directly across the canyon, and in full view of Bell Cave is Horned Owl Cave (Galloway and Agogino, 1962; Gebhard, Agogino and Haynes, 1964; Guilday, Hamilton and Adam, 1967). The stratigraphy of the two caves appears basically similar; however, differences in cultural and faunal remains are noted between the two. Gebhard, Agogino and Haynes (1964:360) identified an Altithermal-age level in the stratigraphy of Horned Owl Cave. A similar deposit is present in Bell Cave, but has yielded a pre-Altithermal fauna. This casts doubt upon the presence of an Altithermal level in Horned Owl Cave.

Investigations at Bell Cave have yielded data of both archaeological and paleontological significance. Cultural material was found in mixed context in the dry, powdery upper 12 inches of deposits. Artifacts ranged in age from the Late Middle Period to very Late Prehistoric. One Folsom point mid-section was also found; it bears fine retouch on the broken proximal end. Two points are typologically similar to Late Middle Period corner-notched dart points reported from many sites in Wyoming. Two other points are small side-notched arrow points, characteristic of the Late Prehistoric Period. Other lithic artifacts include scrapers and cutting tools which as yet are typologically undiagnostic. Several bone tools, such as awls and knappers are also not diagnostic of specific cultures or time periods. Four large potsherds have been recovered and are identifiable as Intermountain Ware, of Shoshonean affinities (Mulloy, 1958:197; Frison, 1971:276-280). Perishable materials include a wooden fire drill, a dog travois pole, and pieces of woven fabric.

Scattered human skeletal remains are present and include several vertebrae, phalanges, teeth, pelvic fragments, a fibula, clavicle, ulna, radius, femoral head, and ribs. Not enough has been recovered for detailed morphological studies (Gill, this volume) but remnants of flesh on some of the bones suggest a Late Prehistoric Period burial. Dr. George Frison (personal communication, 1973) recalls a private collector removing parts of a Late Prehistoric burial from the cave several years ago. The human material may be associated with the several hundred glass trade beads found.

Faunal remains (Table I) include three species which are extinct: the Pleistocene martin (Martes nobilis), the camel (Camelops sp.) and the Pleistocene horse (Equus sp.). The pika, heather vole, collared lemming, mountain sheep, mountain goat and gyrfalcon are not found in the area today but are present at higher altitudes and latitudes. These species, as well as the rest of the fauna, show cold-climate similarities with Little Box Elder Cave (Anderson, 1968, this volume) and Chimney Rock Animal Trap (Hager, 1972) and indicate a Pleistocene age for parts of the deposit. This is the third reported occurrence of the collared lemming in the continental United States (Guilday, Hamilton, and Adam, 1967: 100) and the first occurrence of the gyrfalcon as a fossil form in the New World (Walker, in press).

SUMMARY

Excavations at Bell Cave have been of a preliminary nature, and future work is planned. The presence of a Pleistocene fauna and of a reworked Folsom point is significant, and it is hoped that future excavations will allow us to refine our views concerning their stratigraphic context.

The cave offers potential for significant further studies relating to late Pleistocene and Holocene events in the Laramie Plains area.

REFERENCES

Anderson, Elaine
1968 Fauna of the Little Box Elder Cave, Converse County, Wyoming. I. The Carnivora. University of Colorado Studies, Series in Earth Sciences, 6:1-60. Boulder, Colorado.

Frison, George C.
1971 Shoshonean antelope procurement in the Upper Green River Basin, Wyoming. Plains Anthropologist, 16(54):258-284. Topeka, Kansas.

Galloway, Eugene, and George A. Agogino
1962 Pictographs at Wall Rock Cave, Albany Co., Wyoming. The Wyoming Archaeologist, 5 (3):11-14. Sheridan, Wyoming.

Gebhard, David, George A. Agogino, and C. Vance Haynes, Jr.
1964 Horned Owl Cave, Wyoming. American Antiquity, 29(3):360-368. Salt Lake City, Utah.

Gill, George W.
n.d. Human skeletons from Wyoming and their bearing on the concept of morphological dating. This volume: 100-107.

Guilday, John E., Harold W. Hamilton, and Eleanor K. Adam
1967 Animal remains from Horned Owl Cave, Albany County, Wyoming. Contributions to

[1]Department of Anthropology, University of Wyoming, Laramie, Wyoming 82071.

TABLE I. PRELIMINARY FAUNAL LIST, BELL CAVE, ALBANY COUNTY, WYOMING

Class Pisces	
genus et species indet.	fish
Class Reptilia	
Sceloporus undulatus	fence lizard
Class Aves	
Order Anseriformes	
Family Anatidae	
Subfamily Anserinae	
Branta canadensis	Canada goose
Subfamily Anatinae	
Anas platyrhynchos	mallard duck
genus et species indet.	duck
Order Falconiformes	
Family Accipitridae	
Subfamily Buteoninae	
Buteo regalis/lagopus	ferruginous/American rough-legged hawk
Aquila chrysaetos	golden eagle
Haliaetus leucocephalus	bald eagle
Subfamily Falconinae	
Falco rusticolus	gyrfalcon
Order Galliformes	
Family Tetraonidae	
Bonasa/Centrocercus sp.	ruffed/sage grouse
Family Phasianidae	
Subfamily Odontophorinae	
genus et species indet.	quail
Order Passeriformes	
Family Corvidae	
Pica pica	American magpie
Corvus corax	raven
Class Mammalia	
Order Insectivora	
Family Soricidae	
Sorex cinereus	masked shrew
Sorex palustris	water shrew
Order Chiroptera	
Family Vespertilionidae	
Lasionycteris noctivagans	silver-haired bat
Myotis lucifugus	little brown bat
Eptesicus fuscus	big brown bat
Order Lagomorpha	
Family Ochotonidae	
Ochotona princeps	pika
Family Leporidae	
Sylvilagus sp.	cottontail rabbit
Lepus sp.	jackrabbit
Order Rodentia	
Family Sciuridae	
Marmota flaviventris	yellow-bellied marmot
Spermophilus richardsoni	Richardson's ground squirrel
Spermophilus lateralis	golden-mantled ground squirrel
Spermophilus tridecemlineatus	thirteen-lined ground squirrel
Cynomys sp., cf. C. gunnisoni	white-tailed prairie dog
Family Geomyidae	
Thomomys talpoides	northern pocket gopher
Family Cricetidae	
Peromyscus maniculatus	deer mouse
Neotoma cinerea	bushy-tailed wood rat
Phenacomys intermedius	heather vole
Dicrostonyx torquatus	Greenland collared lemming
Lagurus curtatus	sagebrush vole
Microtus montanus	montane vole
Microtus ochrogaster	prairie vole
Ondatra zibethicus	muskrat
Family Erethizontidae	
Erethizon dorsatum	porcupine
Order Carnivora	
Family Mustelidae	
Martes americana	pine marten
Martes nobilis*	Pleistocene marten
Mustela frenata	long-tailed weasel
Mustela vison	mink
Taxidea taxus	badger
Mephitis mephitis	striped skunk
Family Felidae	
Lynx rufus	bobcat
Family Canidae	
Canis lupus	gray wolf
Canis latrans	coyote
Vulpes vulpes	red fox
Vulpes velox	swift fox
Order Artiodactyla	
Family Cervidae	
Cervus elaphus canadensis	wapiti
Odocoileus hemionus	mule deer
Camelops sp., cf. C. hesternus*	camel
Family Antilocapridae	
Antilocapra americana	pronghorn antelope
Family Bovidae	
Oreamnos americanus	mountain goat
Ovis canadensis	mountain sheep
Ovis sp., cf. C. aries	domestic sheep
Ovis sp.	large mountain sheep
Bison bison	bison
Order Perissodactyla	
Family Equidae	
Equus, sp., cf. E. conversidens*	Pleistocene horse
Equus, sp., cf. E. caballus	domestic horse
Order Primates	
Family Hominidae	
Homo sapiens	man

*--- extinct species

Geology, 6(2):97-100. Laramie, Wyoming.

Hager, Michael W.
1972 A Late Wisconsin-Recent vertebrate fauna from the Chimney Rock Animal Trap, Larimer County, Colorado. Contributions to Geology, 11(2):63-72. Laramie, Wyoming.

Mulloy, William
1958 A preliminary historical outline for the Northwestern Plains. University of Wyoming Publications, 22(1):1-235. Laramie, Wyoming.

Walker, Danny N.
in press A Pleistocene Gyrfalcon. The Auk, 91. Lawrence, Kansas.

HISTORY OF THE BISON IN WYOMING, WITH PARTICULAR REFERENCE TO EARLY HOLOCENE FORMS

MICHAEL WILSON[1]

INTRODUCTION

Archaeological studies relating to aboriginal life styles on the Great Plains and the Plains periphery have long been tied to studies of fossil bison. Indeed, early bison bone bed excavations were made by paleontologists, and the recovery of artifacts was viewed as no more important than that of the bison themselves (Stewart, 1897; Lucas, 1898; Williston, 1902; Sternberg, 1903; Barbour and Schultz, 1936, 1941; Sellards, Evans, and Meade, 1947).

Some of the early fascination with such bison was with the character of the bone beds themselves. Few paleontologists believed that man could have possessed the technology and organization sufficient for driving bison herds to their death. As recently as 1947, Sellards and others (ibid.: 935) suggested that in the case of the Plainview site bone bed, "it seems improbable that man could have killed so many bison within the small area of the bone bed in the short period of time indicated." These authors, while not excluding the possibility that man was the agent of the kill, suggested the possibility of a natural stampede; along with an alternative hypothesis of gradual accumulation. Earlier authors, such as Kindle (1921) presented behavioral hypotheses, based upon reports of mass kills of cattle in bad weather.

Recent studies have reinforced the hypothesis that man did, indeed, cause the formation of such bone beds. Sites have been described in which geomorphic features evidently were used as agents either of driving or of the killing of animals (Wheat, 1967, 1972; Frison, 1970; Forbis, 1960; Lobdell, 1973, and this volume). In other sites, there is clear evidence of the construction of pounds or traps, in which the bison were contained at the end of a drive (Frison, 1971).

The application of population dynamics studies (Reher, 1970, 1973) to bison bone beds has demonstrated that the kills were catastrophic and not attritional in nature; thus the synchronous driving of large numbers of bison by prehistoric man is now clearly proven.

THE EARLIEST WYOMING BISON

Although a number of isolated finds of bison bones have been made in alluvial deposits of Wyoming, there is as yet no clear evidence of the presence of Wisconsinan and pre-Wisconsinan species of bison in the state. The earliest reasonably secure finds are apparently of early post-glacial age.

However, it is clear from the distribution of specimens of the fossil "species" Bison latifrons and B. alleni that they very probably ranged through much of the state. Both of these large forms have been recovered in nearby areas of Idaho and Nebraska (Skinner and Kaisen, 1947; Hopkins, 1951). Geologic correlation of events between American Falls Lake in Idaho and Lake Bonneville in Utah suggests an approximate age of 33,000 years for some of the Idaho Bison latifrons specimens (Hopkins, Bonnichsen and Fortsch, 1969:1).

Perhaps the earliest Wyoming bison presently known are a series of at least six individuals tentatively referred to B. antiquus figginsi. These specimens were recovered in 1969 at a depth of 14 feet in the Kerr-McGee Corporation's North Walker Mine, in the Shirley Basin mining district of south-central Wyoming (Fletcher, 1970). Unfortunately, measurements of the specimens have not yet been published; however, comparison of a skull illustrated in Fletcher's Figure 1 (ibid.:6) with an engineering ruler inserted for scale suggests a tip-to-tip horn spread of approximately 930 mm. A pollen study showed the bison deposits to be characterized by spruce-pine-fir pollen, in contrast with the grass and Compositae pollen of later deposits. This suggests a Pleistocene age for the deposits (ibid.:5); however, the exact temporal position within the Pleistocene is not known. Very likely the bison are of late Wisconsin or early Holocene age, on the basis of morphological similarity to other early Holocene forms.

Scattered bison remains were recovered at the Union Pacific (U. P.) Mammoth Site, southwest of Rawlins, Wyoming. They were recorded briefly in the literature and assumed to be of archaeological context (Anonymous, 1961; Irwin, 1970); however, their association with the mammoth is unclear. A very large radius, a large atlas vertebra, the distal end of a tibia, and a thoracic vertebra show staining and mineralization comparable with that seen on the mammoth bones. However, a bison mandible and other skeletal elements also from the site show decidedly less staining and are probably more recent.

The U. P. site bison radius is that of a large, rugose male. In all aspects it exceeds in size the paleo-bison radii recovered from Bone Bed 2 at Bonfire Shelter (Dibble and Lorrain, 1968:128), as shown in Table I. The tibia appears much smaller, but is within the upper part of the range of the Bonfire Shelter, Bone Bed 2 tibiae. The axis vertebra is considerably longer than any from Bonfire Shelter, although its transverse width more or less agrees with

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TABLE I. MEASUREMENTS OF THE UNION PACIFIC SITE BISON RADIUS
(Univ. Wyoming, Geology Collections)

Standard Measurement*	U. P. Site	Bonfire Shelter, Texas Min.	Av.	Max.
1. Length	396.4 mm.	--	383.0	--
2. Transverse width, proximal end	129.2 mm.	91.0	103.3	124.0
3. Anterior-posterior width, proximal end	65.7 mm.	46.5	52.4	63.0
4. Transverse width, distal end	119.7 mm.	86.5	96.0	110.0
5. Transverse width, center of shaft	65.5 mm.	50.0	53.8	57.6
6. Anterior-posterior width -- center	44.0 mm.	29.0	35.4	41.8

* Standard measurements and Bonfire Shelter sample after Dibble and Lorrain, 1968.

the latter sample.

Artifacts (not including projectile points) from the site may indicate Clovis affinities, and a radiocarbon date of 11,280 ± 350 years B.P. (I-449; Haynes, 1964:1410) has been obtained. The paleontology of the site is currently under study by the present author.

EARLY HOLOCENE BISON

A number of archaeological sites of Early Prehistoric age have been excavated in Wyoming (Fig. 1), and good bison bone samples have been recovered. In a few cases, bone recovery was not pursued with much vigor; however, recent excavations have greatly expanded the available sample. A recurrent problem with these samples has been our inability to bend them to fit the view of bison taxonomy advocated by Skinner and Kaisen (1947). Some discussion of these problems is relevant here.

For more than 100 years, compilations and revisions of North American fossil bison species have been appearing (Leidy, 1852; Allen, 1876; Lucas, 1899; Hay, 1913; Figgins, 1933; Frick, 1937; Schultz and Frankforter, 1946; Skinner and Kaisen, 1947; Guthrie, 1966a; Wilson, 1969; Flerow, 1969; Guthrie, 1970; Wilson, in press). These have all differed in the details of

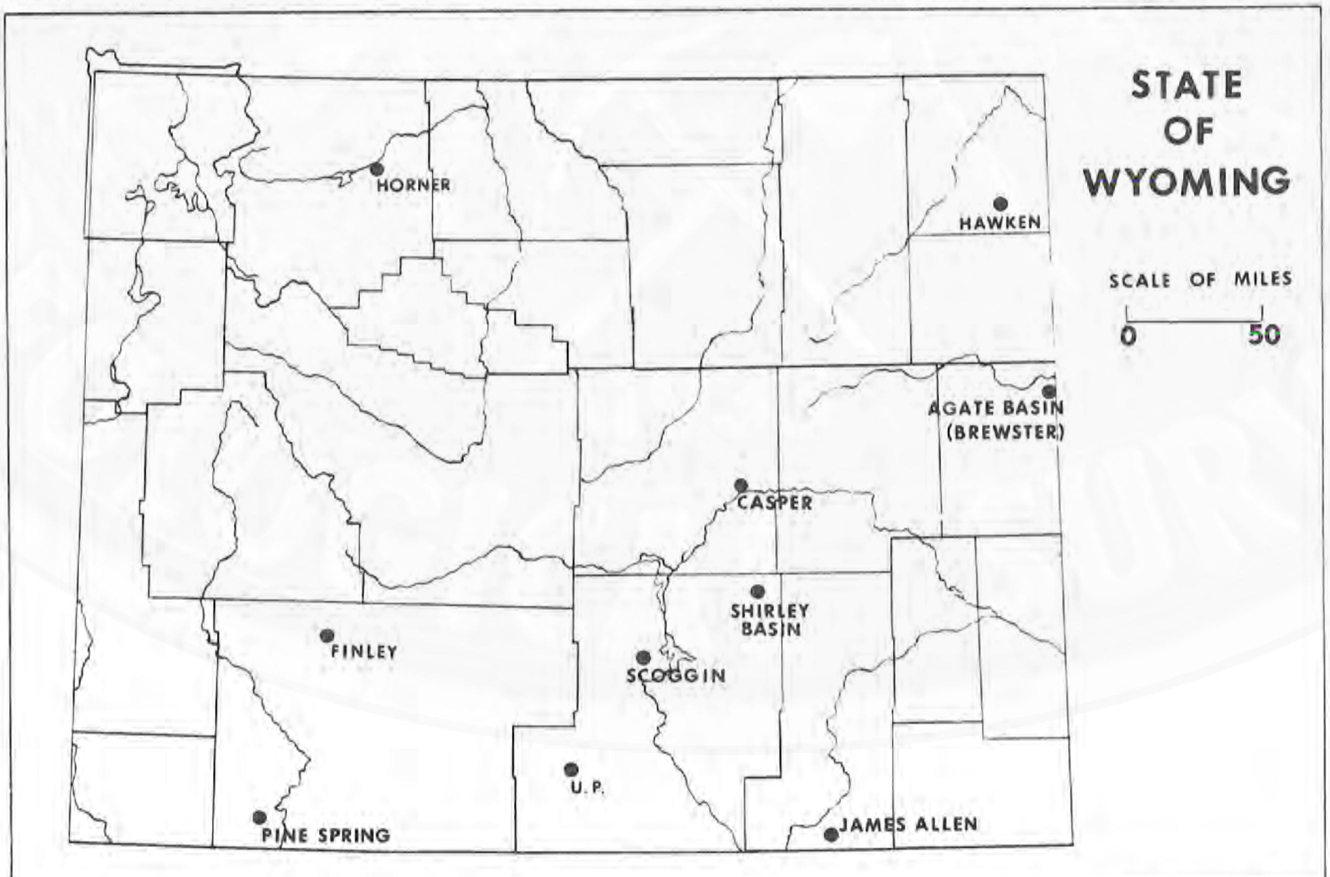

FIGURE 1. Important early bison sites in the state of Wyoming. The James Allen site sample (Mulloy, 1959) lacks cranial material and is not considered in the text. "Bison sp." material reported from the Pine Spring site (Sharrock, 1966) has not been described in any detail, nor is it clear what bones were recovered.

classification, especially where samples of particular species were small. The primary problems in taxonomy are clear:

1. Definition of species has been made largely on the basis of horn cores -- secondary sexual characters which are quite possibly the most variable part of the animal (for a discussion of this problem, see Guthrie, 1966a.)
2. Most fossil taxa are described on the basis of very small samples; yet they are viewed as if they have as sound a basis as does the modern species, Bison bison.
3. Although we have a fairly good idea of the range of variation of the modern bison, the possibility of geographical trends in variation has not been investigated adequately. If clinal variation could be demonstrated for modern (or at least Historic) forms, this could serve as a model for the analysis of past populations and species.

The present author has, in the course of six years of study, been moving more and more to a position of "lumping" fossil form-species together. In 1969 I took the position that the four early Alaskan form-species accepted by Skinner and Kaisen (1947; Bison crassicornis, B. preoccidentalis, B. alaskensis, and B. geisti) were synonymous and all referable to B. crassicornis. This was not a completely original viewpoint. Lucas (1899) considered B. alaskensis a synonym of B. crassicornis; Fuller and Bayrock (1965) considered B. preoccidentalis a synonym of B. crassicornis; and Guthrie (1966a) suggested the synonymy of the group. Later, he went even further, and synonymized all four with Bison priscus (Guthrie, 1970).

In addition, I viewed the early Holocene form-species B. antiquus and B. occidentalis as only phenotypically distinct -- that is, they were biospecifically identical and thus could interbreed (Wilson, 1969). This position had been suggested by Hillerud (1966) and by Butler (1968) in a brief discussion.

More recent evidence, much of it from the state of Wyoming, has convinced me of the probability of this position. The sample from the 10,000-year-old Casper site in central Wyoming includes three very large male bison crania. One of these exceeds the maximum horn-core spread for either B. antiquus or B. occidentalis (this measurement in specimen NC 2326 is estimated at 1,090 mm.). However, this skull in virtually all other respects resembles B. antiquus; a second, smaller skull resembles B. antiquus; and the third resembles B. occidentalis or perhaps the very poorly defined B. antiquus figginsi (=B. taylori). The females of the population all tend to resemble males of Bison bison bison; that is, their horn cores have a posteriad deflection (Wilson, in press). In this respect they differ widely from female B. antiquus described by Chandler (1916) from California.

It appears that B. antiquus and B. occidentalis are conspecific. Hillerud (1966) synonymized the two and came up with B. antiquus occidentalis for the latter; however, he failed to tackle the problem of what seemed to be a polyphyletic origin for his species (B. antiquus antiquus derived from B. alleni, and B. antiquus occidentalis derived from B. crassicornis). Elsewhere, Fuller and Bayrock suggested (1965) that B. occidentalis should more properly be viewed as a subspecies of the modern species, B. bison: therefore, they proposed the combination B. bison occidentalis.

The resolution of this dilemma is perhaps not as difficult as it looks. Wilson (in press) suggests

1. the synonymy of B. antiquus and B. occidentalis;
2. thus that both subspecies gave rise to the modern bison -- a suggestion which is counter to the claim of Skinner and Kaisen (1947:157) that antiquus became extinct without descendants;
3. therefore, both can be viewed as chronosubspecies of B. bison: B. bison antiquus and B. bison occidentalis; and
4. the problem of polyphyletic origin is overcome through the synonymy of B. alleni and B. crassicornis as southern and northern subspecies of B. priscus: thus, they become B. priscus alleni and B. priscus crassicornis. There is ample support for such a synonymy in the literature (see, for instance, Romer, 1951; Guthrie, 1970; as well as Dalquest, 1957 for B. alleni/B. chaneyi problem).
5. There is some evidence to suggest that B. priscus alaskensis can be maintained for early Alaskan forms of B. priscus, as it seems to be older than B. priscus crassicornis (Harington and Clulow, 1973).

The Casper site population seems to lie close to the arbitrary line dividing "northern" forms (B. priscus crassicornis/ B. bison occidentalis) from "southern" forms (B. priscus alleni/B. bison antiquus). These taxa are resolved into "northern" and "southern" phenotypes at each time level (Fig. 2): "northern" phenotypes have narrow frontals, a high index of orbital protrusion, posteriad deflection of horn core axes, and a distal twist to the horn cores; while "southern" phenotypes have broad frontals, low orbital protrusion, horn cores directed laterally, and little or no distal twist to the cores (see discussion in Wilson, in press). At least some of this clinal variation may have persisted into modern times (Bison bison; see Figgins, 1933). Of course, since this is a clinal aggregate of trends, intermediate forms exist, doubtless in large numbers, at each time level.

