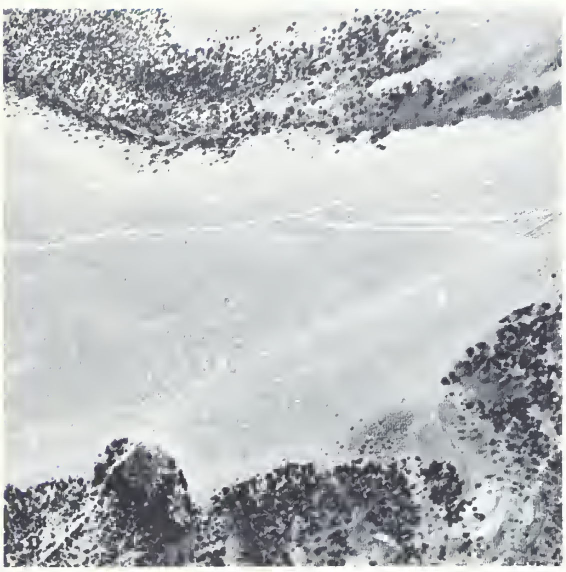
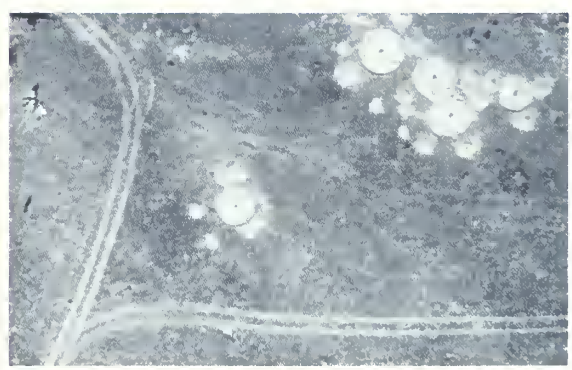
REMOTE SENSING

The American Great Plains





Supplement No. 9

Frontispiece. False-color infrared vertical air photograph of circular markings in the grasslands of eastern Montana. Rings are uniformly 48.7 m in diameter. No satisfactory explanation has yet been suggested for their origin. See Section 5 for discussion. Photograph courtesy of Robert E. Carroll of ECON, INC., Helena, Montana.

REMOTE SENSING
The American Great Plains

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Supplement No. 9

to Remote Sensing: *A Handbook for Archeologists and Cultural Resource Managers*

Cultural Resources
National Park Service
U.S. Department of the Interior
Washington, D.C.

1984

Library of Congress Cataloging in Publication Data

Main entry under title:

Remote sensing supplement.

Supplements to Remote sensing: a handbook for archeologists and cultural resource managers by T. R. Lyons and T. E. Avery.

1. Aerial photography in archeology—Collected works. 2. Photography in archeology—Collected works. I. Lyons, Thomas R. Remote sensing. CC76.4.L96 Suppl.9 930.1 028 80-81

Preface

This publication is number nine in the remote sensing "Handbook" series. The Handbook series was initiated with the publication of *Remote Sensing: A Handbook for Archeologists and Cultural Resource Managers* in 1977, and has been supplemented by eight additional manuals covering a number of technical aspects of cultural resources remote sensing as well as applications in diverse environments. While many remote sensing techniques are universally applicable to cultural resources, some aspects of any technology must be adapted to fit differing problems and environments. This is certainly true in the heavily vegetated (and farmed) midwestern United States. Remote sensing of cultural resources in this country was pioneered in the arid West, and it is not uncommon to hear the opinion that aerial photos and other remote sensor data are of little use in areas with dense vegetation. Recently, however, experimental work (including that detailed in this volume) has demonstrated that remote sensing can be easily adapted to fit the needs of the Midwestern archeologist and cultural resource manager.

Perhaps a word of caution should be inserted at this point. Some have construed that the thesis behind the publication of this series is that remote sensing is a solution to all cultural resource problems and needs. This is certainly not the case with remote sensing or any other of the wide range of archeological techniques available to the cultural resources scientist. This volume and the others which comprise the Handbook series, however, illustrate that when appropriately and properly applied, the methods and techniques of remote sensing can form a useful and sometimes necessary part of any integrated program of cultural resources research or treatment.

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Acknowledgments

The authors wish to acknowledge the spiritual and practical assistance of F. A. Calabrese and Thomas D. Thiessen of the Midwest Archeological Center in the preparation of the manuscript. We are especially grateful for contributions provided by Robert E. Carroll, Leslie B. Davis, Terry L. Steinacher, John W. Weymouth, Thomas A. Witty and Charles A. Reher. Robert E. Warren and Michael K. Trimble provided welcome assistance in writing as did, in fact, the many people cited throughout the text following the notation "personal communication." Marie Johnson and Jean Sparks prepared immaculate copy from the author's drafts, and eased the burdens of scholarship in many other ways.

Barbara L. Daniels and Larry Nordby deserve particular mention for their meticulous work in the copy editing of this volume.

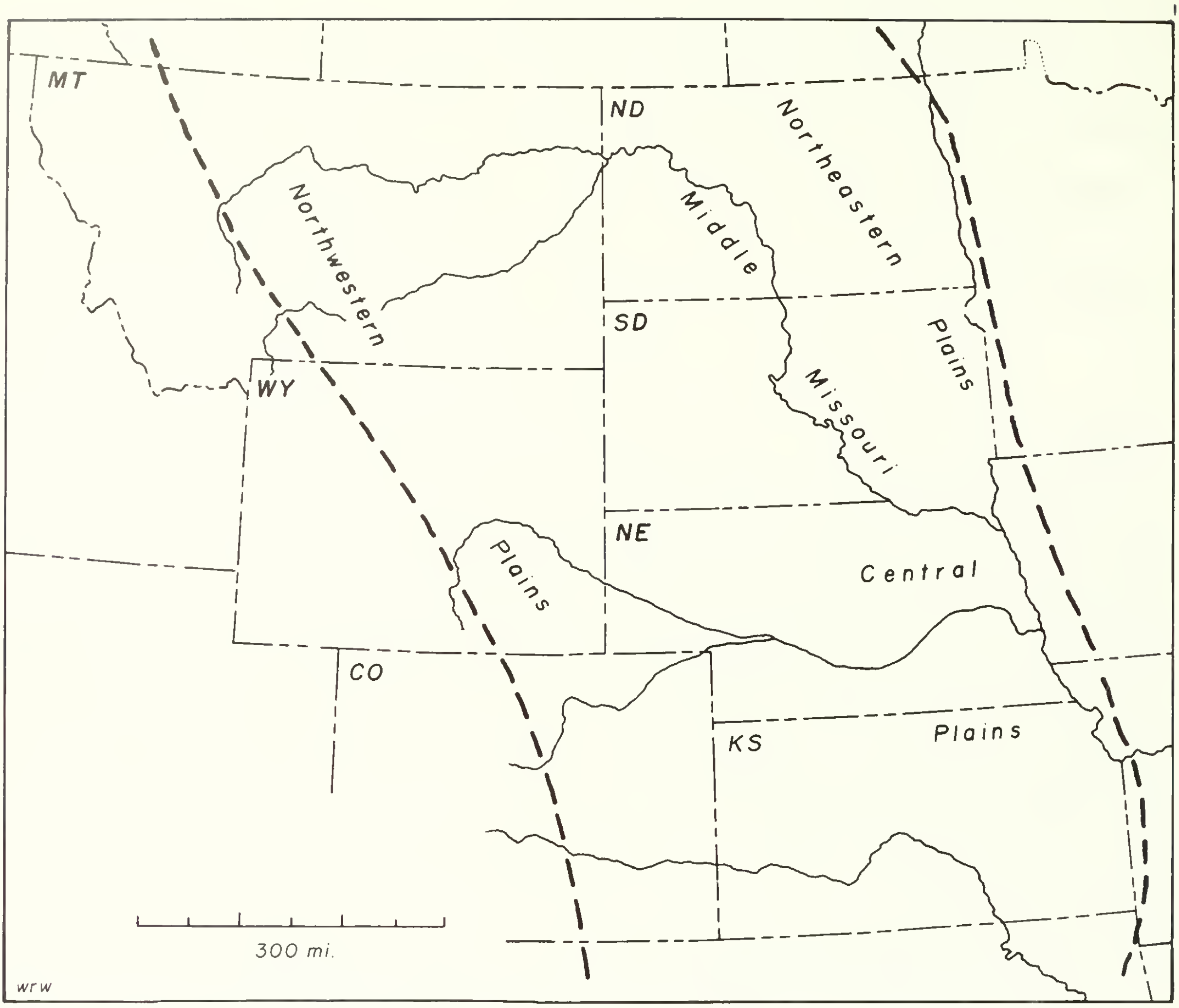


Figure 1. The Central and Northern Plains in the United States and their cultural subdivisions. (After Wedel, 1961.)

Section 1

Introduction

In this supplement to *Remote Sensing: A Handbook for Archeologists and Cultural Resource Managers* (Lyons and Avery 1977), we are concerned with the potential and realized application of remote sensing techniques in the Central and Northern Great Plains of the United States, that is, with most of the northern three-quarters of the area defined by Wedel (1961: Fig. 1), for archeological purposes, as the Great Plains. This area consists of the states of North Dakota, South Dakota, Nebraska, and Kansas, plus the grassland portions of Colorado, Wyoming, and Montana. Each of the four cultural subdivisions of that area (Fig. 1) contains distinctive archeological surface and subsurface features capable of being detected by the remote sensing techniques discussed in this manual.

In the Central Plains are the remains of villages of some of the Caddoan-speaking peoples (principally the Pawnee and the Wichita), as well as those of the Omaha, Oto, and other village dwellers who entered the area in late prehistoric to protohistoric times; these remains have been the focus of much detailed archeological work since the 1930's. In the Middle Missouri are the remains of conspicuous, often heavily fortified, villages of the historic Mandan, Hidatsa, and Arikara, and the sometimes equally prominent villages of their prehistoric predecessors.