Bison from the Finley site (an approximately 8,000-year-old Cody Complex bison kill in the Killpecker dune field of south-

TABLE II. MEASUREMENTS OF A BISON CRANIUM FROM THE FINLEY SITE

	Standard Measurement*	Finley site	B. antiquus min.	B. antiquus av.	B. antiquus max.	B. occidentalis min.	B. occidentalis av.	B. occidentalis max.
1.	Spread of horn cores, tip to tip	...	816	881	975	670	747	875
2.	Greatest spread of cores, outside curve	...	...	...	...	735	782	892
3.	Length of core on upper curve, tip to burr	...	220	281	344	222	279	330
4.	Length of core on lower curve, tip to burr	...	280	336	395	275	340	405
5.	Length, tip of core to upper base at burr	...	197	245	280	210	243	290
6.	Vertical diameter of core	113.5	90	98	108	76	91	100
7.	Circumference of core	345	290	320	358	253	290	336
8.	Greatest width at auditory openings	304	...	...	...	259	275	307
9.	Width of condyles	137.5	...	...	...	124	131	147
10.	Depth, occipital crest to top, foramen magnum	116.5	...	...	...	...	...	...
11.	Depth, occipital crest to bottom, foramen magnum	155	...	...	...	136	158	177
12.	Transverse diameter of core	110	92	107	122	85	98	114
13.	Width between bases of horn cores	270x	...	...	...	...	...	...
14.	Width of cranium between horn cores and orbits	316x	292	319	357	277	299	340
21.	Angle of posterior horn core divergence	75°	...	...	...	...	...	...
22.	Angle of proximal horn core depression	10°	...	...	...	...	...	...

* Standard measurements and B. antiquus/B. occidentalis samples after Skinner and Kaisen, 1947. Under the taxonomic system used in the present paper, these would be viewed as B. bison antiquus and B. bison occidentalis.

western Wyoming) were identified as B. occidentalis by Schultz and Frankforter (1951) on the basis of metapodials. No crania were recovered in their investigations at the site, and only one complete metacarpal was available for detailed comparison. Recent visits to the site by Dr. George C. Frison have resulted in the collection of a large sample of metapodials and other post-cranial material, in addition to several large cranial fragments, from the backdirt of craters dug into the site by vandals seeking projectile points. Measurements of the best-preserved cranial fragment (rear of cranium with base of left horn core) are given in Table II. The cranium does resemble B. bison occidentalis in some respects; however, the horn core base is much more robust than has been described for the subspecies. In addition, wide posterior cranial breadth measurements (Table II, #8 and #9) and proximal horn core depression suggest similarity with "southern" forms; hence, they are more likely B. bison antiquus. I suspect that a larger sample will show more variation, and "boundary-line" characteristics similar to those noted at Casper.

Other Paleo-Indian bison finds from Wyoming have received preliminary consideration. Two female bison crania were recovered from the Folsom level at the Brewster (Agate Basin) site in eastern Wyoming, dated to 10,375 ± 700 years B.P. (I-472; Haynes, 1967). They were identified tentatively as B. antiquus (Bass, 1970; Agogino, 1972). One of these is presently in the Geology Museum of the University of Wyoming. It exhibits considerable similarity to females from the Casper site, refered to B. bison antiquus. Like the Casper specimens, it shows some "northern" phenotypic characters as well (Wilson, in press).

A large sample of bison bones was recovered from the Horner site near Cody, Wyoming, dated in excess of 8,500 years (Haynes, 1967). A preliminary report on the site has appeared (Jepsen, 1953), but as yet no satisfactory description of the bison has been published.

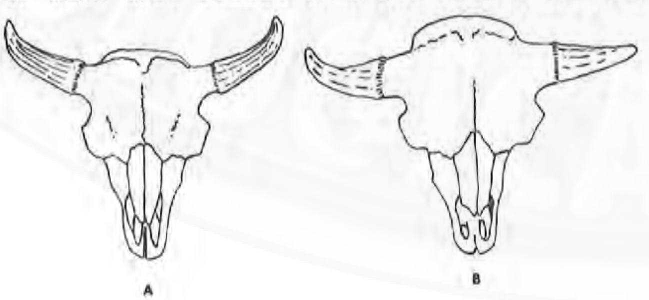

FIGURE 2. Illustrations of bison phenotypes. A, "northern" phenotype (young B. bison bison) with relatively narrow cranium and posteriad deflection to the horn cores. B, "southern" phenotype (mature B. bison antiquus) with broad cranium and lateral direction to the horn cores. Both drawings adapted from photographs in Skinner and Kaisen, 1947. Differences in orbital protrusion are age-dependent as well as clinal, and are thus not apparent here.

BISON AND THE ALTITHERMAL

A nagging question troubling students of the bison has been the dating of the period when bison of the early Holocene type became smaller, approaching the size of the modern bison. Recently, dates were obtained from two sites apparently bracketing this period of dwarfing in Wyoming.

TABLE III. MEASUREMENTS OF MODERN BISON FROM THE BIGHORN MOUNTAINS

Standard Measurement[1]	Specimen Number[2] 1	2	3	4	5	6	7	8	9	10
1. Spread of horn cores, tip to tip	567	...	...	541	...	...	...	508	576	719
2. Greatest spread of cores on outside curve	617	...	...	541	...	...	...	515	607	719
3. Core length on upper curve	186	...	190	143	...	...	...	140	197	225
4. Core length on lower curve	222	...	228	181	...	...	...	175	238	244
5. Length, tip of core to upper base	167	...	162	140	...	...	...	127	181	216
6. Vertical diameter of horn core	89	89	86	71	76x	92	...	70	92	98
7. Circumference of horn core	254	286	248	235	...	273	...	228	265	305
8. Greatest width at auditory openings	264	250	...	228x	...	276	248	234	264	260
9. Width of condyles	120.5	106	...	121x	...	124	124	114	128	124
10. Depth, occipital crest to top of foramen magnum	105	92	...	102	105	102	...	89	92	121
11. Depth, occipital crest to bottom of foramen magnum	...	...	...	149	...	159	...	127	138	165
12. Transverse diameter of horn core	83	86	92	76	83	94	78	79	95	95
13. Width between bases of horn cores	203	212	...	194	206	258	...	216	228	244
14. Width of cranium between horn cores and orbits	270	272	...	266	267	292	...	248	270	276
15. Greatest postorbital width	324	330	...	298	280	356	...	296	319	324
16. Anterior orbital width at notch	235	264	...	241	197	264	...	222	222	251
17. Width of skull at masseteric process	182	184	...	...	...	197	...	168	...	197
20. $M^1 - M^3$, alveolar length	...	88	...	...	...	...	...	93	...	...
O-T. Length, occipital crest to tip of nasals	429	466	...	...	...	445	...	397	403	438
O-N. Length, occipital crest to nasal-frontal suture	...	...	...	210	206	267	...	218	232	248
N-T. Length of nasal bone	184	232	...	...	...	178	...	195	171	190
Index of horn core curvature	133	...	141	129	...	...	...	138	131	113
Index of horn core compression	107	103	94	93	92	98	...	89	97	103
Index of horn core proportion	73	...	77	61	...	...	...	61	74	74
Index of horn core length	69	...	...	54	...	...	...	56.5	73	82
Index of orbital protrusion	83	83	...	89	95	82	...	84	85	85

[1] after Skinner and Kaisen (1947) and Guthrie (1966b).
[2] most of these specimens are in private collections, and thus have no catalog numbers. Detailed data concerning provenience and disposition of specimens are in the possession of the author.

Bison from the Hawken site, near Sundance, in northeastern Wyoming were found in association with side-notched points, and have been radiocarbon dated to 6,470 ± 140 years B.P. (RL-185). Several male bison were recovered and all are very large. They resemble B. bison occidentalis more closely than do earlier forms, although the horn cores are unusually robust (up to 112 mm. vertical diameter) at their bases. This suggests that the zone separating "northern" and "southern" phenotypes had moved somewhat southward in the interval between 10,000 and 6,500 years ago (Wilson, MS).

In contrast, bison recovered from the Scoggin site in south-central Wyoming, and dated to 4,540 ± 110 years B.P. (RL-174) are quite modern in appearance and fall metrically well within the range of B. bison bison (Lobdell, 1973). Thus the period of the dwarfing of bison in at least the Wyoming area (it may not have been synchronous across all of North America) was between 6,500 and 4,500 years ago. This interval corresponds very closely with the Altithermal (Hypsithermal) interval of the Rocky Mountain area (Richmond, 1965:227; 6,500 to 4,000 years B.P.) and a causal relationship is probable.

LATE HOLOCENE BISON

In late Holocene times (including Historic times) there is considerable evidence that both the Plains bison (B. bison bison) and the Wood bison (B. bison athabascae) were present in Wyoming (Skinner and Kaisen, 1947; Christman, 1971; Meagher, 1970). As yet, relatively few metric studies have been performed upon late Holocene bison samples from the state, although excellent samples are available (Frison, 1970; and unpublished material).

The discrimination of the two modern subspecies in late Holocene archaeological samples will be extremely difficult, particularly in sites of Early Middle Period age. At such a stage, it is most likely that individuals of B. bison bison would have been slightly larger than those of today -- enough to cause metric confusion with the woodland form (Wilson, 1973).

The author is currently collecting measurements of modern bison skulls from Wyoming, particularly those from mountainous areas. The size of the sample at present does not permit clear subspecific "mapping" of the state; however, such interpretation will certainly be possible as the sample increases.

From the small sample yet available, some disturbing anomalies have come to light in view of currently "expected" morphological characteristics. One segment of the sample, a series of ten modern male skulls collected from the plateau atop the Bighorn Mountain chain in northern Wyoming, is tabulated in Table III. This is as yet a small sample; thus the reader is cautioned as to the use of statistical indices of comparison with other populations. Nevertheless, a number of trends are apparent.

In comparison with B. bison bison, one specimen shows horn cores much larger and longer than those recorded by Skinner and Kaisen (1947:162) from Montana. Nevertheless, most skulls are smaller in horn spread than the minimum for B. bison athabascae. Several basal horn core measurements exceed or match the range for B. bison athabascae reported by Skinner and Kaisen (1947:164), but fall within the extended range published by Bayrock and Hillerud (1964).

Cranial breadth in the Bighorn Mountains sample is considerable, suggesting a "southern" phenotype; however, the published tables show B. bison athabascae to be more variable than B. bison bison in this regard. No trends are apparent. In several other cranial and horn core measurements the Bighorn sample seems to "straddle" the published subspecific samples.

The indices are also instructive. Horn cores are all straighter than average for B. bison bison and somewhat closer to B. bison athabascae; however, one specimen has cores even straighter than the latter. Indices of compression tend to be high, with several specimens showing antero-posterior compression rather than the more prevalent dorso-ventral compression. This more closely fits the range of B. bison bison, but three specimens go beyond the range for this subspecies and far beyond the range for B. bison athabascae. Indices of proportion are low, indicating rather stubby horn cores most like those of B. bison bison. Indices of horn core length are high as in B. bison athabascae, with one individual showing horns longer than any recorded for either subspecies in the two studies cited.

The subspecific assignment of these skulls is thus unclear. Early records from nearby areas of the state suggest that some form of Wood bison (B. bison subsp., cf. B. bison athabascae) lived in the area (Christman, 1971; Meagher, 1970). If the present sample of skulls does indeed represent the Wood bison, it is clear that the measurements of the northern Canadian sample (Skinner and Kaisen, 1947; Bayrock and Hillerud, 1964) are not directly applicable to those bison from areas to the south. Perhaps, as we have earlier suggested, a number of clinal gradients can be drawn on individual measured characteristics. Only through the measurement of large numbers of modern bison skulls from the entire bison range will we be able to make our synoptic measurement tables useful.

CONCLUSION

Although an almost overwhelming amount of data concerning bison from Wyoming sites still await analysis, trends in both time and space are beginning to come into focus.

The most important of these trends as presently visible are:

1. a north-to-south North American cline in phenotypes at all time levels (accepting the probability of modern clines) involving a

frontal-occipital-horn core functional matrix; and

2. the coincidence of dwarfing from B. bison antiquus and B. bison occidentalis to the modern subspecies with Altithermal (Hypsithermal) times, particularly during the interval from 6,500 to 4,500 years ago.

Metric data concerning these trends are in varying stages of compilation and analysis; some are to appear shortly (Wilson, in press). If nothing else, the problems and suggestions forthcoming from such data show that there will be plenty of room for ample numbers of bison researchers in the years to come.

ACKNOWLEDGEMENTS

Over the past few years I have had many opportunities for discussion of bison taxonomy and morphology with interested colleagues. Dr. George C. Frison, my present advisor, has been a veritable fountain of both information and encouragement. My fellow students have contributed in countless ways to the development of the hypotheses developed above. Jean Bedord is currently working with a project involving both synchronic and diachronic analyses of bison metapodial morphology. Her well-controlled metric comparisons will add significantly to the value of these bones in the analysis of fossil bison relationships. George Zeimens, in the course of preparation and measurement of most of the bison material in our collections, has become an expert in the identification of even very fragmentary bison remains, and his trained eye has opened the door to many new discoveries and observations in the samples. Danny Walker has freely shared with the author an extensive acquaintance with the paleontological and zoological literature, along with numerous original suggestions concerning points of analysis.

Visits with John Hillerud, B. Robert Butler, Brian O. K. Reeves, B. Miles Gilbert, C. S. Churcher, J. A. Brophy, Elaine Anderson, and many other researchers have been fruitful and thought-provoking. I thank them all.

REFERENCES

Agogino, George A.
1972 Excavations at a Paleo-Indian site (Brewster) in Moss Agate Arroyo, eastern Wyoming. National Geographic Society Research Reports, 1955-1960: 1-6. Washington, D.C.

Allen, Joel A.
1876 The American bisons, living and extinct. Memoirs of the Museum of Comparative Zoology, Harvard College, 4(10):1-245. Cambridge, Massachusetts.

Anonymous
1961 Rawlins site yields ancient bison. Wyoming Archaeologist, 4(9):12. Cheyenne, Wyoming.

Barbour, E. H., and C. B. Schultz
1936 Palaeontologic and geologic consideration of early man in Nebraska, with notice of a new bone bed in the early Pleistocene of Morill County, Nebraska. Bulletin of the University of Nebraska State Museum, 1(45):431-450. Lincoln, Nebraska.
1941 A new fossil bovid from Nebraska with notice of a new bison quarry in Texas. Bulletin of the University of Nebraska State Museum, 2(7):63-68. Lincoln, Nebraska.

Bass, William M.
1970 Excavations of a Paleo-Indian site at Agate Basin, Wyoming. National Geographic Society Research Reports, 1961-1962: 21-25. Washington, D.C.

Bayrock, L. A., and Jim Hillerud
1964 New data on Bison bison athabascae Rhoads. Journal of Mammalogy, 45(4):630-632. Lawrence, Kansas.

Butler, B. Robert
1968 A Guide to Understanding Idaho Archaeology. Second Edition, revised. Special Publication, Idaho State University Museum. 117 p. Pocatello, Idaho.

Chandler, Asa C.
1916 A study of the skull and dentition of Bison antiquus Leidy, with special reference to material from the Pacific Coast. University of California Publications, Bulletin of the Department of Geology, 9(11):121-135. Berkeley, California.

Christman, Gene M.
1971 The Mountain Bison. The American West, 8(3):44-47. Palo Alto, California.

Dalquest, W. W.
1957 First record of Bison alleni from a late Pleistocene deposit in Texas. Texas Journal of Science, 9:346-354. Austin, Texas.

Dibble, David S., and Dessamae Lorrain
1968 Bonfire Shelter: a stratified bison kill site, Val Verde County, Texas. Texas Memorial Museum, Miscellaneous Papers, 1:1-138. Austin, Texas.

Figgins, J. D.
1933 The bison of the western area of the Mississippi Basin. Proceedings of the Colorado Museum of Natural History, 12(4): 16-33. Denver, Colorado.

Flerow, C. C.
1969 The evolution of Bisons. VIII^e Congrès INQUA, Paris, Résumés des Communications, Section 4: Paléontologie Animale: 123. Paris, France.

Fletcher, Calvin D.
1970 Extinct bison -- Shirley Basin Mining District. Wyoming Geological Association, Earth Science Bulletin, 3(1):5-9, 9 figs. Casper, Wyoming.

Forbis, R. G.
1960 The Old Women's Buffalo Jump, Alberta. National Museum of Canada, Contributions to Anthropology, 1960, Bulletin, 180:56-123. Ottawa, Canada.

Frick, C.
1937 Horned ruminants of North America. Bulletin of the American Museum of Natural History, 69:1-669. New York, New York.

Frison, George C.
1970 The Glenrock Buffalo Jump, 48CO304: Late Prehistoric Period buffalo procurement and butchering. Plains Anthropologist Memoir, 7, vol. 15(no. 50, part 2):1-45, Topeka, Kansas.
1971 The buffalo pound in northwestern Plains prehistory: site 48CA302, Wyoming. American Antiquity, 36(1):77-91. Washington, D.C.

Fuller, W. A., and L. A. Bayrock
1965 Late Pleistocene mammals from central Alberta, Canada. In R. E. Folinsbee and D. M. Ross (Eds.), Vertebrate Paleontology in Alberta: report of a conference held at the University of Alberta, Aug. 29 - Sept. 3, 1963. University of Alberta, Department of Geology, Bulletin, 2:53-63. Edmonton, Alberta, Canada.

Guthrie, R. Dale
1966a Bison horn cores -- character choice and systematics. Journal of Paleontology, 40(3):738-740. Tulsa, Oklahoma.
1966b Pelage of fossil bison -- a new osteological index. Journal of Mammalogy, 47(4):725-727. Lawrence, Kansas.
1970 Bison evolution and zoogeography in North America during the Pleistocene. Quarterly Review of Biology, 45(1):1-15. Baltimore, Maryland.

Harington, C. R., and F. V. Clulow
1973 Pleistocene mammals from Gold Run Creek, Yukon Territory. Canadian Journal of Earth Sciences, 10(5):697-759. Ottawa, Canada.

Hay, O. P.
1913 The extinct bisons of North America; with description of one new species, Bison regius. Proceedings of the United States National Museum, 46:161-200. Washington, D.C.

Haynes, C. Vance, Jr.
1964 Fluted projectile points: their age and dispersion. Science, 145:1408-1413. Washington, D.C.
1967 Carbon-14 dates and early man in the New World. In P. S. Martin and H. E. Wright, Jr. (Eds.), Pleistocene Extinctions: the Search for a Cause: 267-286. Yale University Press, New Haven, Connecticut.

Hillerud, J. M.
1966 The Duffield Site and Its Fossil *Bison*, Alberta, Canada. M.Sc. Thesis, University of Nebraska, Lincoln, Nebraska. 198 p.

Hopkins, Marie L.
1951 Bison (Gigantobison) latifrons and Bison (Simobison) alleni in southeastern Idaho, Journal of Mammalogy, 32(2):192-197. Lawrence, Kansas.

Hopkins, Marie L., Robson Bonnichsen, and David Fortsch
1969 The stratigraphic position and faunal associates of Bison (Gigantobison) latifrons in southeastern Idaho, a progress report. Tebiwa, 12(1):1-8. Pocatello, Idaho.

Irwin, Henry
1970 Archaeological investigations at the Union Pacific Mammoth Kill site, Wyoming, 1961. National Geographic Society Research Reports, 1961-1962: 123-125. Washington, D.C.

Jepsen, G. L.
1953 Ancient buffalo hunters of northwestern Wyoming. Southwestern Lore, 19(2):19-25 Denver, Colorado.

Kindle, E. M.
1921 Animal behavior as a factor in the formation of bone beds. Canadian Field-Naturalist, 35(2):33-34. Ottawa, Canada.

Leidy, J.
1852 Memoir on the extinct species of American ox. Smithsonian Contributions to Knowledge, 5(3):1-20. Washington, D.C.

Lobdell, John E.
1973 The Scoggin Site: An Early Middle Period *Bison* Kill. M.A. Thesis (Anthropology), University of Wyoming, Laramie, Wyoming. 82 p.

Lucas, F. A.
1898 The fossil bison of North America, Science, series 2, vol. 8:678. Washington, D.C.
1899 The fossil bison of North America. Proceedings of the United States National Museum, 21:755-771. Washington, D.C.

Meagher, Margaret M.
1970 The Bison of Yellowstone National Park: Past and Present. Ph.D. Dissertation, University of California, Berkeley, California. 172 p.

Mulloy, William
1959 The James Allen site, near Laramie, Wyoming. American Antiquity, 25(1):112-116. Salt Lake City, Utah.

Reher, C. A.
1970 Population dynamics of the Glenrock Bison bison population. Plains Anthropologist Memoir 7, vol. 15(no. 50, part 2):51-55. Topeka, Kansas.
1973 The Wardell Bison bison sample: population dynamics and archaeological interpretation. University of Michigan, Museum of Anthropology, Anthropological Papers, 48:89-105. Ann Arbor, Michigan.

Richmond, Gerald M.
1965 Glaciation of the Rocky Mountains. In H. E. Wright, Jr. and D. G. Frey (Eds.) The Quaternary of the United States: 217-230. Princeton University Press, Princeton, New Jersey.

Romer, Alfred S.
1951 Bison crassicornis in the late Pleistocene of New England. Journal of Mammalogy, 32(2):230-231. Lawrence, Kansas.

Schultz, C. B., and W. D. Frankforter
1946 The geologic history of the bison in the Great Plains (a preliminary report). Bulletin of the University of Nebraska State Museum, 3(1):1-10. Lincoln, Nebraska.
1951 A preliminary report on the bison remains from the Finley Site (Eden Bison Quarry). In John H. Moss, Early Man in the Eden Valley. University Museum, The University of Pennsylvania, Museum Monographs, 6:119-124. Philadelphia, Pennsylvania.

Sellards, E. H., G. L. Evans, and G. E. Meade
1947 Fossil bison and associated artifacts from Plainview, Texas, with description

of artifacts, by Alex D. Krieger. Geological Society of America Bulletin, 58:927-954. New York, New York.

Sharrock, Floyd W.
1966 Prehistoric occupation patterns in Southwest Wyoming and cultural relationships with the Great Basin and Plains culture areas. University of Utah Anthropological Papers, 77:1-191. Salt Lake City, Utah.

Skinner, M. F., and O. C. Kaisen
1947 The fossil Bison of Alaska and a preliminary revision of the genus. Bulletin of the American Museum of Natural History, 89(3):123-256. New York, New York.

Sternberg, C. H.
1903 Experiences with early man in America. Transactions of the Kansas Academy of Science, 18:89-93. Topeka, Kansas.

Stewart, Alban
1897 Notes on the osteology of Bison occidentalis. Kansas University Quarterly, 6(3):127-135. Lawrence, Kansas.

Wheat, Joe Ben
1967 A Paleo-Indian bison kill. Scientific American, 216(1):44-52. New York, New York.
1972 The Olsen-Chubbuck Site, a Paleo-Indian bison kill. Memoirs of the Society for American Archaeology, 26:1-180. Washington, D.C.

Williston, S. W.
1902 An arrowhead found with bones of Bison occidentalis Lucas in western Kansas. American Geologist, 30:313-315. Minneapolis, Minnesota.

Wilson, Michael
1969 Problems in the speciation of American fossil bison. In R. G. Forbis, L. B. Davis, O. A. Christensen, and G. Fedirchuk (Eds.), Post-Pleistocene Man and his Environment on the Northern Plains: 178-199. Archaeological Association, University of Calgary, Calgary, Alberta, Canada.
1973 The Early Historic fauna of southern Alberta: some steps to interpretation. In R. M. Getty and K. R. Fladmark, (Eds.), Historical Archaeology in Northwestern North America: 213-248. Archaeological Association, University of Calgary, Calgary, Alberta, Canada.
in press The Casper Site Local Fauna and its fossil bison. In George C. Frison (Ed.), The Casper Site: a Hell Gap Bison Kill on the High Plains: 125-171. Academic Press, New York, N.Y.
MS Fossil Bison from the Hawken Site, Wyoming. Manuscript in preparation.

HUMAN SKELETONS FROM WYOMING AND THEIR BEARING ON THE CONCEPT OF MORPHOLOGICAL DATING

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INTRODUCTION

A recent preliminary analysis of human skeletal material from the University of Wyoming collections has provided new information on the skeletal biology of prehistoric man in the northwestern Plains. In addition, the information gained has shed light on the controversial subject of morphological dating on the basis of human skeletal remains. This report will begin with the results of the preliminary analysis; then comments will be made regarding the biological affinities of the populations examined. Lastly, the concept of morphological dating will be discussed and redefined with emphasis upon the particular insights gained from the recent analysis.

DESCRIPTIVE ANALYSIS

A collection of 25 adult human skeletons from the state of Wyoming is being studied from the standpoint of metrics and non-metric discrete and continuous traits. None of the specimens have been previously described. Almost all of the 15 male and 10 female specimens are in fragmentary condition but a few complete crania are present within the sample. Collection of data has consisted of the recording of 47 observations of discrete and non-discrete skeletal characteristics, and 35 cranial and 19 post-cranial measurements (Montagu, 1960; Olivier, 1969; Bass, 1971; Gill, 1971). The latter will eventually be used in the calculation of stature and at least 12 indices including cranial and post-cranial data. In this preliminary report only 11 measurements and indices will be presented (Tables I and II).

The chronological outline used in this study is that proposed by Mulloy (1958) for the northwestern plains. A few of the specimens have been dated accurately through association with diagnostic cultural materials. The samples listed in the tables as "Late Prehistoric" actually include some Proto-historic specimens (with associated trade items) as well as specimens from times prior to White contact. The Late Middle Prehistoric Period specimens, which in terms of absolute chronology date from a period of about 1500 B.C. to A.D. 500, are in most cases rather securely dated through archaeological context. The sample listed as "Bighorn" in Table I is without archaeological provenience, but probably dates from the Late Prehistoric Period. The female specimen labelled "Torrington" in Table II is a skull which reputedly came from the same site as the three skulls described by Howells (1938) in his paper, "Crania from Wyoming Resembling Minnesota Man". In his report he considered the likelihood of great antiquity for these specimens based upon patterns of morphological traits. As will be demonstrated below our evidence tends to weaken his argument for their antiquity.

The skeletons within these samples were collected from all parts of the state of Wyoming except the southwestern region. No specimens have yet been collected from the Red Desert area or further west of that region. Most of the specimens came from the vicinity of the Bighorn Mountains of north-central Wyoming, a few from near the east-

TABLE I. MALE CRANIA.

Measurement or Index	Late Middle Period (n=1)	Late Prehistoric (n=3)	Bighorn (n=3)
Cranial length	198	190.0	185.0^{5}
Cranial breadth	147	148.0	142.8^{4}
Basion-bregma	141	125.0	129.7
Cranial capacity	1615 cc	1468 cc	1428 cc
Cranial module	162.00	154.56	151.78
Cranial index	74.24	78.17	77.62^{4}
Length-height index	71.21	66.04	71.11
Total face index	82.52	89.22^{2}	------
Upper face index	54.55	54.33^{2}	48.08
Orbital index	81.82	83.21	82.43^{5}
Nasal index	50.91	48.77	52.09^{4}

The above measurements are in millimeters except cranial capacity which is expressed in cubic centimeters. The small superscript numbers seen in the last two columns indicate sample numbers that differ in some way from the value shown for n at the top of the column. In all cases within this table and others cranial capacity was calculated utilizing the formulas of Lee and Pearson (Olivier, 1969).

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central border of the state; and some from the Laramie area. In our limited sample, physical characteristics do not appear to differ noticeably between various parts of the state; but they do differ somewhat by temporal zone.

It may be seen from the tables that all samples indicate a people with rather long and large skulls of either mesocranic or slightly dolichocranic proportions. Faces range from medium to fairly broad as does nose form (some mesorrhine, most chamaerrhine). Orbital form is medium or mesoconch in all samples and is of a basically rhomboid form.

In addition to the metric traits certain rather unique morphological traits show continuity through time in this region of the northwestern Plains. Fairly large, rugged faces exist among males at all temporal levels, and among both sexes there is found a very high frequency of alveolar prognathism with accompanying lack of a lower nasal sill. These latter two conditions appear to be somewhat more prevalent among the earlier populations but certainly remain as the predominant condition among the later populations as well. Among the four studiable Late Middle Period skulls 100 percent show either no nasal sill at all or very reduced sills (2 specimens each); but even by Late Prehistoric and Historic times 45.5 percent still show dull sills or none at all (sample of 11, mostly male). No sharp nasal sills have yet been found among Wyoming crania.

A feature that appears to differ noticeably between the Late Middle Period populations and the more recent ones is the height of the cranial vault. The low cranial vault typical of the Great Plains Sioux, and found consistently throughout the Late Prehistoric Wyoming populations, does not seem to have been present during the Late Middle Period. Certainly our limited sample sizes at this point must be kept in mind, but on the other hand this trend in the data is further supported when reports of additional Wyoming samples are consulted. Tables III and IV list additional specimens and population samples known from all major time periods.

Table III lists the three male samples of Table I (Bighorn sample included in Late Prehistoric) in comparison with other known male crania from Wyoming, as well as a few other selected Plains samples. The Arikara and Pawnee are included to show a contrasting Plains population since, as may be seen from the table, they differ noticeably from the Wyoming populations and the other Sioux-related Plains groups (Lakotid). The major difference is a smaller, less rugged skull of a slightly more brachycranic form among the Arikara and Pawnee. Other differences in stature, robusticity and the percent occurrence of certain discrete traits also exist between the Arikara-Pawnee population and the Sioux-related goups.

The Torrington specimen listed in Table III is a Wyoming male described by Howells (1938); it is of unknown age. The PK burials from the Bighorn Mountain region of northern Wyoming have been described by Bass and Lacy (1963) and I would say correctly assigned by them to a Sioux-related population. They have been dated to 990 ± 240 years B.P. (A.D. 960, A-548; Haynes, Damon and Grey, 1966:18). The Turk burials shown in both Tables III and IV are also from a Late Prehistoric site in the southern Bighorn Mountains of Wyoming dated to 760 ± 160 years B.P. (A.D. 1190, A-583; Haynes, Damon and Grey, 1966:18). Birkby and Bass (1963) provide a rather complete description of these specimens with drawings. The large "Lakotid" sample was drawn by Neumann (1952) from among various bands of historic Dakota Sioux.

The Late Middle Period and Late Prehistoric female samples in Table IV are those from Table II shown in contrast with contemporaneous materials from other parts of Wyoming and the Great Plains, and also compared with two well-dated earlier specimens from

TABLE II. FEMALE CRANIA.

Measurement or Index	Torrington (n=1)	Late Middle Period (n=2)	Late Prehistoric (n=1)
Cranial length	---	175.3[3]	176
Cranial breadth	---	131.5	131
Basion-bregma	---	130[1]	128
Cranial capacity	1272 cc	1268 cc	1272 cc
Cranial module	144.33	144.33[1]	145.00
Cranial index	---	75.80	74.43
Length-height index	---	75.15[1]	72.73
Total face index	---	84.55[1]	85.39
Upper face index	52.34	53.04	50.77
Orbital index	82.93	84.62	80.49
Nasal index	54.35	52.88[3]	54.00

As in Table I the measurements are millimeters. The superscripts seen within the Late Middle Period sample indicate sample numbers for certain characteristics that are greater or smaller than the n value shown for the rest of the traits listed. The cranial measurements for the Torrington specimen are not presented since the skull has obviously been affected by some form of cranial deformation. Only those measurements and indices which theoretically remain unaffected by deformation are listed for that specimen.

TABLE III. MALE COMPARISONS

Measurement or Index	Late Middle Period (n=1)	Torrington Howells '38 (n=1)	Late Prehistoric (n=6)	P.K. Bass & Lacy '63 (n=3)	Turk Birkby & Bass '63 (n=3)	Lakotid Neumann '52 (n=63)	Arikara Bass '64 (n=120)	Pawnee Bass '64 (n=34)
Cranial length	198	190	186.6	189	186.3	184.8	179.2	175.8
Cranial breadth	147	(138)	145.8	139.7	140.0	143.8	140.7	139.6
Basion-bregma	141	---	127.5	129.7	128.0	129.8	132.9	128.7
Cranial capacity	1615 cc	[1422 cc]	1448 cc	[1457 cc]	[1415 cc]	1486 cc	---	---
Cranial module	162.00	---	153.17	153.84	151.5	152.7	---	---
Cranial index	74.24	(72.6)	78.4	74.60	75.15	77.89	78.6	79.3
Length-height index	71.21	---	68.58	67.02	69.18	70.3	74.5	73.2
Total face index	82.52	81.6	89.22	---	---	87.1	---	---
Upper face index	54.55	54.6	50.58	---	48.91*	53.13	53.4	51.8
Orbital index	81.82	80.5	82.72	---	75.56*	90.15	---	---
Nasal index	50.91	50.0	50.67	---	54.00*	48.9	48.9	49.0

* These indices were derived from one individual only.
( ) These are estimated measurements or indices of a single specimen which were derived in part from an estimated measurement.
[ ] These figures were calculated by me from data provided by the original authors.
In some cases values given by the original authors have been rounded off to the first decimal position. As in previous tables measurements are in millimeters. For certain means within the "Late Prehistoric" sample, n is slightly less or greater than 6, and these exact deviations are indicated in Table I.

TABLE IV. FEMALE COMPARISONS

Measurement or Index	Gordon Creek Breternitz '71 (n=1)	McKean Stewart '54 (n=1)	Torrington Combined (n=3)	Late Middle Period (n=2)	Laramie Lady Agogino '61 (n=1)	Late Prehistoric (n=1)	Turk Birkby & Bass '63 (n=1)	Sioux Hrdlička '27 (n=4)
Cranial length	173	172	179.5	175.3	179	176	172	178
Cranial breadth	138	(141)	134.5	131.5	132	131	129	138
Basion-bregma	---	---	122*	130	134	128	122	126
Cranial capacity	[1193 cc]	[1279 cc]	1280 cc	1268 cc	[1307 cc]	1272 cc	[1235 cc]	---
Cranial module	---	---	145.66	144.33	[148.33]	145.00	141.00	147.3
Cranial index	79.7	(82.0)	74.9	75.80	73.70	74.43	75.00	77.7
Length-height index	---	---	67.4*	75.15	74.86	72.73	70.93	70.6
Total face index	---	---	88.4*	84.55	---	85.39	---	86.3
Upper face index	---	---	54.87	53.04	46.27	50.77	---	53.5
Orbital index	78.3	---	82.27	84.62	90.00	80.49	87.50	92.3
Nasal index	---	---	49.28	52.88	---	54.00	50.00	49.3

* These indices were derived from one individual only.
( ) These are estimated measurements or indices of a single specimen which were derived in part from an estimated measurement.
[ ] These figures were calculated by me from data provided by the original authors.
The combined Torrington sample consists of two females described by Howells (1938) and the one Torrington female listed in Table II. Certain means within the "Late Middle Period" sample deviate from n=2 and these are indicated in Table II. As in previous tables measurements are in millimeters.

the region. The more ancient of these earlier specimens is that from Gordon Creek, a Paleo-Indian burial site (9,700 ± 250 B.P.) just across the Wyoming border in north-central Colorado (Breternitz et al., 1971). The McKean site skull from the Early Middle Prehistoric Period, and shown in the table, is approximately 4,500 years old; it has been well described by Stewart (1954). The Torrington sample in Table IV combines the specimen listed in Table II with the other females from the site described by Howells (1938). The "Laramie Lady" was decribed by Agogino (1961) and appears to have been firmly dated as Late Middle Period through fluorine analysis. The large sample of Historic Sioux listed in Table IV was studied by Hrdlička (1927).

BIOLOGICAL AFFINITIES

From the metric data, which have been

supported by the non-metric data, it is clear that the Late Prehistoric Wyoming skeletal populations show close biological affinity to the Historic Sioux. Unfortunately exact tribal affiliations of the Late Prehistoric Wyoming specimens cannot be discerned. However, the sample undoubtedly contains individuals from a number of different but biologically closely related tribal groups.

Even though the close relationship between the Wyoming populations and Sioux is obvious from our findings a few important differences appear to exist as well. The male crania from Wyoming appear a little larger and more rugged than Sioux skulls and seem to possess a somewhat lower vault than even the Sioux. Nasal and orbital indices among all Wyoming samples differ from those of the Sioux. As may be seen from the tables the Wyoming populations in no case show nasal indices as low as those for the Sioux (or Arikara-Pawnee) and in no instance do they show orbital indices as high. In other words the rather narrow aquiline nose and high, rounded orbits described by Neumann (1952) for his Lakotid Plains racial element are not at all predominant among the Wyoming populations.

Probably much more significant than the slight differences in cranial size and orbital form between the Wyoming populations and their neighbors are the differences in morphology of the lower face. The high percentage of individuals lacking nasal sills and showing rather marked alveolar prognathism greatly exceeds the expected. These are the traits identified by Howells (1938) among the Torrington skulls which led him to conclude that the specimens were most likely of great antiquity. As Howells puts it when discussing the Torrington skulls I and III,

> Now, whatever their evolutionary connection, there is almost no general association between prognathism and lack of nasal sill within a particular racial group; in other words, they are independent and not physically connected. Therefore one would not expect more than two or three Siouan (or Pecos) female crania in a hundred to have the same development of the lower nasal and alveolar region as skull III, and not more than one female cranium in five thousand, or at most in one thousand, to resemble skull I in these respects. As to the prospect of finding, associated with one another in the same burial, two Siouan skulls of the type of I and III respectively, this seems from the above figures to have a probability of not more than three chances in a hundred thousand (ibid.:325).

Certainly much of Howells' reasoning was valid in light of the evidence available to him. That is, the chances of finding two skulls exhibiting the morphological patterns of the Torrington crania among a recent population of Dakota Sioux would indeed be remote. However, from our present findings regarding some rather recent Wyoming populations, the chances of finding two such skulls in association would be nearer three chances in 25 than three chances in 100,000.

These findings are likewise consistent with the conclusions of Agogino and Galloway (1963), based upon analysis of artifacts probably associated with the Torrington crania. Their conclusions were that the artifacts, and consequently the skulls, belong to a cultural horizon within the last millenium.

Therefore, even though the traits mentioned by Howells and described here are found among the oldest crania known from this region, it is likewise clear that these very same traits persist more or less unaltered right up until the time of White contact. Why these so-called primitive traits should diminish among the Sioux of the north-central Plains and yet be retained among their neighbors to the west is not clear. But at any rate, from the admittedly limited evidence at hand it seems to have been the case, whatever the reasons.

When we do examine the data in search of possible micro-evolutionary changes through the various temporal levels a few hints at such changes are found. The only two early specimens available, the Gordon Creek and McKean females, show medium sized skulls with low cranial vaults (auricular heights of 100 mm and 108 mm respectively). They also exhibit a rather broad skull form with indices which fall on the mesocranic-brachycranic border -- a condition which disappears by the Late Middle Period (when skulls are found to be larger and longer) and never reappears in this region throughout subsequent periods. This exact pattern of traits, however, in addition to a rather distinctive sagittal contour (exhibited by both of these early skulls) does survive among the Great Plains Arikara to the east and their close relatives the Historic Pawnee. Stewart (1954) was the first to describe this combination of cranial features on the McKean skull when he correctly pointed out its close affinity to what Neumann (1952) had called the Deneid physical type. Bass (1964) later demonstrated very nicely the closeness of the Arikara and Pawnee to this same Deneid pattern of physical traits.

As we move into the Late Middle Period of the northwestern Plains we find, as near as can be determined from the scanty evidence, a continuation of many of the earlier traits such as alveolar prognathism, lack of nasal sill, mesoconch orbital form, and a few characteristic traits of the mandible; however, cranial form appears to be quite different. The larger, longer skull form characteristic of the later periods is certainly present by this time. It seems to differ, however, from those of both the earlier and later periods in being of a higher cranial vault. This apparently unique trait of the Late Middle Period populations may eventually turn out to be nothing more than an artifact of the small sample sizes, but appears at least at this point to be worthy of mention. It can be seen from the tables that only the Late Middle Period females, among all Wyoming samples, exhibit length-height indices at the hypsicranic level. Even though the unusually long skull of the single Late Middle Period male prohibits a high length-height index, it may be worthy of note that his cranial height is 11.3 mm above the next highest mean cranial height among Wyoming males from all samples. Another rugged male skull of quite similar proportions (not shown in the tables) was reported by Steege (1960) and apparently dates from the Late Middle Period. Interestingly, it shows the same high vault as the Late Middle Period male from our collections and also reveals a cranial capacity of 1,600 cc.

With the Late Prehistoric Period comes the final alteration in cranial form which places the Wyoming populations in rather close biological proximity to the Sioux-Lakotid groups of the adjacent north-central Plains. This low cranial vault coupled with a large, long and rather rugged cranial architecture provides the characteristic appearance to these late residents of the northwestern Plains.

What this all means in terms of population dynamics within the region simply cannot be determined from present evidence. Samples are too few, too small, and too fragmentary. In time, as more museum collections from this region are examined and as additional material with provenience is unearthed, a fuller picture will emerge. In addition, it appears that comparison with populations to the west, from the Basin-Plateau region, as well as with those from the northern Plains will form a necessary part of future research. Until this is done all that can be stated with certainty is that certain rather unique patterns of traits show continuity from the earliest temporal levels to the most recent, and yet other traits show closer connections throughout geographical distance (to adjacent populations) than they do throughout time within the region. This is entirely as would be expected within the constructs of the recently proposed "plexiphyletic" model for human evolution (Gill, n.d.).

The plexiphyletic model views human evolution since at least mid-Pleistocene times as change within a single, polytypic species. This evolutionary change at or below the sub-species level (without speciation) is most precisely viewed, according to this view, as a dynamic two-dimensional process involving the interaction of the opposing forces of gene flow and isolation (either geographical or socio-cultural) (Fig. 1). Isolation through such factors as low population density, geographical distance and socio-cultural barriers can be viewed as the reason for retention within the northwestern Plains of certain traits such as alveolar prognathism and reduced nasal sills, while gene flow from adjacent regions (occasionally in the form of actual population migrations) can be viewed as the most likely explanation for the relatively sudden changes in other traits such as

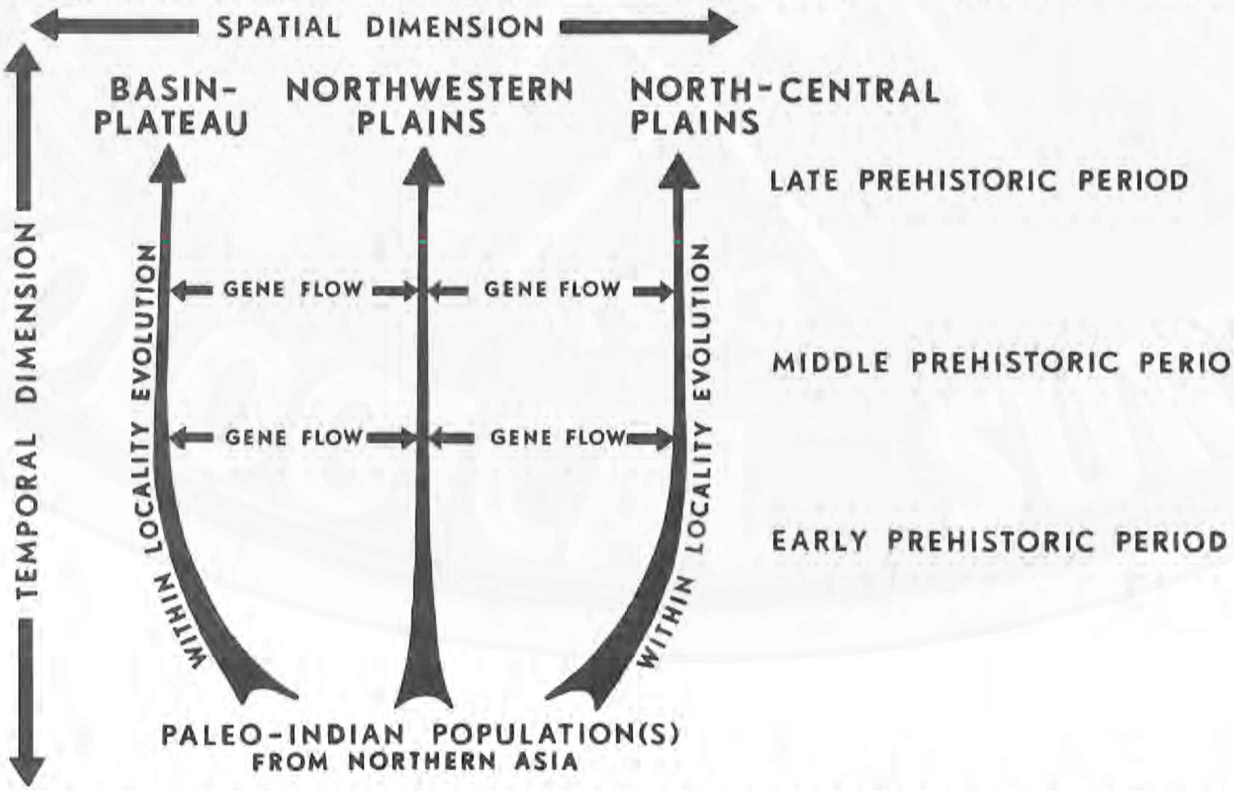

FIGURE 1. A schematic representation of the plexiphyletic model depicting human population dynamics in the Northwestern Plains and adjacent regions. Evolutionary continuity <u>within</u> geographical areas occurs as a result of isolation through time. Continuity <u>between</u> populations of different geographical regions (but of the same temporal horizons) occurs as a result of gene flow across barriers.

cranial size and form, which show greater continuity through space than time.

MORPHOLOGICAL DATING

As T. D. Stewart (1949) pointed out some years ago the basis for the concept of morphological dating was laid as soon as Charles Darwin established evolutionary theory upon a firm foundation. By this time the history of man could be viewed as a process of gradual change, with noticeable alterations in anatomy occurring through time. Once actual fossil representatives of the primitive stages through which man had passed were recovered, then the concept of morphological dating of human remains was actually put into practice. Morphological dating has been defined by Stewart (1949) as "...the idea that the present physical type of man could only be of recent origin, and, reversely, that the more primitive the human physical type the older it must be" (p. 4). Certainly this definition captures the spirit of the technique as it has been employed many times by physical anthropologists. It is the way in which Hrdlička (1903, 1937) attempted to refute the antiquity of Lansing Man, Minnesota "Man" and others, and it is the way in which Howells (1938) attempted to demonstrate a probable antiquity for the same Minnesota "Man", as well as the morphologically similar Torrington, Wyoming crania. Certainly when this technique is adhered to as strongly as it was by Aleš Hrdlička, many problems are encountered. Concerning the Lansing skeleton from Kansas which Bass (1973) has since demonstrated to be approximately 5,550 years old (four C-14 tests averaging 3579 B.C.) Hrdlička made the following statement:

> .... the Lansing skeleton is practically identical with the typical male skeleton of a large majority of the present Indians of the Middle and Eastern States. Any assumption that it is thousands of years old would carry with it not only the comparatively easily acceptable assumption of so early an existence of man on this continent, but also the very far-reaching and far more difficult conclusion that this man was physically identical with the Indian of the present time, and that his physical characteristics during all the thousands of years assumed to have passed have undergone absolutely no important modifications (1903:328-29).