In the Northeastern Plains, the visible archeological remains are dominated by linear and dome-shaped earthen mounds — features which are shared with the Middle Missouri subdivision. Finally, in the Northwestern Plains the dominant visible site type is the so-called tipi ring site. Such features exist there, and elsewhere in the Northern Great Plains, in numbers which may well be in the hundreds of thousands. Other boulder features such as effigies, cairns, and rock piles are also found in quantity in the latter two areas.

Only rarely in the Plains does the relief left by archeological remains exceed about 1.2-1.5 m. The monumental earthen mounds of the Mississippi Valley and elsewhere in the eastern United States are here replaced by more modest structures. Mounds in Plains states are sometimes no more than 15 cm high (although they may be several hundred meters long). More commonly, such structures are 30 to 60 cm high.

Features with negative relief are common, especially along the major stream terraces of rivers in the eastern part of the Plains. The sites of earth-covered pit houses, and even of surface earth-covered dwellings, often leave a shallow, circular depression in the soil. These depressions occur in great numbers where communities were large. Such aggregations of houses, especially in the Northern Plains, were often surrounded by deep ditches that, even in their present filled-in condition, are sometimes 1.5 m deep.

A few other features attain heights exceeding 30 cm or so above the surface, such as the stone cairns in the Northwestern Plains. Most other boulder features, however, tend to be only a few centimeters above the ground, and are visible primarily by their color, which contrasts with that of the adjoining soil or vegetation.

These and some other kinds of sites (especially buried ones and those sites that affect surface soil conditions) often leave evidence of their presence in the form of crop marks, where vegetation differs because former cultural activities have modified the soil. Consequently, the nature of the ground cover is of prime importance in site visibility, whether one is walking or using aerial remote sensing techniques. The next section of this supplement summarizes the principal soil and vegetative patterns in the Central and Northern Plains.