As is suggested by the above statement, Hrdlička had a difficult time imagining evolutionary change operating in any way other than by relatively rapid stages, and in a rather smooth, even fashion -- with little or no chance for some populations to remain in genetic equilibrium for a long period of time. He also had an unusually strong tendency to reject any New World skeleton as ancient no matter what pattern of morphological traits might be exhibited; thus if any completely modern specimen could be found exhibiting the same pattern of traits the comparability was emphasized by Hrdlička. This was his approach in attempting to refute the possibility for the antiquity of the Minnesota skull; that is, by showing that the same traits could be found among the historic Sioux. In fact he went on to say, "If somatological diagnosis is worthy of its name, the Minnesota specimen must be adjudged as inseparable from the Sioux" (1937:193). It was this overstatement which helped spark Howells' justifiable criticism of Hrdlička's position. Howells (1938) states:

> Dr. Hrdlička is also right in pointing out that the primitive characters of the skull may be found occasionally in all Indians, including the Sioux. However, the Minnesota skull, taken as a whole, presents not only an extreme combination of such traits, but has a morphological character of its own which would make it noticeable in any group of Indian skulls. It is typologically unusual; such a form does occur infrequently in known Indian crania, but if the skull is that of a Sioux it is hardly "the characteristic type" as Hrdlička calls it (p. 322).

Certainly Howells' main point is quite valid, and all the way through his report on the Minnesota skull and the Wyoming crania he was much more sophisticated than Hrdlička in the way that he considered the probability of a certain combination of traits occurring at a certain period in time. And since morphological dating of any kind can never be anything more than an expression of probability, his basic approach would then seem to have been sound. Yet, we have clearly seen from the data presented in this report that the probability of great antiquity for the Torrington skulls is reduced considerably from that entertained by Howells at the time of his study. So, are we to conclude from all of this that the pitfalls of morphological dating are simply too great to allow for any consideration of it as a useful tool in dating finds? In other words, should we consider the words of Clark Wissler in 1916 as prophetic when he stated, "The day of anatomical determination of age is passing, particularly in America. Age is a matter to be settled by the geologist and archaeologist" (Stewart 1949:12)? Or, on the other hand, are there a few favorable things to be said for this age-old method of dating, which admittedly has caused so many problems? It appears to me that in spite of the negative evidence put forth in the findings of this report for the utility of the morphological dating method, as applied to the case of the Torrington skulls, that the method under certain circumstances can be effectively employed.

The problems faced by Howells in attempting to assess the Torrington crania were not due to shortcomings in his approach so much as to insufficient skeletal material for comparison. In fact, his assessment of the situation based upon the evidence at hand was actually quite good. We must remember that Howells had no other human skeletal remains available from Wyoming, from any time period, with which to compare the Torrington sample. His grounds for separating the Wyoming remains from the historic Sioux are in fact supported by our recent findings.

So, the pitfalls in applying a concept of morphological dating seem to arise most generally from over-extending the limited data, and in some cases from adopting an oversimplified view of evolutionary process which dictates certain expectations for the fossils which are too narrow. In fact over the years paleoanthropologists have come to realize that human evolution has been anything but a picture of smooth, even, predictable change, particularly when dealing with relatively short periods of time, as in the case of evolutionary change among New World populations. As a matter of fact, rather uneven and some very complicated patterns of change appear to typify evolutionary process among New World populations. This means that a number of factors must be considered if any sort of morphological dating is to be carried out successfully. A few of these are:

1. A broader, less restrictive definition of the concept behind morphological dating must be adopted than the one mentioned above. That is, it must allow for wider genetic variability through both time and space, and for greater complexity in the evolutionary process. The older idea that present physical types of man must, in all cases, be of recent origin can no longer be supported and neither can the reverse of this, as stated in the definition.

2. The local racial history of a region must be reasonably well known in order to allow any sort of valid assessment of unknown specimens.

3. The greater the sample size of the unknown specimens and the greater the number of diagnostic traits considered, the greater the probability of proper temporal placement of them.

Regarding the establishment of a new definition for the concept of morphological dating perhaps the following will serve. It will at least be more in keeping with the present state of knowledge regarding population dynamics:

> Morphological Dating: the dating of unknown skeletal specimens based upon the fact that within a given geographical region quantifiable population changes occur through time, providing characteristic patterns of biological traits unique to the various temporal levels.

It may be seen that implementation of the concept as described above rests upon two main factors: 1) a good understanding of the traits characteristic of populations at the various time levels, which can be gained only through detailed description of numerous well-dated skeletal samples, and 2) as thorough an analysis as possible of the unknown sample in order to decrease the chance of overlooking significant differences between the tested sample and the comparative samples. Regarding this latter point, the best way to increase the probability of successful identification, as mentioned earlier, is through examination of the greatest number of diagnostic traits on the greatest possible number of specimens.

Certainly it can be seen that by following the concept as defined here, and by following it according to the guidelines just stated, successful morphological dating is theoretically possible. In fact we often use it in this way without calling it morphological dating. For instance, in the northwestern Plains when a skeleton is recovered which is clearly Caucasoid in physical appearance, the find is certainly known not to be Late Middle Period or Early Prehistoric Period, but rather to be of a quite recent age, at least since the period of earliest white contact in the region. Even though this is an extreme and oversimplified example it demonstrates the fact that morphological dating, as we view it here, not only can be but is used as a successful method of dating. Extending this method back into the prehistory of the Plains, when much less extreme microevolutionary differences constitute the only differences between temporally contiguous populations, will of course necessitate much more refined techniques of analysis than those used to distinguish a Caucasoid from an American Indian. However, I presently see no reason why refined techniques such as these cannot in time be developed for the study of the native populations of the northwest Plains and elsewhere. In fact as more evidence is gathered and as methods of analysis are improved it would appear that the dating of prehistoric human remains based upon specific patterns of morphological traits will become more and more useful as a tool in scientific investigation.

ACKNOWLEDGEMENTS

The author would like to express his sincere gratitude to Dr. William T. Mulloy and Dr. George C. Frison of the Department of Anthropology, University of Wyoming, for assistance during the preparation of this study. Both were instrumental in the collection of skeletal specimens for the University of Wyoming collections, and their advice as to possible prehistoric population dynamics aided the author in the formulation of the hypotheses presented above.

REFERENCES

Agogino, G. A.
1961 A Middle Prehistoric burial from Laramie, Wyoming. Plains Anthropologist, 6(13): 202-204. Norman, Oklahoma.

Agogino, G. A., and E. Galloway
1963 The skulls from Torrington, Wyoming: a re-evaluation. American Antiquity, 29 (1):106-109. Salt Lake City, Utah.

Bass, William M.
1964 The variation in physical types of the prehistoric Plains Indians. Plains Anthropologist, Memoir 1, 9(24):65-145. Lincoln, Nebraska.
1971 Human Osteology: A Laboratory and Field Manual of the Human Skeleton. Missouri Archaeological Society Special Publica-

tion. Columbia, Missouri. 280 p.
1973 Lansing Man: a half century later. American Journal of Physical Anthropology, 38(1):99-104. Philadelphia, Pennsylvania.

Bass, William M., and Donald C. Lacy
1963 Three human skeletons from the P. K. Burial. Plains Anthropologist, 8(21): 142-157. Lincoln, Nebraska.

Birkby, Walter H., and William M. Bass
1963 Possible Shoshonean skeletal material from the Turk Burial Site, 48 WA 301. Plains Anthropologist, 8(20):103-114. Lincoln, Nebraska.

Breternitz, David A., Alan C. Swedlund, and Duane Anderson
1971 An early burial from Gordon Creek, Colorado. American Antiquity, 36(2):170-182. Washington, D.C.

Gill, George W.
1971 The Prehistoric Inhabitants of Northern Coastal Nayarit: Skeletal Analysis and Description of Burials. Doctoral Dissertation (Anthropology), University of Kansas, Lawrence, Kansas. 283 p.
n.d. A Plexyphyletic Model for Human Evolution. Unpublished manuscript, in possession of the author.

Haynes, C. Vance, Jr., Paul E. Damon, and D. C. Grey
1966 Arizona radiocarbon dates VI. Radiocarbon, 8:1-21. New Haven, Connecticut.

Howells, W. W.
1938 Crania from Wyoming resembling "Minnesota Man". American Antiquity, 3(4):318-326. Menasha, Wisconsin.

Hrdlička, Aleš
1903 The Lansing Skeleton. American Anthropologist, n.s., 5:323-330. Lancaster, Pennsylvania.

Addendum:

Dates given in the preceding article for the Turk and P. K. Burials are the revised dates, as recomputed and listed by C. Vance Haynes, D. C. Grey, P. E. Damon, and R. Bennett (1967), Arizona radiocarbon dates VII, Radiocarbon, 9:12.

1927 Catalogue of human crania in the United States National Museum Collection. Proceedings of the United States National Museum, 69(5):1-127. Washington, D.C.
1937 The Minnesota 'Man'. American Journal of Physical Anthropology, 22(2):175-199. Philadelphia, Pennsylvania.

Montagu, M. F. Ashley
1960 A Handbook of Anthropometry. Charles C. Thomas, Springfield, Illinois. 186 p.

Mulloy, William
1958 A preliminary historical outline for the Northwestern Plains. University of Wyoming Publications, 22(1):1-235. Laramie, Wyoming.

Neumann, Georg K.
1952 Archaeology and race in the American Indian. In James B. Griffin (Ed.), Archaeology of the Eastern United States: 13-34. University of Chicago Press, Chicago, Illinois.

Olivier, Georges
1969 Practical Anthropology. Charles C. Thomas, Springfield, Illinois. 330 p.

Steege, L. C.
1960 A probable Middle Period burial in Wyoming. Plains Anthropologist, 5(10):82-83. Norman, Oklahoma.

Stewart, T. D.
1949 The development of the concept of morphological dating in connection with early Man in America. Southwestern Journal of Anthropology, 5(1):1-16. Albuquerque, New Mexico.
1954 The Lower Level Human Skull, Appendix. In William Mulloy, "The McKean Site in Northwestern Wyoming". Southwestern Journal of Anthropology, 10:432-468. Albuquerque, New Mexico.

THE HOLOCENE STRATIGRAPHIC ARCHAEOLOGY OF WYOMING: AN INTRODUCTION

GEORGE C. FRISON[1], MICHAEL WILSON[2], AND DIANE J. WILSON[3]

ABSTRACT

Current trends in archaeology favor the use of radiocarbon dating and other absolute techniques at the expense of relative chronologies. However, for the Holocene stratigrapher's purposes, it is possible to apply available local radiocarbon dates to relative chronologies, and produce comparative sequences of good predictive and correlative value. Using such a base, the stratigrapher in many cases need not obtain new radiocarbon dates if good artifact assemblages are available for dating purposes. Portrayal of artifact types in technofacies diagrams allows rapid assessment of trends and relationships, as such diagrams are similar to the facies plots of lithostratigraphers and biostratigraphers. Technofacies are purely descriptive and have no implied cultural connotations. Technofacies transects of northern and southern Wyoming reflect a temporal gradation toward smaller projectile size, accompanied by diminution of projectile points and a shift from closed-socketed forms to split-shaft-hafted notched forms. Fluted, lanceolate, bibevelled, large side-notched, stemmed atlatl, corner-notched, and small side-notched points all have value as indicators of the age of deposits. A number of technofacies within the McKean Technocomplex present a complex picture of related types with both temporal and spatial diversity. Recognition of Yonkee and Mallory points as arbitrary types within the McKean Technocomplex aids in the description of this diversity. Even given the difficulties inherent in assessment of the true contemporaneity of radiocarbon-dated materials, there is ample evidence for the presence of diverse yet contemporary artifact styles at least as far back as 8,000 years.

Archaeologists of today rely heavily upon the use of radiocarbon dating in the control of chronology. As a result, it is at times difficult for the modern student of the Holocene to recall that only 25 years ago, the technique had barely been conceived. Prior to 1950, absolute control of chronology was limited to a few special situations where tree rings, varves, or similar structures were present; and to uniformitarian techniques of more limited accuracy, such as estimates of time required for deposition and erosion.

The advent of the radiocarbon dating method (Libby, 1952; 1955) brought what many hoped would be a universal temporal standard to Holocene stratigraphy. Since its initial definition, the official half-life of the isotope ^{14}C has been revised from 5,570 to 5,730 years (Godwin, 1962). The dating of tree rings has brought us to the realization that atmospheric ^{14}C levels have not been constant through time (Suess, 1970). Nevertheless, radiometric dating remains our most widely applicable absolute dating technique, and our base line for the calibration of other curves, such as those of obsidian hydration[3] and lichen growth[4].

Use of the radiocarbon method has brought numerous successes and insights to archaeological chronology. A major success has been the demonstration that megalithic structures in western Europe date to a period early in the development of Near Eastern Bronze Age civilizations, thus making improbable the old hypothesis that the western European structures were "influenced" by stimulus diffusion from centers of civilization in the Near East (see Burl, 1973 for dates of British structures).

Another important advance is the recent demonstration that the type Temple Lake moraine of the North American "Neoglaciation" is pre-Altithermal rather than post-Altithermal in age (Currey, 1974; Miller and Birkeland, 1974). This confirms the original impressions of Hack (1943) and Moss (1949; 1951), and invalidates a tenuous correlation hypothesized by Richmond (1962).

There remain numberless situations where radiocarbon dating is either impossible (due to lack of datable material in a site), or impracticable (due to a lack of funding for an expensive series of dates). Many stratigraphers deal with problems sufficiently broad in scope that they involve large numbers of sites for which dates are required.

Relative chronologies are, of course, available to them. In the case of archaeological materials, temporal variations in artifact styles serve to indicate the relative age of a site. There are, of course, constraints upon the method, but the generalization will serve here. Such chronologies, in conjunction with estimates of absolute age, were the rule prior to the development of radiocarbon dating. In the

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[4]see Frison, George C., this volume, p. 61-64.

[5]see Andrews, J. T., and P. J. Webber, this volume, p. 65-70.

absence of a recent synthesis of detailed data from the northern Plains, Mulloy's (1958) chronology -- based upon relative sequences of horizon styles and very few radiocarbon dates -- is still widely used.

Today, however, archaeologists are in the throes of a move toward greater empirical control of data (the so-called "New Archaeology"). Papers in leading journals such as *American Antiquity* have swung from descriptive papers about archaeological sites, surveys, and artifacts to descriptive papers about data-processing methods (the latter sometimes wrongly called "theory"). In such an environment, it is not surprising that the old relative chronologies have been buffeted about at the hands of "scientific archaeologists". It is quite fashionable among the young archaeologists at national and regional meetings to treat the old chronologies with considerable condescension (and even derision) while stressing the sophistication of modern chronometric methods.

There is little doubt that the methods described in recent papers are often extremely valuable. One gets the occasional impression, however, that all of an author's effort has gone into development of a method -- and very little of that effort has gone into critical evaluation of illustrative data. Sometimes the data do not fit or even justify the method, however sophisticated it might be. A glaring example of such a defiency is the paper by Lyons (1970) concerning an isochronous analytic technique for the comparison of radiocarbon dates. The technique is interesting and perhaps even useful; however, he selects a limited set of Paleo-Indian dates, and generates temporal trends that are subtle enough to be completely invalidated when standard deviations of dates are considered. As cogently pointed out by Wilke and Taylor (1971), Lyons' trends based on C-14 median dates are quite worthless -- and thus his use of data does absolutely no justice at all to his method!

Despite current trends, firm absolute dates are not always completely necessary in studies involving Holocene deposits. Where clear stylistic relationships of artifacts can be demonstrated, a reasonable measure of age can be extrapolated from already-obtained dates on similar materials from nearby sites. We are in a better position now than ever before to utilize horizon styles in the dating of enclosing deposits: we now have absolute dates from many sites with which to calibrate our chronology.

In the present paper we wish to review for the Holocene stratigrapher a few methods and concepts relating to the use of archaeological horizon styles -- the "index fossils" of the Holocene -- in the dating of deposits. We further wish to summarize the comparative resources available in terms of Wyoming's archaeological record.

THEORY AND METHOD

A classic, and as yet not completely resolved problem in archaeology has been the interpretation of the relationship between artifact styles and paleocultural boundaries. When we see regional distribution of a specific style of projectile point, does this imply cultural homogeneity? When we arrive at an apparent geographic boundary in this distribution, does it imply the existence of a cultural boundary?

Discussions of this problem are the rule from classroom to conference, and it is not necessary to dwell upon specific proponents of the respective hypotheses. However, we may note that there do indeed seem to be interregional variations in artifact styles in the archaeological record. In certain Late Prehistoric cases, correlation of styles with cultures has been made. Pottery types from Plains sites have been referred with some degree of confidence to several groups including the Pawnee, Arikara, Cheyenne, Mandan, Hidatsa, Crow, and other groups (Wedel; 1961; Wood, 1971). The resulting distributional data have been used in the reconstruction of Late Prehistoric intercultural dynamics (Lehmer, 1971).

At earlier time levels pottery is not available, and the degree of strictly stylistic input in the manufacture of stone artifacts is not well known. Certain "stylistic" changes are in reality technological ones. For instance, the notable decrease in size in projectile points from Early to Late Prehistoric times can in a general way be correlated with ongoing changes in the overall projectile -- from spear to atlatl dart to arrow (Wedel, 1961; Wormington and Forbis, 1965; see Mulloy, 1958 for period nomenclature).

Along with the decrease in projectile size there comes a change in the point width to shaft width relationship. Early stemmed point types appear to have been socketed in a projectile shaft or foreshaft of approximately the same width (Fig. 1, a). The extent of basal and lateral grinding may be a rough indicator of the extent of socketing.

Socketing would have been an efficient procedure where large shafts were involved; but as diameters decreased, other, less exacting procedures were adopted. The complex admixture of Early Middle Period stemmed and notched types suggests that for these atlatl points more than one hafting procedure was in vogue. Within the McKean Technocomplex of the Early Middle Period a range of stem types suggests true socketing in some variants such as type McKean points (Fig. 2, a) with the blade width and shaft width nearly equivalent. Others, such as Duncan points (Fig. 2, b), are suggestive of a blade width wider than the shaft width, but still a socketed base. However, the expanding-stemmed Hanna points (Fig. 2, c) of the same technocomplex seem more appro-

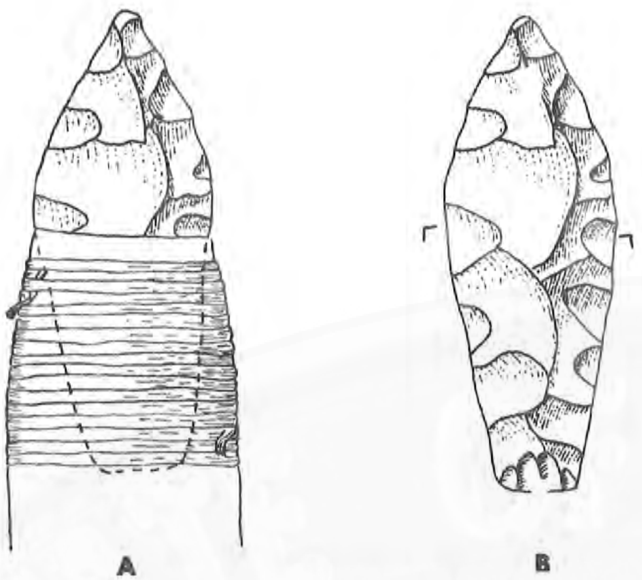


FIGURE 1. Hypothesized hafting procedure for Hell Gap points. A. Hell Gap point in socketed shaft or foreshaft, bound with sinew. B. Hell Gap point, showing extent of lateral and basal grinding (extent of grinding indicated by symbols). Length of original point, approximately 4 inches. After an experimental design by Frison.

priate for a modified socket with open sides -- a split shaft -- in which the widest point of the base protruded from the lateral margin of the socket. True side-notching, as seen in the pre-McKean Early Middle Period Oxbow point type from the northern Plains (Fig. 2, d) probably again represents a split-shaft-socketed form in which the notch functioned to narrow the hafting area of the point to the width of the projectile shaft.

Side-notched and corner-notched points

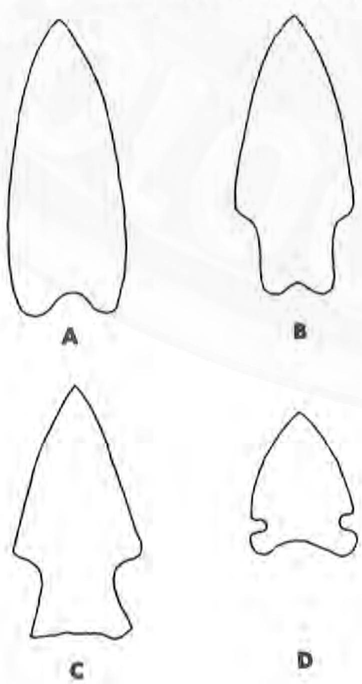


FIGURE 2. Outline drawings of points in the McKean and Oxbow Technocomplexes. A. McKean lanceolate point. B. Duncan point (McKean Technocomplex). C. Hanna point (McKean Technocomplex). D. Oxbow point. Length of A., approximately 2 to 3 inches.

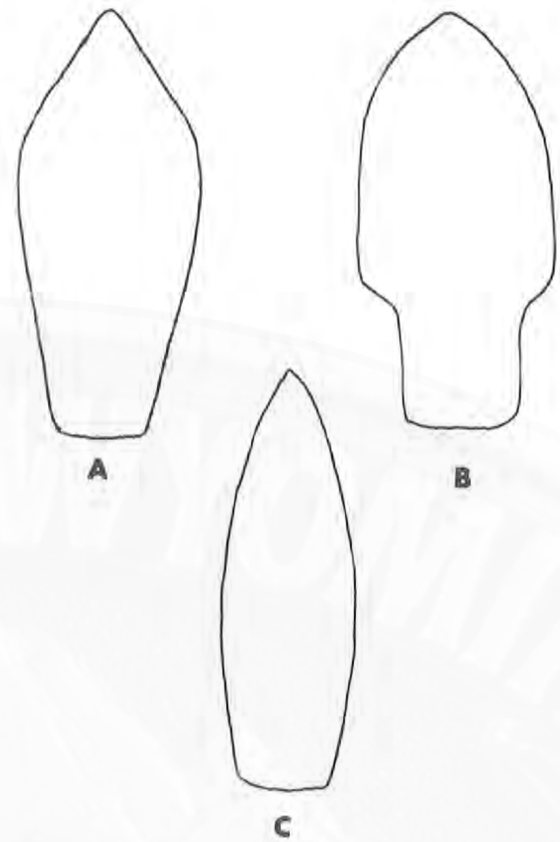


FIGURE 3. Outline drawings of certain Paleo-Indian (Early Prehistoric Period) points. A. Hell Gap point. B. Alberta point. C. Agate Basin point. Length of A., approximately 4 inches.

were most numerous in terms of the overall point inventory during Late Middle Period and Late Period times. With the shift in emphasis toward use of the bow and arrow, full socketing must have become an unworkable procedure. To compromise the needs of adequate blade width with narrow shaft diameter, notches were made in the sides or corners of points. Thus the notch width rather than the blade width is an approximate indicator of projectile diameter. This suggestion is borne out by archaeological discoveries of hafted notched points in dry caves (Frison, 1965; Mulloy, 1958).

Given this admittedly hypothetical approach, one is pressed to find true "stylistic" as opposed to functional changes in projectile point morphology. However, within each of the three broad chronological stages discussed above (spear - atlatl dart - arrow) there remains considerable variation, and specific point varieties seem to characterize certain sites or areas. The differences among typical Hell Gap, Agate Basin, and Alberta points (Fig. 3) may fall within this category, although technological evolution involving the point shoulder is certainly a valid alternative hypothesis for their morphological differences.

In addition, the error of radiocarbon dates at the Paleo-Indian time level does not allow us to confidently claim (in other than random statistical terms) either coincidence or non-coincidence of proximate cultural events. Thus, our perspective on the possible diversity (at any one time level) of Paleo-Indian cultural events is neither clearly synchronic nor diachronic.

At the opposite end of the time scale, we have in early historic records a considerable body of information concerning the distribution, dynamics, and diversity of aboriginal populations. Convincing arguments can be made for intertribal stylistic variation at a single point in time, and, of course, for differing types of activities and subsistence bases (for instance, see Frison, 1967a; 1967b, on the Crow). Authors such as Strong (1940) and Wedel (1961) have demonstrated the value of the direct historical approach, and subsequent authors have attempted tribal identification of Late Prehistoric peoples, with varying degrees of success. Other authors, such as Husted and Mallory (see Husted, 1969: 81-97) have attempted to push far back in time the identification of archaeological cultures with language groups; such efforts are indeed speculative and criticism of their conclusions at this time would be as lacking in supportive evidence as are the hypotheses.

At the present time it would be very foolish for us to advocate an hypothesis that projectile point types equalled cultures. But such an hypothesis (even if not generally applicable) remains available as one of an open set of similar hypotheses. One alternative would be the hypothesis that projectile points were strictly functional, reflecting in their morphology the ongoing subsistence preferences of their users. Not surprisingly, this hypothesis overlaps the previous one -- cultures often tend to be different because of basic ecological differences, or more arbitrary differences in their strategic approach to similar ecological reality.

We must also consider the findings of Ahler (1970), who was faced with an almost bewildering array of "projectile point" types at Rodgers Shelter, in Missouri. Ahler's functional and experimental study strongly suggests that one element in "projectile point" diversity is a functional one, relating to differing uses. In fact, he finds, not all "projectile points" were really used as projectile points. Some were used as knives, others as drills, and still others had various sorts of intermediate prying, twisting, and scraping uses. His findings represent a challenge to other archaeologists to determine whether or not classic "projectile points" were really used for that purpose, with its special set of technological constraints.

Let us breathe a certain sigh of relief and point out, however, that to the Holocene stratigrapher, <u>cultural</u> identification is an esoteric side interest. We can <u>typologically</u> identify a projectile point assemblage without reference to cultural reconstruction. In doing so, we parallel the actions of stratigraphic paleontologists, who in a great many cases use morphological variations of little formal <u>biotaxonomic</u> importance as predictive, correlative devices. Biological reality, like cultural reality, is an esoteric sideline. It really does not matter if a given describable variation marks a genus, a species, a subspecies, or a variety -- as long as the variation is useful to the stratigrapher as a predictor of the condition sought.

The incomplete overlap in goals between biological and stratigraphic paleontologists has been reflected in differing taxonomic philosophies -- basically, the "lumper-splitter" arch-rivalry. Correspondingly different taxonomic philosophies are noted in the discussion of projectile point types. Classic examples from the Northern Plains include Mulloy's lumping (1954) and Wheeler's splitting (1954) of the various projectile point variants of the McKean Technocomplex; or Kehoe's lumping (1966) and Forbis' splitting (1962) of the Late Prehistoric side-notched point types. As long as these sorts of conflicts in taxonomy -- and the differing goals that led to them -- are kept in mind, pointless arguments over the "reality" of arbitrary type-names can be kept to a welcome minimum. There is, in the overall view, no element of "correctness" or "truth" in taxonomic designations -- only the element of <u>utility</u>. If a taxonomic term is useful, keep <u>it</u>. If it has no use, forget it -- but do not prejudge its utility or lack of utility for future researchers with differing goals in mind.

With a taxonomy in hand, we can plot the occurrence of our arbitrary types in time and space -- just as the stratigraphic paleontologist lays a time-space basis for his comparative studies. We can thus talk of technological facies -- <u>technofacies</u>, or <u>distributionally bounded assemblages of</u> specific types. These technofacies will grade into one another in both space and time, in describable ways. In using a facies concept we do not imply the existence of boundary discontinuities, although detailed analysis of facies changes may lead us to the discovery of such discontinuities in some cases.

A simplified, hypothetical technofacies plot showing the existence of a west-to-east temporal gradient in the occurrence of an artifact type, is presented in Figure 4, a. An alternative, less interpretive plot involving an array of columns representing intraregional subareas is shown in Figure 4, b. Such a columnar diagram could well serve as the base for a technofacies plot. Note once again that we are plotting only the occurrence of our arbitrary technological styles or types -- such as projectile point types -- and <u>not</u> the occurrence of archaeological cultures.

FACIES CONCEPTS

The concept of the <u>facies</u>, developed by A. Gressly in 1838 (see Dunbar and Rodgers, 1957: 136) is easily applicable here.

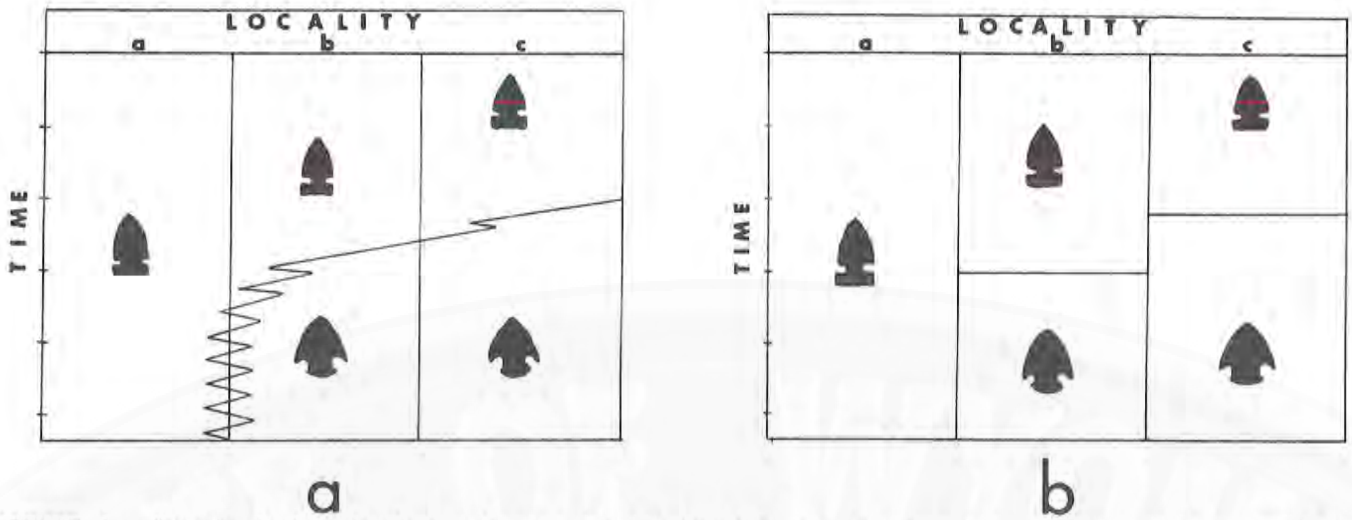


FIGURE 4. Hypothetical technofacies diagram (a) and intraregional sequence diagram (b) showing a temporal and spatial trend of a transgressive nature involving a specific artifact type. Later appearance of side-notched points in an eastward direction (to the right) suggests movement, or onlap of the style from the west. No movement of peoples is necessarily implied.

Basic concepts implicit in the use of facies -- in this case, technofacies, include the following (modified after Dunbar and Rodgers, loc. cit.):

1. Deposits of a given temporal and stratigraphic unit show more than one aspect, each aspect being a facies;
2. Wherever a given facies occurs, it is characterized by the same assemblage of frequent horizon styles; and
3. A given assemblage of frequent horizon styles excludes styles frequent in other facies.

Use of the word "frequent" in point #3 is important: other styles are not rigorously excluded from a facies. They are merely excluded from frequent occurrence, as such occurrence would necessitate the designation of a new technofacies.

Facies change can be signified at more than one level: for instance, changes between assemblages of styles can be viewed as microfacies; while changes between complexes of assemblages can be viewed as macrofacies.

TECHNOLOGICAL SUCCESSION

Discussion of temporal variation in artifact assemblages leads us to investigate the nature of succession. We must recognize that the mechanism of succession is not a genetic one endogenous within the artifact class. It is an enculturative one: that is, artifact makers learn their skills through formal or informal education from other craftsmen. The mechanism is thus complex in that transmission is in many cases through two human "filters". The student can, of course, imitate the work of his educator directly -- thus removing one filter -- but there is still ample leeway for stylistic change during the filtering process.

In cases where educator and student share the same cultural environment, the function of a given artifact class will presumably also be shared. Thus, we can envision a certain limitation of possibilities governing functional attributes of the artifact class in question. Ahler's (1970) detailed analysis of probable use classes of "projectile point" styles at Rodgers Shelter certainly does suggest a limitation of possibilities dependent upon point use.

The conservative nature of societies at the hunter-gatherer level and the limitation of possibilities together are strong enough to favor the transmission of point styles, with slow stylistic drift through time. Stylistic drift is similar in concept to genetic drift, in that it involves random, small-scale changes. No direction of drift is implied: if there is clear direction to stylistic change through time, technological (in terms of the artifact, adaptive) reasons should be sought.

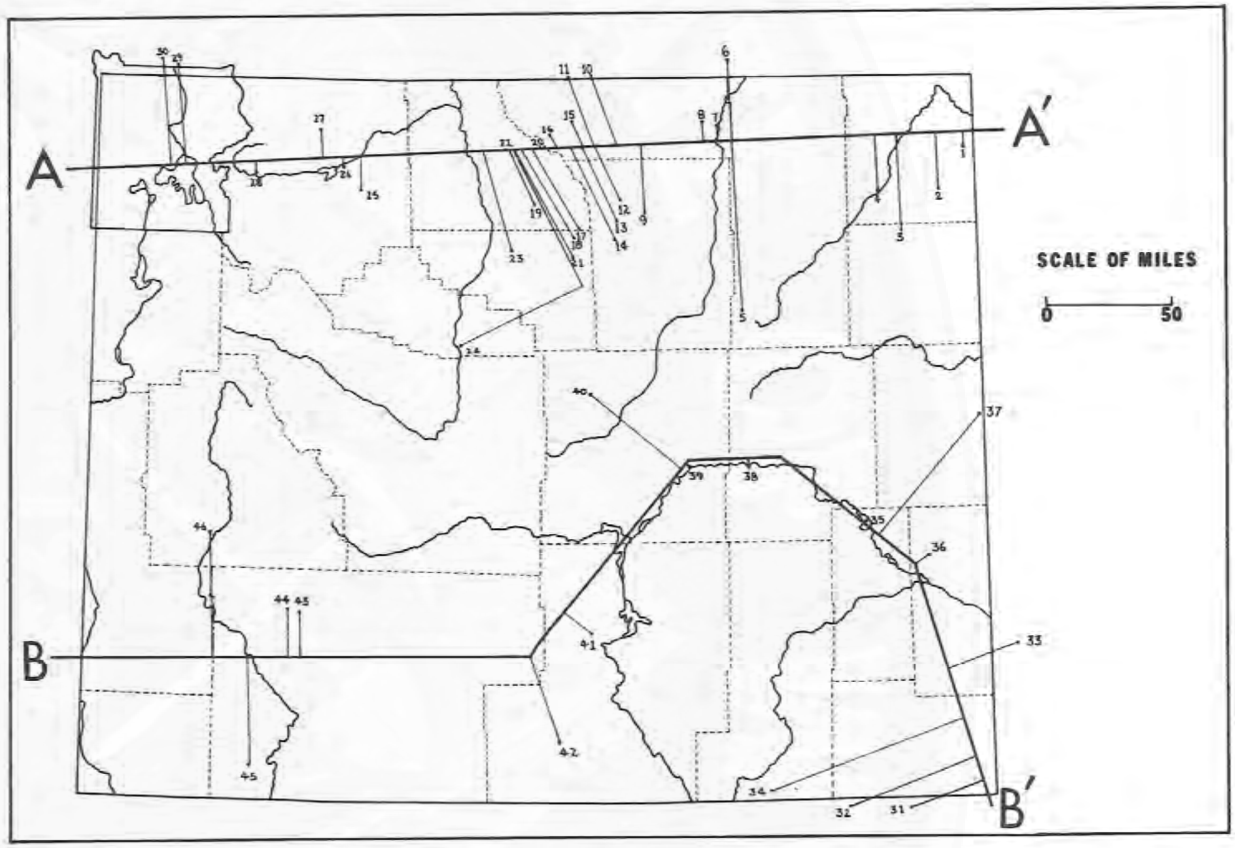
Rapid change in styles is likely to reflect in situ endogenous or exogenous change in the cultural environment (possibly in turn reflecting changes in other aspects of the environment), or migration of populations.

WYOMING TECHNOFACIES TRANSECTS

The following section of this paper describes in some detail two technofacies transects through Wyoming: one in the north, and one in the south. Facies changes are at present incompletely understood, and many large gaps remain in our knowledge. Despite this, clear horizon styles are present, and spatial variation in apparently contemporaneous projectile point styles is observable.

Cultural typologies such as those used by Husted (1969), Reeves (1970), and Lehmer (1971) are avoided here for the most part. These typologies have goals other than those pursued here. Reeves and Lehmer have been

FIGURE 5. Map of Wyoming showing northern technofacies transect (A - A') and southern technofacies transect (B - B') considered in text. Sites are located at dots adjacent to their numbers, and lines project the sites to the transect axes. The following sites are mapped in their approximate locations:



1. Vore Site
2. Hawken Site
3. Fulton Site
4. McKean Site
5. Ruby Site
6. Powers-Yonkee Site
7. 48SH312
8. Mavrakis-Bentzen-Roberts Site
9. Piney Creek Sites
10. Foss Site
11. Kobold Site
12. Sister's Hill Site
13. Schiffer Cave
14. Middle Fork Sites (J0301, 303)
15. Big Goose Creek Site
16. P. K. Burials
17. Leigh Cave
18. Turk Burials
19. Medicine Lodge Creek Site
20. Granite Creek Rockshelter
21. Spring Creek Cave
22. Hanson Site
23. Colby Site
24. Wedding of the Waters Cave
25. Rabbit Bone Cave
26. Horner Site
27. Dead Indian Site
28. Mummy Cave
29. Eagle Creek Site
30. Rigler Bluffs Site
31. Happy Hollow Site
32. Lindenmeier Site
33. Signal Butte Site
34. James Allen Site
35. Glendo Reservoir Sites
36. Hell Gap Sites
37. Agate Basin (Brewster) Site
38. Glenrock Buffalo Jump
39. Casper Site
40. Brown-Weiser Site
41. Scoggin Site
42. U. P. Site
43. Finley Site
44. Eden-Farson Site
45. Pine Spring Site
46. Wardell Buffalo Trap

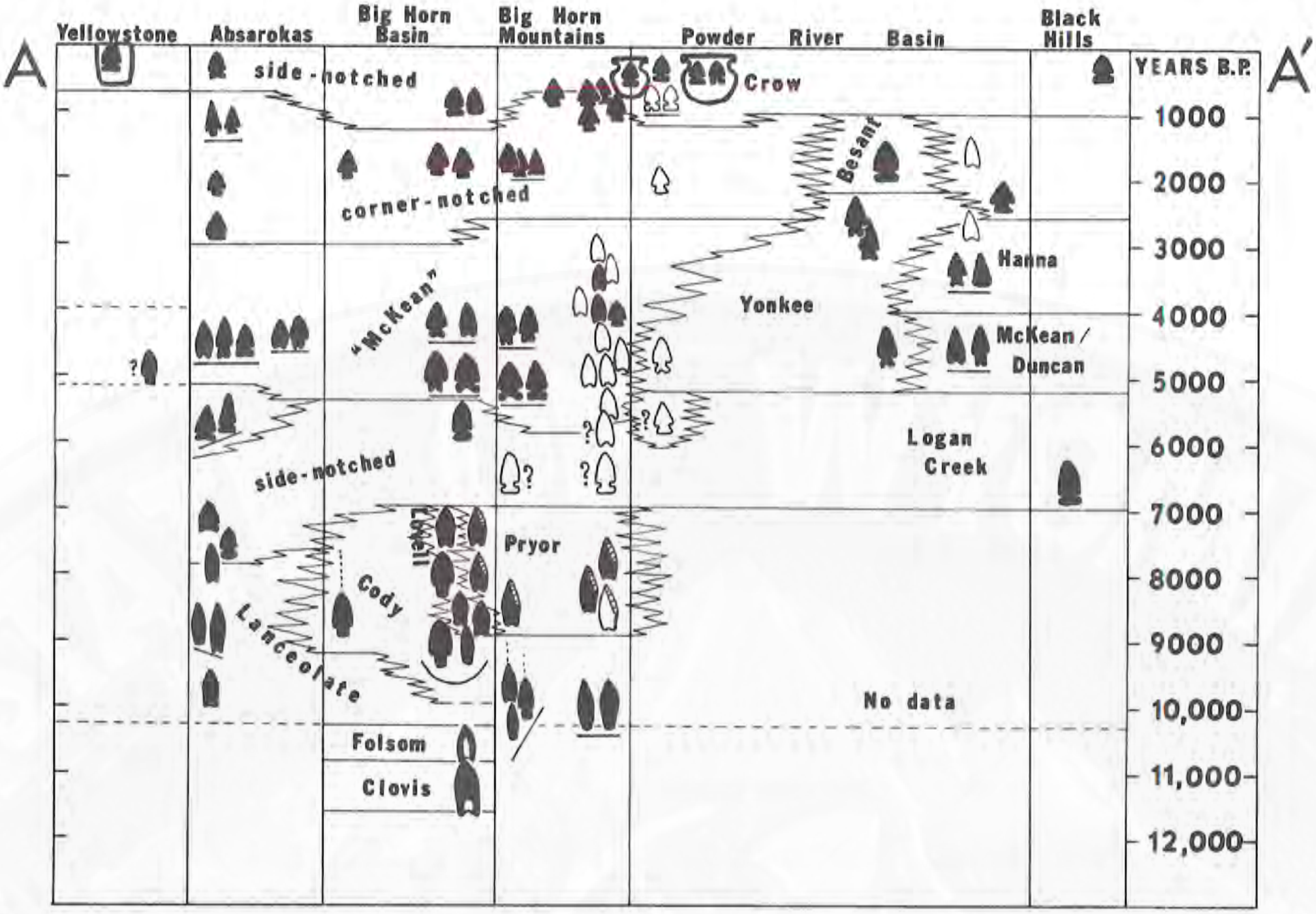


FIGURE 6. Technofacies transect of northern Wyoming. Each projectile point symbol is associated with a date. Symbols linked by horizontal lines represent the same component and date; those linked by slanting lines are closely associated components at a single site, with more than one date available. Outline symbols represent questionable radiocarbon dates, or dates by inference from other evidence. Pottery outlines are shown for Late Prehistoric sites. It is important to remember that this diagram shows technological facies; no cultural patterns or relationships are implied. The point illustrations are not intended to be definitive; researchers should consult the original references cited in the accompanying text.

able to snythesize enormous amounts of data into valuable systematic groupings that show clear promise of paleocultural significance. Both deal with relatively recent archaeological cultures. Husted's cultural groupings go far back in time, to periods with less adequate and less numerous samples; his speculations are best left as simply that for the present until better data are available.

Time-transgressive facies-change lines are indicated on the following technofacies plots only where we believe that dates presently known are significantly different in true age. When differing dates do not do so in a clearly significant fashion, events are assumed to be roughly contemporaneous and no time-transgressive gradients are generated. In doing so, we follow the guidelines of Spaulding (1958) and Reeves (1970), in the hopes of avoiding the unnecessary pitfalls encountered by Lyons(1970) in his ill-fated attempt to justify isochronous analytic procedures (Wilke and Taylor, 1971).

Northern Wyoming Transect

Our first transect runs across northern Wyoming (Fig. 5: A-A'; Fig. 6) from the Black Hills to Yellowstone Park. Several sites up to 75 miles from the line of section are included; the position of these sites is corrected laterally for topographic position rather than being projected along a line normal to the line of section. Some of the sites are just across the border in Montana; however, in view of the strong possibility of local montane differentiation, Montana sites are generally not projected to the Absarokas or Yellowstone Park. Rigler Bluffs and Eagle Creek, two Montana sites, are exceptions to the latter rule, and are included because they lie just north of Yellowstone Park, barely across the border. The Myers-Hindman Site (Lahren, 1971) is somewhat farther north and is not included, although it is clearly a site of potential importance in the area.

The Vore Site near Beulah, Crook County, is a Late Prehistoric multi-component buffalo jump where bison were driven into a sinkhole in gypsum karst. Projectile points are of typical Late Prehistoric small side-notched varieties. Radiocarbon dates on this site, which has not yet been described in any detail in print, are < 230 B.P. (RL-172, 1"-3" depth; unpublished), 200 ± 90 B.P. (A.D. 1750; RL-173, 9' depth; ibid.), and 370 ± 140 B.P. (A.D. 1580; RL-349, deepest level; ibid.)

The Hawken Site, south of Sundance, also in the Black Hills, includes more than one component and is still under investigation. Excavations in one kill area during 1972 resulted in the recovery of a sample of very large *Bison bison occidentalis* with more than 100 large side-notched atlatl dart points. The surprisingly early date of 6,470 ± 140 B.P. (4520 B.C.; RL-185; unpublished) was taken from charcoal in this component. These points strongly resemble the Logan Creek Site points from Nebraska (Kivett, 1962; Wedel, 1961: 87). The Hawken Site thus fills a near-gap in our record from which few sites had previously been known. The Holocene stratigrapher is cautioned that the Hawken Site points are closely similar in overall morphology to certain Late Middle Period points, particularly those classed as Besant. The latter have been recovered from the Ruby Site in Campbell County (see below) and are to be anticipated in the Black Hills. Description of the Hawken points is under way (Frison, n.d.), and it would probably be best for the stratigrapher to await these data.

Late Middle Period corner-notched points were recovered from the Fulton Site, another unpublished site, near Upton, Weston County. These materials were dated to 2,150 ± 150 years B.P. (200 B.C.; RL-350; unpublished).

A series of sites was excavated in the Keyhole Reservoir area of the Belle Fourche River in southwestern Crook County, by Mulloy (1954). The most important of these, the McKean Site (48CK7), yielded two Early Middle Period components. The lower component (not dated) included lanceolate, basally indented points (now known as McKean Lanceolate) and stemmed, basally indented points (now known as Duncan points). Dates from other sites of this typological facies strongly suggest an age of about 4,000 to 4,500 years for the component. The upper component at McKean was characterized by expanding-stemmed points with slightly barbed shoulders (now known as Hanna points) and triangular unnotched points. This component was dated to 3,287 ± 600 B.P. (1337 B.C.; C-715; Libby, 1955: 124).

Two other sites in the Keyhole Reservoir area were dated. One, containing McKean Lanceolate points and rock-filled basin hearths, yielded a date of 2,830 ± 350 B.P. (880 B.C.; C-668; ibid.: 123-124). However, the stratigraphy of the rockshelter was difficult to interpret due to the uneven nature of the floor, and the McKean points came from below the hearths. The date thus cannot be accepted as a clear indicator of the age of the points. A second rockshelter contained McKean points and scattered charcoal; the latter dated to 1,646 ± 200 B.P. (A.D. 304; C-667; ibid.: 124). This date seems unusually late for McKean points, and is thereby questioned. All three Keyhole dates were run early in the development of the radiocarbon method, by the solid carbon technique. Possibly all three should be accepted as only approximate, although C-715 agrees well with expectations.

Besant side- and corner-notched projectile points were recovered from a buffalo kill site, the Ruby Site (48CA302) near Pumpkin Buttes, in Campbell County. Near the kill area was a large ceremonial structure which contained several bison skulls. The structure itself was marked by a series of post-molds forming a football-shaped, or bipointed longhouse (Frison, 1971a). Two dates were run for the site: 1,670 ± 135 B.P. (A.D. 280; GX-1157; ibid.), and 1,800 ± 140 B.P. (A.D. 150; M-2348; Crane and Griffin, 1972: 182). The latter date was cited by Albanese (1971) as 1,790 ± 140 B.P. (same lab number).

In the northern Powder River Basin east of Sheridan, Sheridan County, a group of sites shows evidence of representing a distinctive cultural and typological entity of Early to Late Middle Period age. The recovered points show considerable similarity to points of the McKean Technocomplex (=McKean Lanceolate + Duncan + Hanna + other variants) in the possession of marked basal indentations, but the Powder River specimens are frequently corner-notched, giving them an eared appearance. This calls to mind the Oxbow point type of the northern Plains, dated in some sites in excess of 5,000 years (Dyck, 1970). However, the Powder River specimens (which are of later date) are more attenuated than Oxbow points, and typical Oxbow points tend to be side-notched rather than corner-notched. The Powder River specimens may have typological relationships with both Oxbow and McKean, but such speculations are of limited relevance here. What is important is that these points are remarkably uniform in morphology in the four sites that have been adequately investigated. The points, here designated Yonkee points, range from nearly stemmed to side-notched, with concave to notched or indented bases (Fig. 7). Considerable size variation is noted in the later samples, suggesting the presence of both atlatl darts and the bow and arrow before the end of the Yonkee technofacies.

The Powers-Yonkee Site (24PR5) is a bison kill on a high terrace above a small arroyo near Decker, Montana (just north of the state line). A large sample of points was recovered from the bone bed, which contained very large bison. A C-14 sample gave a date of 4,450 ± 125 B.P. (2500 B.C.; I-410; Bentzen, 1966a). The Mavrakis-Bentzen-Roberts Site, or the Buffalo Creek Site (48SH311) yielded a similar sample of points from a bison bone bed. This site is

30 miles east of Sheridan on a tributary of Buffalo Creek. Small points are well represented in the extensive sample; the appearance of the points is very similar to that noted at Powers-Yonkee (Bentzen, 1966b). However, it is not improbable that a detailed statistical study would reveal differences indicating ongoing temporal variation in the technofacies. Dates on this site were surprisingly late: 2,600 ± 200 B.P. (650 B.C.; I-644; Trautman, 1963), and 2,460 ± 140 B.P. (510 B.C.; RL-160; unpublished).

The third site excavated, 48SH312 (Frison, 1968), was again a bison kill. Located near 48SH311, it yielded a smaller sample of Yonkee points, illustrated by Frison (ibid.: 37). After the publication of this article, a date of 2,910 ± 140 B.P. (960 B.C.; RL-162; unpublished) was obtained.

Level II at the Kobold Site, near Decker, Montana (Frison, 1970a) yielded another component characterized by Yonkee points. Frison (ibid.: 26) observes that the points fit within the range of variation noted by Mulloy (1954) at the McKean Site. However, Frison admits that "the total projectile point assemblages from the two sites are quite different." In fact, very few of the illustrated McKean Site specimens were of the Yonkee type. This would seem to support the existence of a technofacies gradient (involving changes in the percentages of point types) of a spatial as well as temporal nature within the overall McKean Technocomplex. Our present definition of the Yonkee point type does not imply cultural differentiation; merely stylistic variation of note to stratigraphers.

Other levels at the Kobold Site are of considerable interest to stratigraphers, but no radiocarbon dates are available. Several obsidian hydration dates were taken (Frison, 1970a), but the presence of locally derived black non-volcanic glass makes comparison of dates and computation of rates difficult.[6] Level I contained a small component of corner-notched points with grinding at the juncture of the notch and the base (i.e., at the corner of the stem). Frison (ibid.: 26) suggests an Altithermal age. Apart from the unusual basal grinding, the points, in the absence of a stratigraphic context, "would probably be regarded as Late Middle Period points" (ibid.). Level II at Kobold, with its Yonkee points, was dated to approximately 4,700 years B.P., a date regarded as probably a little early (ibid.: 28).

Later levels at Kobold included a level of corner-notched points with slightly convex to slightly concave bases (Level III), and a level of side-notched points with straight or indented bases (Level IV); the former dated on obsidian to 1634 B.P. and 2532 B.P., and the latter dated to 917 B.P. All dates must be regarded as approximate, since the hydration rate is tentative.

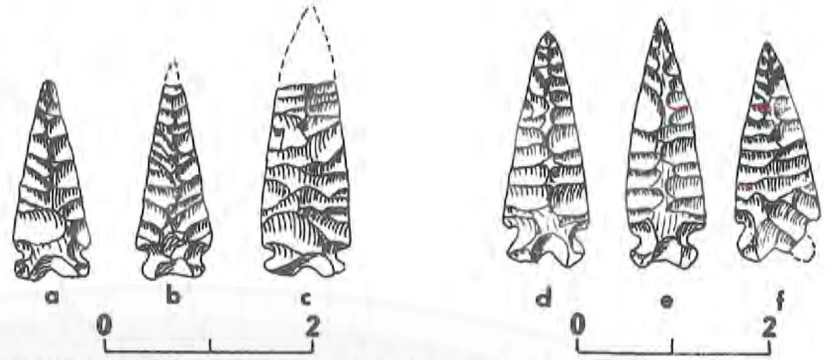


FIGURE 7. Illustrations of Yonkee points from two Powder River Basin sites. a – c., points from the Powers-Yonkee Site (24PR5) in southern Montana. d – f., points from the Mavrakis-Bentzen-Roberts Site in northern Wyoming. Scales are in inches. After Bentzen (1966a, 1966b).

The nearby Foss Site yielded a date of 480 ± 100 B.P. (A.D. 1470; RL-161; unpublished) for Late Prehistoric side-notched points. A brief preliminary report on the site has been published (Fry, 1971).

At a buffalo kill on Big Goose Creek, west of Sheridan, Frison (1967a) recovered Late Prehistoric side-notched points with pottery of a generalized Mandan-Hidatsa type. The latter is thought referable to the Crow Indians (Frison, ibid.). The site was dated to 450 ± 110 B.P. (A.D. 1500; M-1859; Crane and Griffin, 1970) and 530 ± 110 B.P. (A.D. 1420; M-1860; ibid.). Similar materials at the Piney Creek Sites, south of Buffalo, Johnson County, were dated to 370 ± 100 B.P. (A.D. 1580; M-1748; Frison, 1967b: 27), and 340 ± 100 B.P. (A.D. 1610; M-1747; ibid.). At these sites, the sample included side-notched points with basal notches.

The earliest site on the eastern flank of the Bighorn Mountains is the Sister's Hill Site, southwest of Buffalo, Johnson County. This deeply buried site contained several cultural levels including Hell Gap and Agate Basin points. Unfortunately, because of the great amount of overburden, the excavation was of rather limited exposed area, and the recovered cultural sample is small (Agogino and Galloway, 1965). Two radiocarbon dates have been run but their applicability is indirect: I-221 of 9,650 ± 250 B.P. (7700 B.C.; Trautman, 1964) is a composite sample from three occupational units spanning an unknown period of time; and A-372 of 9,600 ± 230 B.P. (7650 B.C.; Damon, Haynes, and Long, 1964) is from channel fill overlying the occupation levels.

Early deposits at the Medicine Lodge Creek Site, a large rockshelter near Hyattville, on the western flank of the Bighorns, have yielded lanceolate points of a number of types, including Plainview-like points with concave bases, Agate Basin-like points, Cody Complex points, James Allen-like points, and others. A number of radiocarbon dates in the 8,000 to 10,000 year range have been received; however, it is felt best

[6] see Frison, this volume, p. 61-62.

for our purposes to lump the artifact types together as "lanceolate" and indicate the approximate range in age. The stratigraphy of the site and the succession of types are complex; and a number of intrasite correlations have yet to be completed through stratigraphic testing and description. However, it does appear that the succession of types differs in several respects from that seen at Hell Gap, in the eastern portion of the state (see southern transect, below).

On both slopes of the Bighorns lanceolate points are succeeded by stemmed, bibevelled points known as Pryor Stemmed points (defined by Husted, 1969). Two dates were run on Pryor levels at the Grey-Taylor Site (48JO303) in the canyon of the upper Middle Fork of the Powder River. One of these was run in a private lab at Sheridan by Don Grey: 8,600 ± 245 B.P. (6650 B.C.; Grey-3; unpublished list). The other was run on an aliquot of the same sample at Arizona: 7,800 ± 110 B.P. (5850 B.C.; A-484; Haynes, Damon, and Grey, 1966: 17). Grey feels that the Arizona date should be considered more reliable (Frison, 1973b: 310). Pryor Stemmed points recovered from Schiffer Cave, along the North Fork of the Powder River (Frison, ibid.) were dated to 8,500 ± 160 B.P. (6550 B.C.; RL-99; ibid.: 310) and 8,360 ± 160 B.P. (6410 B.C.; RL-100; ibid.). Frison cites a date of 8,320 ± 220 B.P. (6370 B.C.; RL-152; ibid.) for a Pryor Stemmed layer at Medicine Lodge Creek.

The Pryor Stemmed horizon seems to represent a well-marked cultural and typological episode in the Bighorn Mountains area. The cultural significance of the sample is discussed by Frison (ibid.). In connection with Lovell Constricted, another Husted (1969) type, Frison questions "the compulsion to name point types too freely" (op. cit.: 311), and this is stressed again here to be a problem when cultural inferences are being sought. However, named types are valuable in stratigraphic studies, and the need to compromise paleocultural and stratigraphic goals thoroughly justifies the recognition of Pryor Stemmed and Lovell Constricted points as distinctive types. It is not the naming of types that is a problem; but rather, the misuse of types. There is an unfortunate tendency for types to sound like cultures -- rather than artifacts. If this tendency can be avoided by the researcher, types are perfectly valid and useful as descriptive aids (Wormington, 1957: 2-3).

Succeeding levels in Bighorn Mountains sites seems to be characterized by the presence of McKean Technocomplex point types, although a side-notched stratum of approximately Altithermal age seems to be emerging at Medicine Lodge Creek. In addition, side-notched points at 48JO301 (near 48JO303) have been compared with Logan Creek points (Grey, 1959a: 2), suggesting the presence of such a stratum on the east slope. Unfortunately, 48JO301 and 303 have never been adequately described apart from a few preliminary reports (Grey, 1959b, c, d; 1960).

Numerous dates on succeeding McKean Technocomplex layers at 48JO303 were run by Don Grey in his private lab; these dates range from 5,600 ± 190 B.P. (3650 B.C.; Grey-2; unpublished list) to 3,170 ± 160 B.P. (1220 B.C.; Grey-6; unpublished list). Reports on the site indicate that McKean points were found in all levels -- implying the use of arbitrary levels or the possible admixture of cultural materials, perhaps by rodents. Thus the range of dates is probably extreme. Dates from the Arizona lab on the same site include 3,980 ± 70 B.P. (2030 B.C.; A-485; Haynes, Damon, and Grey, 1966: 18) and 3,450 ± 40 B.P. (1500 B.C.; A-483; Haynes, Damon, and Grey, 1966: 17).

A date of 4,170 ± 150 B.P. (2220 B.C.; Grey-25; Frison and Huseas, 1968) was run on material from Leigh Cave, in Tensleep Canyon on the west slope of the Bighorns. Points from the site fall within the McKean Technocomplex and most closely resemble Duncan and Hanna types, with the latter predominating. A McKean Technocomplex level including some side-notched points at the Granite Creek Rockshelter in Shell Canyon, on the west slope, was dated to 4,700 ± 130 B.P. (2750 B.C.; RL-389; unpublished). This was unfortunately a salvage operation at a construction site, and it is possible that this level is actually a composite of two succeeding occupations, one of side-notched point users, and the following one by the makers of McKean Technocomplex points.

Dates on corner-notched point components in the Bighorn Mountains suggest the value of this general type as a time marker. On the east slope, dates include 1,140 ± 145 B.P. from upper Layer I at 48JO303 (A.D. 810; Grey-9; unpublished list); 975 ± 180 B.P. (A.D. 975; Grey date; Anonymous, 1969) from Rock Creek Cave; 760 ± 160 B.P. (A.D. 1190; A-583; Haynes, Damon, and Grey, 1966: 18; corrected in Haynes, Grey, Damon, and Bennett, 1967: 13) from the Turk Burial in northeastern Washakie County (atop the Bighorns) (Birkby and Bass, 1963; Grey, 1963); and 990 ± 240 B.P. (A.D. 960; A-548; Haynes, Damon, and Grey, 1966: 18; corrected in Haynes, Grey, Damon, and Bennett, 1967: 13) from the P. K. Burials in Sheridan County (Bass and Lacy, 1963). West slope dates include 1,620 ± 165 B.P. (A.D. 330; Grey-10, unpublished list) from Wedding of the Waters Cave, Hot Springs County, in the Owl Creek Mountains (Frison, 1962); and 1,725 ± 200 B.P. (A.D. 225; M-433; Crane and Griffin, 1958) from Spring Creek Cave, south of Tensleep (Frison, 1965).

Recent work in the Bighorn Basin has gone a long way to aid in the establishment of sequences of both local and regional correlative value. The recent discovery and testing of a mammoth kill site, the Colby Site, near Worland, Washakie County, resulted in the recovery of two large fluted spear points reminiscent of the Clovis type. However, the Colby points are notable in their possession of deeply concave bases, and rounded basal ears (Fig. 8). Their formal

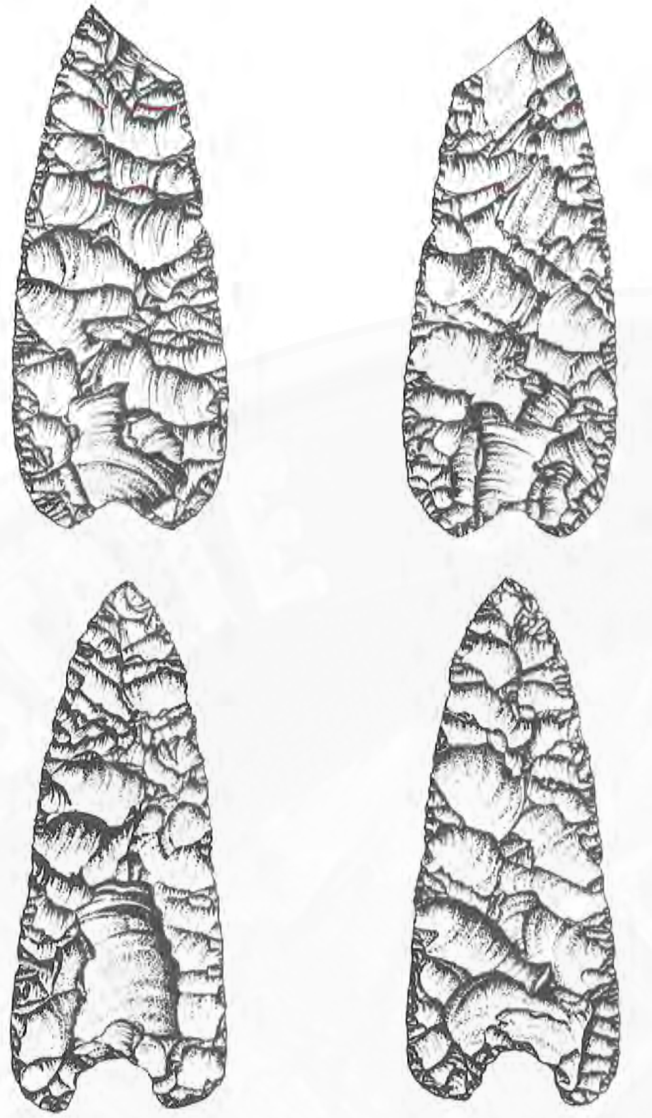


FIGURE 8. Clovis-like projectile points from the Colby Mammoth Kill Site near Worland, Wyoming. Upper, two views of red chert point found <u>in situ</u>; Lower, two views of cream-colored chert point recovered by Mr. Donald Colby, discoverer of the site. 75 % natural size.

typological assignment is thus unclear, although the site itself resembles other Clovis sites in the presence of several butchered mammoths. The radiocarbon date of 11,200 ± 220 B.P. (9250 B.C.; RL-392; unpublished) is in good agreement with other Clovis dates from western North America (Haynes, 1964).

An extensive Folsom campsite, the Hanson Site, was recently discovered and tested near Shell, Wyoming. This site has yielded a date of 10,700 ± 670 B.P. (8750 B.C.; RL-374; unpublished) and further work of a long-term nature is planned. The artifacts closely resemble those from the contemporary Lindenmeier Site in northern Colorado (Wormington, 1957: 31-39), reinforcing the Folsom point as a valuable time marker over a wide area of the west.

Sites in the Bighorn Canyon (Husted, 1969) display a complex sequence of Paleo-Indian lanceolate point types and type-groups. Agate Basin-like, Alberta-like, and Lovell Constricted points all occur in various combinations, and the overall sequence is not clear. Sample sizes for some of the types are regrettably small. The three point types have been dated between 9,000 and 7,000 years B.P. on the basis of a good series of radiocarbon dates (<u>ibid</u>.: 82) which need not be repeated here. Lovell Constricted points appear to be a good type with a definable temporal distribution and, as is presently known, apparently a restricted spatial distribution (Husted, <u>ibid</u>.; Frison, 1973b).

Later levels in Bighorn Canyon sites include McKean Technocomplex material and a few early side-notched points, the latter dating to 5,475 ± 190 B.P. (3525 B.C.; I-692; Husted, 1969: 88). Corner-notched points appear around 1,700 years B.P. after a hiatus in the record. The arrival of late side-notched points in the Bighorn Basin is documented at the Mangus Site in the Montana portion of the canyon, where side-notched and triangular unnotched points have been dated to 1,050 ± 70 B.P. (A.D. 900; SI-99; <u>ibid</u>.: 82) and 1,070 ± 70 B.P. (A.D. 880; SI-100; <u>ibid</u>.).

In the western part of the Basin the record is less complete. An extensive Cody Technocomplex bison kill, the Horner Site, was excavated near Cody, Park County (Jepsen, 1953). Here, a large sample of parallel-stemmed lanceolate points of the Eden and Scottsbluff types was recovered, along with several hundred butchered bison. The site has never been adequately described in print. Several early Libby dates (Libby, 1955) have been supplemented by newer dates which appear to be more reliable.

Dates from the site include 6,619 ± 350 B.P. (4669 B.C.; C-302; <u>ibid</u>.: 122), 7,132 ± 350 B.P. (5182 B.C.; C-302 and averaged with the former to give a date 6,876 ± 250 B.P.; <u>ibid</u>.), 6,151 ± 500 B.P. (4201 B.C.; C-795; <u>ibid</u>.: 125), 7,690 ± 850 B.P. (5740 B.C.; C-795 and averaged with the former to give a date of 6,920 ± 500 B.P.; <u>ibid</u>.), 7,880 ± 1,300 B.P. (5930 B.C.; SI-74; Long, 1965); 8,750 ± 120 B.P. (6800 B.C.; UCLA-697A; Berger, Fergusson, and Libby, 1965); and 8,840 ± 120 B.P. (6890 B.C.; UCLA-697B; <u>ibid</u>.). The newer dates are all older than the Libby dates widely cited in general works of the past two decades.

A small corner-notched point component from Rabbit Bone Cave, in the Oregon Basin area southeast of Cody, was dated to 1,670 ± 100 B.P. (A.D. 280; SI-530; Stuckenrath and Mielke, 1972).

The best sequence for the Absaroka Mountains is without a doubt that at Mummy Cave, along the North Fork of the Shoshone River, west of Cody. Dates from the various components are summarized by Wedel, Husted, and Moss (1968). Despite the fact that excavations were completed several years ago, the site remains very poorly documented in the literature -- as is the case with too many classic Wyoming sites. To summarize the sequence at Mummy Cave, we can state that lanceolate points of various varieties have been recovered from several levels dating between 10,000 and 7,500 years B.P. Until the level samples have been described, it will not be possible to discuss either their sequence or their relationships.

About 7,500 years ago the first side-notched points appeared in the area -- fully 1,000 years before their presently documented appearance in the Black Hills. Points resembling Oxbow points are dated at approximately 5,700 years B.P., and elements of the McKean Technocomplex appeared about 4,500 years ago. This agrees well in age with another McKean site in the Absarokas, the Dead Indian Site (48PA551) in Sunlight Basin, northwest of Cody. At the latter, dates of 4,430 ± 250 B.P. (2480 B.C.; W-2599; Frison, this volume: 64), and 4,180 ± 250 B.P. (2230 B.C.; W-2597; ibid.) were obtained. Apart from a brief preliminary report (Smith, 1970) this site remains unpublished.

Later levels at Mummy Cave include corner-notched points between about 2,500 and 1,000 years ago, and finally, small side-notched points.

Data from Yellowstone Park are not abundant as yet. However, one interesting site north of the park in Montana, the Rigler Bluffs Site, yielded a "parallel-stemmed serrated projectile point" associated with a hearth dated to 5,040 ± 150 B.P. (3090 B.C.; Grey-29; unpublished date list), and 4,900 ± 300 B.P. (2950 B.C., W-1135; Ives, Levin, Robinson and Rubin, 1964). The point was tentatively ascribed to the McKean Technocomplex (Haines, 1966), but was viewed by Lahren (1971: 170) as not diagnostic. Late Prehistoric side-notched points from the nearby Eagle Creek Site (Arthur, 1966a, 1966b) were dated to approximately A.D. 1700 (Lahren, ibid.). This level yielded Shoshonean flat-bottomed pottery (Arthur, 1966a).

This transect of northern Wyoming has demonstrated the existence of a number of recognizable artifact types of use in the correlation of Holocene deposits (Fig. 6). Clovis and Folsom fluted points mark an easily recognizable early Holocene time horizon, and succeeding lanceolate points, while typologically rather chaotic at present in this area, show promise of allowing local subdivision of the period between 10,000 and 7,000 radiocarbon years B.P. In the Bighorn Mountains and the adjacent basin, Pryor Stemmed and Lovell Constricted points distinctively mark a period of time between about 9,000 and 6,500 years ago, and future additions to our dated sample will probably allow better definition of the extremes of this range.

Large side-notched points hold promise as indicators of near-Altithermal age, although confusion with Besant points is entirely possible. The McKean Technocomplex, with all its variation, is still useful to us in that the notched and basally indented varieties are easily recognized. Yonkee points, while doubtless a McKean variant, occur in sufficiently pure components in the Powder River Basin to be worthy of recognition as a distinct technofacies.

The appearance of corner-notched points signals the interval between 3,000 and 500 years ago, while small side-notched points indicate Late Prehistoric age, generally on the order of 1,000 years or less. Association of Crow pottery makes this date even later -- 500 years or less, in all likelihood. However, earlier pottery types are known from elsewhere in Wyoming, so caution should be exercised in identification.

Southern Wyoming Transect

Our second transect crosses southern and central Wyoming (Fig. 5: B-B'; Fig. 9, next page). Rather than crossing in a straight line, it runs northward from the Cheyenne area to the North Platte River, then westward along the Platte to Pathfinder Reservoir, southwestward to the Red Desert, and finally westward across the desert, Green River Basin, and Bear River drainage. Sites up to about 75 miles from the transect are included; some of these are in Colorado and Nebraska. No dates are available from the Bear River area.

At the Happy Hollow Rockshelter (5WL 101) in Weld County, Colorado, 12 miles south of Cheyenne, three components were sampled (Steege, 1967). Two dates were taken from lower hearths: 2,680 ± 90 B.P. (730 B.C.; GaK-844; ibid.: 14), and 2,170 ± 80 B.P. (220 B.C.; GaK-1302; ibid.), but the cultural associations were not clear. Corner-notched points from the site are likely in part from this level. Plains Woodland pottery was recovered from the middle component, and a date of 1,270 ± 80 B.P. (A.D. 680; GaK-1303; ibid.) seems applicable. Corner-notched points have been associated with such pottery in the same general area (Reher, 1973). The upper component at Happy Hollow contained Upper Republican pottery and side-notched points; a date of 780 ± 90 B.P. (A.D. 1170; GaK-1304; ibid.) is acceptable (compare Wedel, 1961, concerning Upper Republican pottery).

In areas east and west of Cheyenne three important ancient sites have yielded dates. A Folsom fluted component at the Lindenmeier Site, in the uplands north of Fort Collins, Colorado, was dated to 10,850 ± 550 B.P. (8900 B.C.; I-141; Haynes, 1967: 270). A late Paleo-Indian component at the James Allen Site, southwest of Laramie, Albany County, Wyoming (Mulloy, 1959) was dated to 7,900 ± 400 B.P. (5950 B.C.; M-304; ibid.: 113). Allen points are characterized by lanceolate outline, oblique flaking, and concave bases.

Early work at the Signal Butte Site, in extreme western Nebraska, yielded Early Middle and Late Middle Period materials in stratified context (Strong, 1935). Signal Butte I, containing stemmed and lanceolate points as well as a few large side-notched points of the McKean Technocomplex, has been dated to 4,550 ± 220 B.P. (2600 B.C.; L-385B; Olson and Broecker, 1961) and 4,170 ± 250 B.P. (2220 B.C.; L-385D; ibid.).

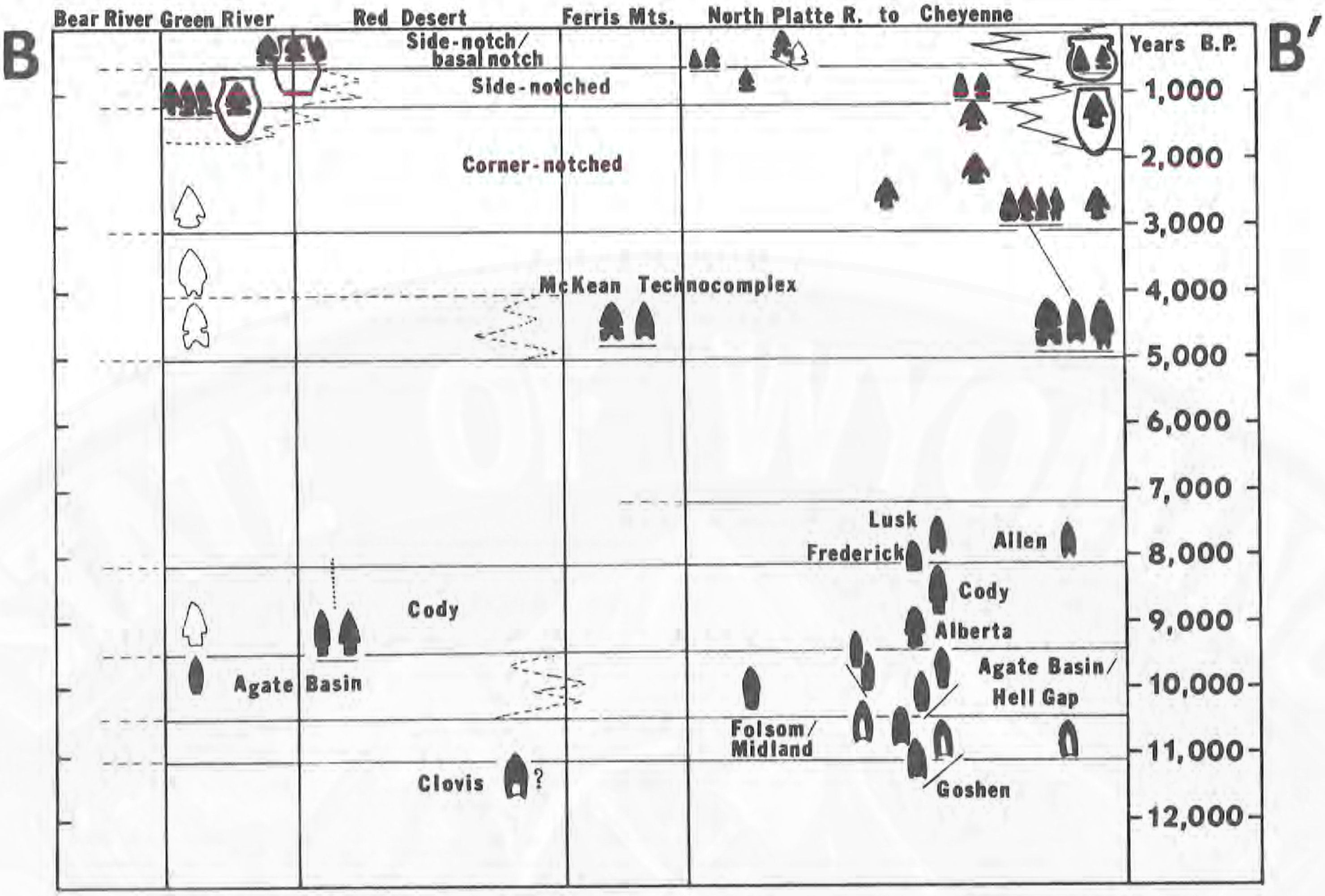


FIGURE 9. Technofacies transect of southern Wyoming. Each projectile point symbol is associated with a date. Symbols linked by horizontal lines represent the same component and date; those linked by slanting lines are closely associated components at a single site, with more than one date available. Outline symbols represent questionable dates, or dates by inference from other evidence. Pottery outlines are shown for Late Prehistoric sites. It is important to remember that this diagram shows technological facies; no cultural patterns or relationships are implied. The point illustrations are not intended to be definitive; researchers should consult the original references cited in the accompanying text. (B - B' on Figure 5.)

Signal Butte II, containing unnotched, corner-notched, Hanna, and Duncan points (Reeves, 1970: Table 29) was dated to 2,630 ± 100 B.P. (680 B.C.; L-385A; Olson and Broecker, 1961: 170).

Three archaeological levels have been radiocarbon dated in the Glendo Reservoir area of northern Platte County, Wyoming. One of these, appearing to be an Early Period level, gave a late date and is thus inconclusive at present. The upper level of 48P124, containing barbed corner-notched points, was dated to 1,325 ± 150 B.P. (A.D. 625; M-971; Mulloy, 1965: 41). Another Middle Period component at 48P123, again containing barbed corner-notched points, was dated to 2,020 ± 200 B.P. (70 B.C.; M-972; Mulloy and Steege, 1967: 169). A small Late Prehistoric component from a series of stone cairns was dated to 1,025 ± 150 B.P. (A.D. 925; M-973; ibid.: 170). This component contained triangular unnotched and small side-notched points.

Two Paleo-Indian (Early Period) sites in east-central Wyoming, Hell Gap in Goshen County (actually a complex of sites) and Agate Basin/Brewster in Niobrara County, have yielded valuable information concerning the sequence of point types in the Early Period. Irwin-Williams, Irwin, Agogino, and Haynes (1973: 52) have summarized the Paleo-Indian sequence at Hell Gap as follows:

9000 - 8800 B.C. (10,950 - 10,750 B.P.): Goshen
8800+- 8600 B.C. (10,750+- 10,550 B.P.): Folsom
8700 - 8400 B.C. (10,650 - 10,350 B.P.): Midland
8500 - 8000 B.C. (10,450 - 9,950 B.P.): Agate Basin
8000 - 7500 B.C. (9,950 - 9,450 B.P.): Hell Gap
7500 - 7000 B.C. (9,450 - 8,950 B.P.): Alberta
6800 - 6400 B.C. (8,750 - 8,350 B.P.): Cody
6400 - 6000 B.C. (8,350 - 7,950 B.P.): Frederick
6000 - 5500 B.C. (7,950 - 7,450 B.P.): Lusk

Radiocarbon dates have been taken from several levels as the basis for this sequence; they have been summarized elsewhere (Haynes, 1967; Irwin-Williams and others, op. cit.) and will not be listed here. Median dates in excess of 10,000 years and similarly early dates from the Casper Hell Gap Site (Frison, in press) suggest that Irwin-Williams and others might have underestimated slightly the antiquity of the Hell Gap levels in their summary chronology.

The Agate Basin or Brewster Site in eastern Niobrara County has yielded Agate Basin and Folsom points. There is some discussion concerning the precise number of levels present in the site complex; however, three radiocarbon dates are available. Dates of 9,350 ± 450 B.P. (7400 B.C.; Humble-1252; Crane and Griffin, 1963) and 9,990 ± 225 B.P. (8040 B.C.; M-1131; ibid.) seem to apply to the Agate Basin level(s); while a date of 10,375 ± 700 B.P. (8425 B.C.; I-472; ibid.) has been referred to the Folsom level. The site has never been described adequately in print, although the subject of numerous brief communications (Agogino and Frankforter, 1964; Bass, 1970; Agogino, 1972).

A component of corner-notched points at the Lance Creek Site in Niobrara County (Reeves, 1970: 251) was dated to 2,450 ± 75 B.P. (500 B.C.; A-364; Damon, Haynes and Long, 1964: 102).

Farther west along the North Platte River, a Late Prehistoric bison kill site (48CO304) was excavated near Glenrock, Converse County (Frison, 1970b). Two levels at the site contained side-notched arrow points, but they differed in attributes. Points from the lower level had straight to concave bases; while those from the upper level had basal notches as well as side notches. Base-notching is a late occurrence in this area on side-notched arrow points, and may have diffused eastward with Shoshoneans (Frison, 1967b: 40-41). The upper level at Glenrock was dated to 210 ± 100 B.P. (A.D. 1740; M-2350; Frison, 1970b: 7) and 280 ± 100 B.P. (A.D. 1670; M-2349; ibid.). Albanese (1970) uses geologic evidence to suggest a minimum age of 450 to 750 years for the site; such an age certainly seems logical for the lower kill level.

Side-notched points were recovered from the Lee Site (48NA326), north of Casper, Natrona County (Randall, 1962; Reeves, 1970). This level was dated to 1,020 ± 86 B.P. (A.D. 930; Gulf Oil Co. date; Reeves, ibid.: 273). The points were quite similar to those from 48P129 at Glendo Reservoir (Mulloy and Steege, 1967; Reeves, loc. cit., incorrectly cited as 48P123).

The Brown-Weiser Site (48NA330) is a single-component rockshelter of Late Prehistoric age, located on the southern end of the Bighorn mountain range in northwestern Natrona County. Small unnotched triangular and side-notched, basally notched points were recovered (Brown, 1961) and a date of 450 ± 141 B.P. (A.D. 1500; Grey-11; unpublished date list) was run in a private lab.

An important bison kill site containing the remains of over 70 Bison bison antiquus along with a number of Hell Gap points was excavated on the northwestern outskirts of Casper, Natrona County. The Casper Site (48NA304) was dated to 9,830 ± 350 B.P. (7880 B.C.; RL-125; Frison, in press) on charcoal, and to 10,060 ± 170 B.P. (8110 B.C.; RL-208; ibid.) on bone. These dates from a pure component help to place the Hell Gap materials from Sister's Hill and the Hell Gap Site under better temporal control. Stylistic variation within the Casper Site point sample was not great, reinforcing the validity of Hell Gap as a useful type in correlations.

Approximately 70 miles southwest of Casper, another bison kill was excavated adjacent to a bedrock cuesta west of the North Platte valley. The Scoggin Site, dated to 4,540 ± 110 B.P. (2590 B.C.; RL-174; Lobdell, 1973: 19), has been described in detail by Lobdell (1973; this volume, p. 19-21), and appears to have been a combined jump and pound. The point sample, clearly falling within the range of the McKean Technocomplex, includes typical McKean Lanceolate forms along with large side-notched and basally notched forms. The side-notched points tend to be broader with respect to length than the lanceolate, unnotched points. Unfortunately, Lobdell did not publish his raw metric data from individual points (although a summary table of statistics derived from these metric data was included), and he does not seem to have measured the width of the point between notches. The difference in proportions between point types suggests two hafting procedures -- perhaps involving open and closed sockets.

Lobdell (1973: 55-56) argues for inclusion of these large side-notched points within the McKean "type" or "continuum" envisioned by Mulloy (1954). However, the existence of intergrades (as would be expected in a true continuum) has not been demonstrated. It might be argued that the two point types -- lanceolate and side-notched -- are stylistically identical and different only in a functional aspect related to hafting procedure. However, functional differences are as important in typology as are stylistic differences.

Large side-notched points closely similar to those from the Scoggin Site were recovered from the Pine Spring Site (discussed below) by Sharrock (1966). At Pine Spring, McKean Lanceolate points were not in evidence, but stemmed points referable to the Duncan type were recovered. Unfortunately, Sharrock's "Occupation 2" evidently includes several components (and seems to have been an arbitrary level rather than an "occupation"). It is possible that the large side-notched and Duncan points came from succeeding occupations -- just as it is possible that they occurred together.

Despite this deficiency in our data base, it is apparent that the McKean Lanceolate type somehow passes from the assemblage between Scoggin and Pine Spring. More site assemblages are required for adequate documentation of the detailed nature

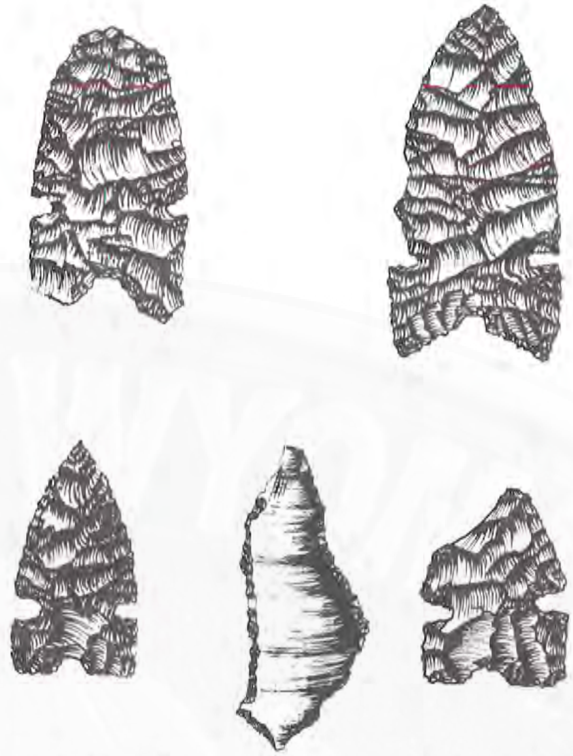


FIGURE 11. Mallory side-notched projectile points from the Scoggin Site, south-central Wyoming; and (bottom, center) retouched flake tool from same site. 80% natural size. After Lobdell, 1973.

FIGURE 10. McKean Lanceolate projectile points from the Scoggin Site, south-central Wyoming. 80% natural size. After Lobdell, 1973.

of this lateral technofacies change.

The possibility of different hafting procedures, and the lack of intermediate forms warrant the recognition of the large side-notched point as a valid type within the McKean Technocomplex. We apply no cultural significance to the type at the present time, but advance it as a stratigraphic marker of potential importance, in view of its relatively widespread occurrence from Signal Butte, Nebraska, to Pine Spring, Wyoming. Lobdell (1973: 54) notes manuscript use of the name "Mallory" by Forbis, Strong, and Kirby (n.d.), and the name is accepted here. Mallory and McKean points from the Scoggin Site are shown here in Figures 10 and 11 (after Lobdell, 1973: Figs. 16 and 17).

About 50 miles south of the Scoggin Site, in a spring area southwest of Rawlins, Carbon County, the remains of a butchered mammoth were recovered along with stone tools. The U.P. Mammoth Site was subsequently dated to 11,280 + 350 B.P. (9330 B.C.; I-449; Haynes, 1967) and most authors suggest it to have been a kill enacted by Clovis projectile point makers (Irwin, Irwin, and Agogino, 1962; Haynes, 1964; McGrew, 1961; Irwin, 1970). Bifacial tools were recovered from the site, but none of them were projectile points. The U.P. Site date agrees quite well with that from the Colby Site (see above, northern Wyoming transect).

In the Killpecker Dune Field at the western edge of the Red Desert (Ahlbrandt, T.S., this volume, p. 51-60) an extensive campsite of Cody Complex point makers was excavated and quite extensively documented (Moss, 1951; Satterthwaite, 1957). Points from the site were lanceolate with inset, parallel-sided stems; the points ranged from broad to very slender. The broad points are referred to the Scottsbluff type; the slender ones to the Eden type. Apparently these materials have very close typological affinities with the sample from the Horner Site, near Cody (see above, northern Wyoming transect). Thus, the Finley Site probably dates in excess of 7,500 or 8,000 years B.P. No dates were obtained during the early work at the site; but Ahlbrandt (this volume: 56) has published a limiting date of 5,845 + 115 B.P. (3895 B.C.; Teledyne-1-648$\overline{6}$) on calcified root tubules overlying deposits correlative with the Finley Site bone deposit.

The recent discovery of a kill area by amateurs reopens the need for study at the Finley Site. Bone dates on material from this area will be obtained soon.

Near the Finley Site, Frison (1971b) excavated a Late Prehistoric campsite of apparent Shoshonean affinities. The sample of small side-notched projectile points included several specimens with basal notches. Flat-bottomed Shoshonean (Intermountain) pottery was also recovered from this assemblage, dated to 230 ± 100 B.P. (A.D. 1720; RL-101; ibid.: 258).

Pottery was also recovered from the Wardell Site, a Late Prehistoric buffalo kill site and meat-processing area near Big Piney, Sublette County. However, this site is older -- having yielded dates of 990 ± 100 B.P. (A.D. 960; RL-103; Frison, 1973a: 74), 1,580 ± 110 B.P. (A.D. 370; RL-102; ibid.), and 1,170 ± 100 B.P. (A.D. 780; RL-111; ibid.). The earliest date is from a charred log which may have lain as deadfall for many years before its use -- so the date is regarded as a little too early. The associated pottery is conoidal, pointed-bottomed plain ware with a brushed surface (ibid.: 68-69). Points from the site are side-notched without basal notching (ibid.: 27-29).

A long sequence of archaeological occupations was evident at the Pine Spring Site (48SW101), in southwestern Sweetwater County (Sharrock, 1966). As noted above, the separation of components was not good, with the result that "Occupation 2" seems to contain 3 or more components.

Occupation 1 at Pine Spring, yielding lanceolate Agate Basin points, gave dates of 11,830 ± 410 B.P. (9880 B.C.; GX0355; ibid.: 21), and 9,695 ± 195 B.P. (7745 B.C.; GX0354; ibid.). The former is considered to be unreliable; thus the latter is accepted as the age of the component.

"Occupation 2" is clearly a mixed level, containing Scottsbluff, Mallory, Duncan, and corner-notched points. The Duncan and Mallory points may be from the same component, preceded by Scottsbluff and followed by the corner-notched points. A date of 3,635 ± 80 B.P. (1685 B.C.; GX0356; ibid.: 26) cannot be assigned with confidence to any of these: it is later than other dates for Mallory, and early for corner-notched material. Perhaps it relates to the Duncan material, as Duncan points have been recovered in late McKean Technocomplex components elsewhere.

Occupation 3 contained small corner-notched and side-notched points, along with pottery. No radiocarbon date was run, but the pottery (of Great Basin - Southwestern affinities) has been dated to approximately A.D. 950 - 1200 (ibid.: 26).

In summary, our transect of southern Wyoming has yielded fewer data than were derived from the northern transect. Nevertheless, clear temporal trends are apparent, and a few geographic trends are possible (Fig. 9).

As noted in the north, fluted points mark a well-defined horizon ending (in this case) about 10,500 years B.P.; and a succession of lanceolate types fill the period between 10,500 and 7,000 years B.P. However, unlike our experience with the northern transect, we have some evidence regarding the temporal ordering of these lanceolate spear points. Agate Basin and Hell Gap points, differing primarily in the location of the widest point of the blade, occupy the period between 10,500 and 9,500 years ago. Pure components at Casper (Hell Gap) and Pine Spring (Agate Basin) suggest the types to be distinct, but their relationships are not yet clear.

Stemmed points of the Cody Technocomplex and related Alberta type occupy the period from about 9,500 to 8,000 years B.P.; while basally indented or straight-based lanceolate forms of the Allen, Lusk, and Frederick types mark late pre-Altithermal times.

McKean Technocomplex materials distinctively mark the interval from about 5,000 to 3,000 years B.P. A distinctive element throughout the transect at this time level is the Mallory point, a large side-notched, basally indented form.

From about 3,000 to 1,000 years B.P. corner-notched points, sometimes strongly barbed, dominate the sample. Shortly before 1,000 years B.P. conoidal pottery appears in the east and west: the eastern material being cord-marked pottery of Plains Woodland affiliations; and the western material being brushed plain ware of possible Athapaskan affinities. In the east, this conoidal ware is succeeded by decorated pots of the Upper Republican type; while later sites in the west contain flat-bottomed Intermountain Ware of probable Shoshonean derivation.

Small side-notched points mark the last 1,000 years B.P., with basal notching appearing about 500 years ago.

Lateral facies changes are possible at the Agate Basin/Hell Gap level (westward loss of Hell Gap?) and the McKean Technocomplex level (westward loss of McKean Lanceolate and emphasis on Mallory?). Local differentiation is noted in the last 1,000 year segment; however, it is marked by pottery types rather than projectile point types.

CONCLUDING REMARKS

Despite the uneven nature of our data base, we have been able to generate a number of spatial and temporal trends in the styles of prehistoric projectile points from Wyoming. The purpose of documenting these preliminary trends is to provide information of value to the Holocene stratigrapher. Since no cultural associations and trends, or movements of human populations are implied, we caution other archaeologists against using our trends for the generation of cultural inferences without re-examination of the data in the original references.

There is no doubt that this is a completely justified use of archaeological data. The idea is hardly a new one: southwestern stratigraphers have been using archaeological evidence in their studies for years. Hunt and Hunt (1961) briefly summarized certain of the temporal trends for the Great Basin, Colorado Plateau, and High Plains -- for the use of Holocene stratigraphers. Although stressing the general paucity of material in cutbanks, they found the technique useful:

> One of the limitations...is that sites with sufficient tools to be useful for geologic stratigraphy and geologic mapping are mostly at the surface, and these provide only a limital date for the underlying deposit. Only rarely are diagnostic artifacts contained within a deposit over sufficient extent or in sufficient numbers to be exposed in a cross-section cut and thus useful in geologic mapping. Nevertheless, the sites, especially the younger ones, are sufficiently numerous to be of great assistance in many areas for distinguishing the different stages of Recent deposits (ibid.: 197).

In discussion the cultural setting of human artifacts, Bidney (1967: 27) contends that "It is the use or function of an artifact, its contribution to cultural life in a given social context, which is of significance -- not the artifact in and by itself." This, however, would leave us with rather little to say about many archaeological artifacts. We feel that the artifacts themselves -- even without clear cultural context -- are indeed of importance for their temporal connotations. As Wormington (1957: 2) has stated,

> Actually...a projectile point type is essentially an artificial construct, and in typology there are no eternal verities. An individual or a group of individuals may feel that certain traits characterize a sufficiently large number of points that a recurring pattern, believed to be culturally significant and delimited in time and space, can be recognized.

She elsewhere states (ibid.: 3) that "If type names are to serve as a means of communication, it is essential that the reader and writer attach the same meaning to the words." This is of critical importance. All too often, cultural constructs are far broader than individual artifact types, and authors feel it necessary to "broaden" their types to "continua" that correspond with the cultural constructs. Regrettably, this diffusion of type characteristics often results in the inclusion of a wide variety of forms under one great grab-bag title, with the result that the original significance of the type name is lost, and the new meaning is hard to discern in typological terms.

Archaeological types are arbitrary: they are not synonymous with the typologies of those who made the artifacts; and they do not of necessity correspond with cultures. Any number of arbitrary types can be derived from a cultural assemblage, and these types deserve validity if they are useful (as "index fossils") to stratigraphers -- for Holocene stratigraphy is as valid a use of artifacts as is cultural reconstruction. Let assemblages of types be used in cultural reconstruction: thus both ends will be served, and neither at the expense of the other. Stratigraphers can "split" and culture historians can "lump" -- and perhaps the twain shall meet.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to all those persons who have shared with us either directly or through the literature, data and interpretations from Wyoming archaeological samples.

Particular thanks are expressed to past and present students of the University of Wyoming who have labored long and hard in the field with the senior author during the past decade. For their special contributions along these lines, George Zeimens and Charles A. Reher are deserving of much gratitude.

The superb illustrations of the Scoggin Site and Colby Site points are the work of Connie Robinson.

The distribution of labor on the foregoing article was as follows: Frison oversaw description of site materials, and provided for tabulation many new dates and data, in addition to having conducted many of the listed excavations; M. Wilson generated the technofacies concept and oversaw the continuity of the article; and D. J. Wilson took care of radiocarbon dates and their related data.

REFERENCES

Agogino, George A.
1972 Excavations at a Paleo-Indian site (Brewster) in Moss Agate Arroyo, eastern Wyoming. National Geographic Society Research Reports, 1955-1960: 1-6. Washington, D.C.

Agogino, George A., and Eugene Galloway
1965 The Sister's Hill Site: a Hell Gap site in north-central Wyoming. Plains Anthropologist, 10:196-211. Topeka, Kansas.

Agogino, George A., and W. D. Frankforter
1964 The Brewster Site: a Paleo-Indian site in eastern Wyoming. The Wyoming Archaeologist, 8(4):7-11. Casper, Wyoming.

Ahlbrandt, T. S.
n.d. Dune stratigraphy, archaeology, and the chronology of the Killpecker Dune Field. This volume: 51-57.

Ahler, S. A.
1970 Projectile point form and function at Rodgers Shelter, Missouri. Missouri Archaeological Society Research Series, 8:1-146. Columbia, Missouri.

Albanese, John P.
1970 Geology of the Glenrock Site area, Wyoming. Plains Anthropologist Memoir 7, 15(50, part 2):56-66. Topeka, Kansas.
1971 Geology of the Ruby Site area, Wyoming 48CA302. American Antiquity, 36(1):91-95. Washington, D.C.

Anonymous
1969 Rock Creek Cave 48JO315. The Wyoming Archaeologist, 12(2):19-29. Cheyenne, Wyoming.

Arthur, George W.
1966a The Eagle Creek Site, 24PA301. Archae-

ology in Montana, 7(2):11-12. Billings, Montana.
1966b An archaeological survey of the Upper Yellowstone River drainage, Montana. Agricultural Economics Research Report 26:1-199. Department of Agricultural Economics and Rural Sociology, Montana Agricultural Experiment Station, Bozeman, Montana.

Bass, W. M.
1970 Excavations of a Paleo-Indian site at Agate Basin, Wyoming. National Geographic Society Research Reports, 1961-1962: 21-25. Washington, D.C.

Bass, W. M., and D. C. Lacy
1963 Three human skeletons from the P.K. Burial. Plains Anthropologist, 8(21): 142-157. Lincoln, Nebraska.

Bentzen, Raymond C.
1966a The Powers-Yonkee Bison Trap 24PR5. The Wyoming Archaeologist, 9(1):7-20. Cheyenne, Wyoming.
1966b The Mavrakis-Bentzen-Roberts Bison Trap. 48SH311. The Wyoming Archaeologist, 9 (1):27-39. Cheyenne, Wyoming.

Berger, R., G. J. Fergusson, and W. F. Libby
1965 UCLA radiocarbon dates IV. Radiocarbon, 7:336-371. New Haven, Connecticut.

Bidney, David
1967 Theoretical Anthropology. Second Edition. Schocken, New York. 528 p.

Birkby, Walter H., and W. M. Bass
1963 Possible Shoshonean skeletal material from the Turk Burial Site, 48WA301. Plains Anthropologist, 8(20):103-114. Lincoln, Nebraska.

Brown, Bob
1961 Casper group reports site work. The Wyoming Archaeologist, 4(9):1. Casper, Wyoming.

Burl, A.
1973 Dating the British stone circles. American Scientist, 61(2):167-174. New Haven, Connecticut.

Crane, H. R., and J. B. Griffin
1958 University of Michigan radiocarbon dates II. Science, 127(3306):1098-1105. Washington, D.C.
1963 University of Michigan radiocarbon dates VIII. Radiocarbon, 5:228-253. New Haven, Connecticut.
1970 University of Michigan radiocarbon dates XIII. Radiocarbon, 12(1):161-180. New Haven, Connecticut.
1972 University of Michigan radiocarbon dates XIV. Radiocarbon, 14(1):155-194. New Haven, Connecticut.

Currey, D.R.
1974 Probable pre-Neoglacial age of the type Temple Lake moraine, Wyoming. Arctic and Alpine Research, 6(3):293-300. Boulder, Colorado.

Damon, P. E., C. V. Haynes, and A. Long
1964 Arizona radiocarbon dates V. Radiocarbon, 6:91-107. New Haven, Connecticut.

Dunbar, C. O., and John Rodgers
1957 Principles of Stratigraphy. John Wiley and Sons, New York, New York. 356 p.

Dyck, Ian G.
1970 Two Oxbow settlement types in central Saskatchewan. Na'pao, 2(2):1-29. Saskatoon, Saskatchewan.

Forbis, R. G.
1962 A stratified buffalo kill in Alberta. In Carling Malouf and Stuart Conner (Eds.), Symposium on Buffalo Jumps. Montana Archaeological Society Memoir 1:3-7. Missoula, Montana.

Forbis, R. G., W. D. Strong, and M. Kirby
n.d. Signal Butte and MacHaffie: Two stratified sites of the northern Great Plains. Manuscript. (Cited after Lobdell, 1973).

Frison, George C.
1962 Wedding of the Waters Cave, 48HO301, a stratified site in the Big Horn Basin of northern Wyoming. Plains Anthropologist, 7(18):246-265. Lincoln, Nebraska.
1965 Spring Creek Cave, Wyoming. American Antiquity, 31(1):81-94. Salt Lake City, Utah.
1967a Archaeological Evidence of the Crow Indians in Northern Wyoming: a study of a Late Prehistoric Buffalo Economy. Ph.D. Dissertation (Anthropology), University of Michigan, Ann Arbor, Michigan. 336 p.
1967b The Piney Creek Sites, Wyoming. University of Wyoming Publications, 33(1):1-92. Laramie, Wyoming.
1968 Site 48SH312: an Early Middle Period bison kill in the Powder River Basin of Wyoming. Plains Anthropologist, 13 (39):31-39. Topeka, Kansas.
1970a The Kobold Site, 24BH406: a Post-Altithermal record of buffalo jumping for the Northwestern Plains. Plains Anthropologist, 15(47):1-35. Topeka, Kansas.
1970b The Glenrock Buffalo Jump, 48CO304: Late Prehistoric Period buffalo procurement and butchering. Plains Anthropologist Memoir 7, 15(50, part 2):1-45. Topeka, Kansas.
1971a The buffalo pound in northwestern Plains prehistory: site 48CA302, Wyoming. American Antiquity, 36(1):77-91. Washington, D.C.
1971b Shoshonean antelope procurement in the Upper Green River Basin, Wyoming. Plains Anthropologist, 16(54):258-284. Topeka, Kansas.
1973a The Wardell Buffalo Trap 48SU301: communal procurement in the Upper Green River Basin, Wyoming. Anthropological Papers of the Museum of Anthropology, University of Michigan, 48:1-111. Ann Arbor, Michigan.
1973b Early Period marginal cultural groups in northern Wyoming. Plains Anthropologist, 18(62):300-312. Topeka, Kansas.
in press The Casper Site: a Hell Gap Bison Kill on the High Plains. Academic Press, New York. 259 p.
n.d. The Hawken Site. Manuscript in preparation.

Frison, George C., and Marion Huseas
1968 Leigh Cave, Wyoming (Site 48WA304). The Wyoming Archaeologist, 11(3):20-33. Cheyenne, Wyoming.

Fry, Gary R.
1971 Preliminary report Foss Thomas Site. The Wyoming Archaeologist, 14(1):15-22. Cheyenne, Wyoming.

Godwin, H.
1962 Half-life of radiocarbon. Nature, 195: 984. London, England.

Grey, Donald C.
1959a 48JO301 The Sweem-Taylor Site. The Wyoming Archaeologist, 2(7):1. Sheridan, Wyoming.
1959b Wyoming society reports at Lincoln. The Wyoming Archaeologist, 2(10):1-2. Sheridan, Wyoming.
1959c The Sweem-Taylor Site, 48JO301. The Wyoming Archaeologist, 2(10):3-4. Sheridan, Wyoming.
1959d A possible Meserve site in north central Wyoming. The Wyoming Archaeologist, 2(10):5-6. Sheridan, Wyoming.
1960 Work completed at 48JO301 and 303. The Wyoming Archaeologist, 3(7):3-4. Sheridan, Wyoming.
1963 The Turk Burial Site, 48WA301, Washakie County, Wyoming. Plains Anthropologist, 8(20):98-102. Lincoln, Nebraska.

Hack, J. T.
1943 Antiquity of the Finley Site. American Antiquity, 8:235-241. Menasha, Wisconsin.

Haines, Aubrey L.
1966 The Rigler Bluffs Hearth Site: 24PA401. Archaeology in Montana, 7(2):5. Billings, Montana.

Haynes, C. Vance, Jr.
1964 Fluted projectile points: their age and dispersion. Science, 145:1408-1413. Washington, D.C.
1967 Carbon-14 dates and early man in the New World. In P. S. Martin and H. E. Wright, Jr. (Eds.), Pleistocene Extinctions: the Search for a Cause: 267-286. Yale University Press, New Haven, Connecticut.

Haynes, C. Vance, Jr., P. E. Damon, and D. C. Grey
1966 Arizona radiocarbon dates VI. Radiocarbon, 8:1-21. New Haven, Connecticut.

Haynes, C. Vance, Jr., D. C. Grey, P. E. Damon, and R. Bennett
1967 Arizona radiocarbon dates VII. Radiocarbon, 9:1-14. New Haven, Connecticut.

Hunt, C. B., and Alice P. Hunt
1961 Use of archaeology in Recent stratigraphy. United States Geological Survey Professional Paper 424-B:195-197. Washington, D.C.

Husted, W. M.
1969 Bighorn Canyon Archaeology. Smithsonian Institution, River Basin Surveys, Publications in Salvage Archaeology, 12:1-138. Lincoln, Nebraska.

Irwin, Henry
1970 Archaeological investigations at the Union Pacific Mammoth Kill Site, Wyoming. National Geographic Society Research Reports, 1961-1962: 123-125. Washington, D.C.

Irwin, C., H. Irwin, and G. A. Agogino
1962 Ice Age man vs. mammoth in Wyoming. National Geographic Magazine, 121(6): 828-837. Washington, D.C.

Irwin-Williams, C., H. Irwin, G. Agogino, and C. V. Haynes
1973 Hell Gap: Paleo-Indian occupation on the High Plains. Plains Anthropologist, 18(59):40-53. Topeka, Kansas.

Ives, P. C., B. Levin, R. D. Robinson, and M. Rubin
1964 U.S. Geological Survey radiocarbon dates VII. Radiocarbon, 6:37-76. New Haven, Connecticut.

Jepsen, G. L.
1953 Ancient buffalo hunters of northwestern Wyoming. Southwestern Lore, 19(2):19-25. Denver, Colorado.

Kehoe, T. F.
1966 The small side-notched point system of the Northern Plains. American Antiquity, 31(6):827-841. Salt Lake City, Utah.

Kivett, Marvin F.
1962 Logan Creek Complex. Paper read at 20th Plains Conference, Lincoln, Nebraska.

Lahren, Larry A.
1971 Archaeological investigations in the Upper Yellowstone Valley, Montana: a preliminary synthesis and discussion. In A. H. Stryd and R. A. Smith (Eds.), Aboriginal Man and Environments on the Plateau of Northwest America: 168-182. University of Calgary Students' Press, Calgary, Alberta, Canada.

Lehmer, Donald J.
1971 Introduction to Middle Missouri archaeology. National Park Service, Anthropological Papers, 1:1-206. Washington, D.C.

Libby, W. F.
1952 Radiocarbon Dating. First Edition. University of Chicago Press, Chicago, Illinois. 124 p.
1955 Radiocarbon Dating. Second Edition. University of Chicago Press, Chicago, Illinois. 175 p.

Lobdell, J. E.
1973 The Scoggin Site: an Early Middle Period Bison kill. The Wyoming Archaeologist, 16(3):1-36, and 16(4):37-71. Cheyenne, Wyoming.

Long, A.
1965 Smithsonian Institution radiocarbon measurements II. Radiocarbon, 7:245-256. New Haven, Connecticut.

Lyons, T. R.
1970 Isochronous interpretation of some C^{14} dates -- a technique for temporal and regional studies. Plains Anthropologist, 15(49):153-160. Topeka, Kansas.

McGrew, Paul O.
1961 The Rawlins Mammoth. Wyoming Geological Association, 16th Annual Field Conference Guidebook: 315-317. Casper, Wyoming.

Miller, C. D., and P. W. Birkeland
1974 Probable pre-Neoglacial age of the type Temple Lake moraine, Wyoming: discussion and additional relative age-data. Arctic and Alpine Research, 6(3):301-306. Boulder, Colorado.

Moss, J. H.
1949 Possible new glacial substage in the middle Rocky Mountains. Geological Society of America Bulletin, 60:1972. New York, New York.
1951 (Editor) Early man in the Eden Valley. University of Pennsylvania Museum, Museum Monographs, 6:124 p. Philadelphia, Pennsylvania.
1951 Late glacial advances in the southern Wind River Mountains, Wyoming. American

Journal of Science, 249:865-883. New Haven, Connecticut.

Mulloy, W.
1954 The McKean Site in northeastern Wyoming. Southwestern Journal of Anthropology, 10(4):432-460. Albuquerque, New Mexico.
1958 A preliminary historical outline for the Northwestern Plains. University of Wyoming Publications, 22(1):1-235. Laramie, Wyoming.
1959 The James Allen Site, near Laramie, Wyoming. American Antiquity, 25(1): 112-116. Salt Lake City, Utah.
1965 Archaeological investigations along the North Platte River in eastern Wyoming. University of Wyoming Publications, 31(2):23-51. Laramie, Wyoming.

Mulloy, W., and L. C. Steege
1967 Continued archaeological investigations along the North Platte River in eastern Wyoming. University of Wyoming Publications, 33(3):169-233. Laramie, Wyoming.

Olson, E. A., and W. S. Broecker
1961 Lamont natural radiocarbon measurements VII. Radiocarbon, 3:141-175. New Haven, Connecticut.

Randall, A. G.
1962 Correlation of Lee Site artifact rock type with quarry sites, Wyoming. Wyoming Geological Association, Symposium on Early Cretaceous Rocks of Wyoming and Adjacent Areas, 17th Annual Field Conference Guidebook: 309-315. Casper, Wyoming.

Reeves, Brian O. K.
1970 Culture Change in the Northern Plains 1000 B.C. - A.D. 1000. Ph.D. Dissertation (Archaeology), University of Calgary, Calgary, Alberta, Canada. 356 p.

Reher, C. A.
1973 A survey of ceramic sites in southeastern Wyoming. The Wyoming Archaeologist, 16(1):5-55, and 16(2):56-126. Cheyenne, Wyoming.

Richmond, G. M.
1962 Quaternary stratigraphy of the La Sal Mountains, Utah. United States Geological Survey Professional Paper 450-E: E121-E125. Washington, D.C.

Satterthwaite, Linton
1957 Stone artifacts at and near the Finley Site, near Eden, Wyoming. University of Pennsylvania Museum, Museum Monographs, (unnumbered): 1-27. Philadelphia, Pennsylvania.

Sharrock, Floyd W.
1966 Prehistoric occupation patterns in southwest Wyoming and cultural relationships with the Great Basin and Plains culture areas. University of Utah Anthropological Papers, 77:1-191. Salt Lake City, Utah.

Smith, Sharon K.
1970 Preliminary report site 48PA551. The Wyoming Archaeologist, 13(1):23-33. Cheyenne, Wyoming.

Spaulding, A. C.
1958 The significance of differences between radiocarbon dates. American Antiquity, 23(3):309-311. Salt Lake City, Utah.

Steege, L. C.
1967 Happy Hollow Rock Shelter. The Wyoming Archaeologist, 10(3):11-36. Cheyenne, Wyoming.

Strong, W. D.
1935 An introduction to Nebraska archaeology. Smithsonian Miscellaneous Collections, 93(10):1-322. Washington, D.C.
1940 From history to prehistory in the northern Great Plains. Smithsonian Miscellaneous Collections, 100:353-394. Washington, D.C.

Stuckenrath, R., and J. E. Mielke
1972 Smithsonian Institution radiocarbon measurements VII. Radiocarbon, 14(2): 401-412. New Haven, Connecticut.

Suess, H. E.
1970 Bristlecone-pine calibration of the radiocarbon time-scale 5200 B.C. to the present. In I. U. Olsson (Ed.) 12th Nobel Symposium Proceedings, Uppsala, Sweden, August 11-15, 1969: Radiocarbon variations and absolute chronology: 303-311. Almquist and Wiksell, Stockholm, Sweden; John Wiley and Sons, New York, New York.

Trautman, M. A.
1963 Isotopes, Inc. radiocarbon measurements III. Radiocarbon, 5:62-79. New Haven, Connecticut.
1964 Isotopes, Inc. radiocarbon measurements IV. Radiocarbon, 6:269-279. New Haven, Connecticut.

Wedel, W. R.
1961 Prehistoric Man on the Great Plains. University of Oklahoma Press, Norman, Oklahoma. 355 p.

Wedel, W. R., W. M. Husted, and J. H. Moss
1968 Mummy Cave: prehistoric record from Rocky Mountains of Wyoming. Science, 160(3824):184-185. Washington, D.C.

Wheeler, R. P.
1954 Two new projectile point types: Duncan and Hanna points. Plains Anthropologist, 1:7-14. Lincoln, Nebraska.

Wilke, P. J., and R. E. Taylor
1971 Comments on isochronous interpretations of radiocarbon dates. Plains Anthropologist, 16(52):115-116. Topeka, Kansas.

Wood, W. R.
1971 Biesterfeldt: a Post-Contact Coalescent site on the northeastern Plains. Smithsonian Contributions to Anthropology, 15:1-108. Washington, D.C.

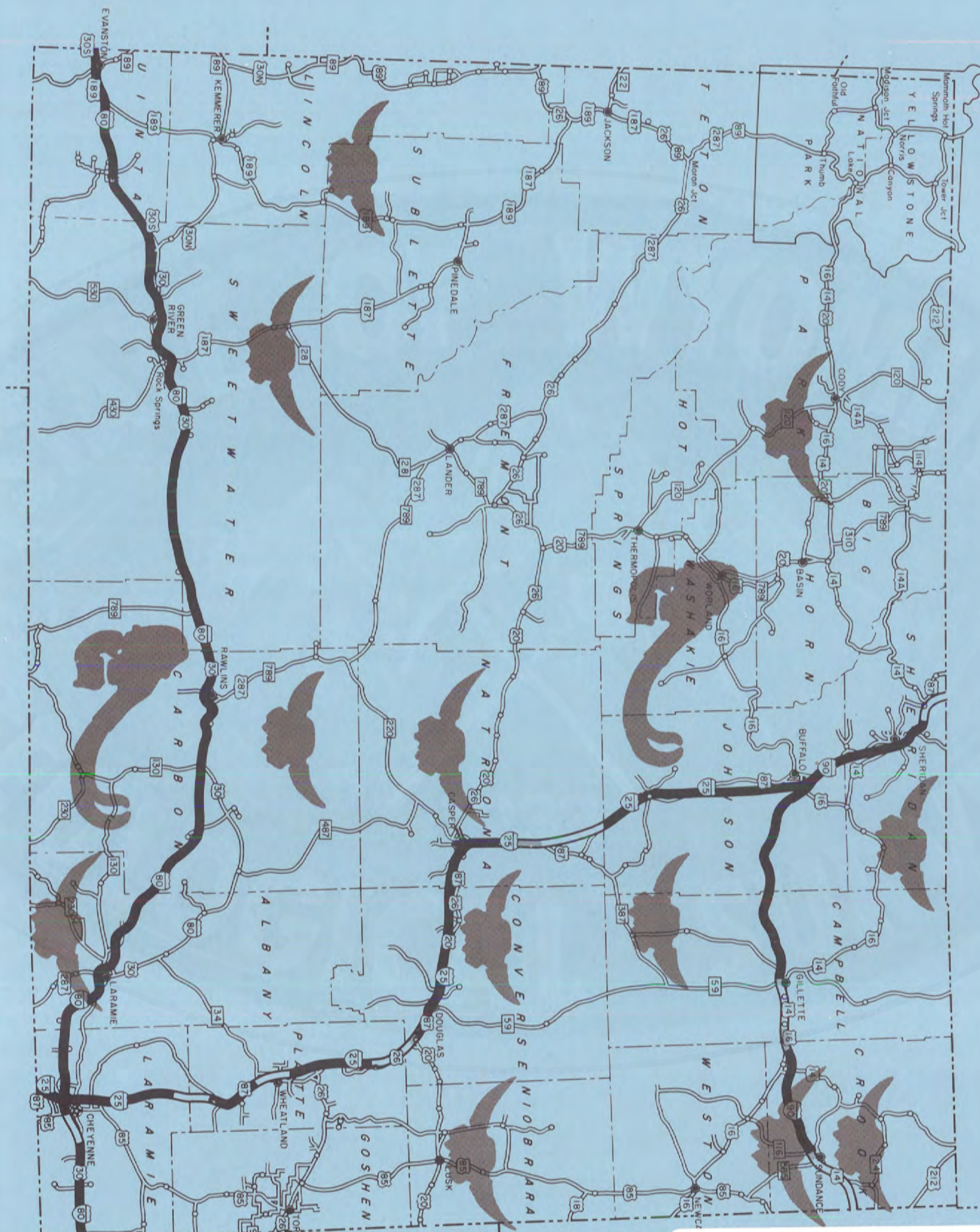
Wormington, H. M.
1957 Ancient man in America. Fourth Edition. Denver Museum of Natural History Popular Series, 4:322 p. Denver, Colorado.

Wormington, H. M., and R. G. Forbis
1965 An introduction to the archaeology of Alberta, Canada. Denver Museum of Natural History Proceedings, 11:1-207. Denver, Colorado.

STATE OF WYOMING

1933

GEOLOGICAL SURVEY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GREEN RIVER
Rock Springs
PINEDALE
LANDER
CODY
THERMOPOLIS
WORLAND
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