Most of this supplement will focus on the use of air photos for finding and mapping historic and prehistoric archeological sites. Other supplements in the series, e.g., the one on Oregon (Aikens et al. 1980: 1), recognize that air photos are important in discovering archeological sites, but they place more stress on their value in understanding the distribution of those sites across the landscape. Aerial views are also major sources of data for mapping environmental variables important to human exploitative patterns, and for modeling settlement-subsistence systems, as we see in Section 4.

Air photos have been widely used in the Plains ever since 1946, with the founding of the Smithsonian Institution's Missouri River Basin Surveys Program. At first, they were used principally in those parts of the Plains where the earth lodge villages of semisedentary gardening tribes were to be found. Today, however, they are finding ever-increasing application in a wide range of other tasks. The use of nondestructive remote sensing techniques (Lyons and Ebert 1978) has, nevertheless, only begun, and we can look forward to a greater understanding of the relationships between man and environment in the Great Plains.

Exploiting Air Imagery

The application of remotely sensed imagery to cultural resource studies is becoming increasingly important. Immediately practical applications, as well as long range uses in a variety of scientific problems, are abundant (see Lyons 1976; Lyons and Ebert 1978; Lyons and Hitchcock 1977). Some of the problems and applications for those responsible for managing cultural resources in the Plains, as well as for those more concerned with understanding the evolution and exploitation of the natural and cultural landscape over the centuries, are detailed in the following sections.

Air photos may either be used in lieu of maps, or as a base for constructing maps, for almost any managerial or scientific purpose (Lyons and Avery 1977: 32-33). Air photos can be used in the place of topographic or planimetric maps. In some parts of the West, adequate maps simply do not exist. Even when good maps are available, they may show too little relief, too few landmarks, or no vegetation, making it impossible to locate precisely a given site or area. In parts of Montana, for example, the only real landmark in several thousand acres of rolling grassland might be a solitary windmill, but the subtleties expressed on air photos will permit one to locate a very small area on that photo with great accuracy. By-products of air imagery are discussed at length in later sections.

The archeological interpretation of remote sensor data, and generalized specifications for archeological photography, have been outlined elsewhere (Lyons and Avery 1977: 53-65, 84-87). Consult this source for a good synopsis of the bases for soil, shadow, and crop marks.

A great deal of variation exists as to the best time of year to obtain air coverage. Because much of the Plains — especially in the western regions — remains a grassland, and because a large part of the area in the eastern part is under cultivation, crop marks are important in photointerpretation. Crop marks are most easily seen when the grass is low, especially following a rain in late spring or early fall. Local professional pilots are usually the best single source for information as to when certain surface manifestations will be visible. Most pilots will stress, however, that it is difficult to predict exactly when conditions will be fully optimal for the best visibility of a given kind of feature; the amount of moisture stored in the soil, the timing and intensity of rainfall, variation from annual seasonal temperatures, and many other factors influence the degree of visibility of crop marks.

Because many kinds of sites are identifiable by positive or negative relief, the ideal time of day is generally in the early morning or late afternoon, when the angle of the sun will produce sharp shadow marks. The flat light of midday is as poor for yielding detail in low relief areas in the air as it is on the ground. Photography very late in the day, just minutes before sundown, is sometimes useful for illuminating low-relief features, although the photograph will probably be technically poor and will not reproduce well.

The Agriculture Stabilization and Conservation Service of the U.S. Department of Agriculture takes air photos of most counties in the Midwestern and Plains states about every seven years. Counties which are only lightly farmed are not photographed as regularly as this. For example, McPherson County, in the heart of the western Nebraska sandhills, has not been photographed since 1955. Nevertheless, there are substantial parts of the nation for which there are long sequences of air imagery, although interrupted by gaps during World War II.

Figure 2. Big Hidatsa Village (32ME12), a historic Hidatsa site of the eighteenth to nineteenth century. View is east southeast. Photograph courtesy of the North Dakota State Highway Department.

Long-term studies of many different kinds of features are therefore possible on these photos, such as the growth of towns, road systems, agricultural expansion, and other elements which affect historical or archeological sites. Negatives for flights made in 1936 to 1941 have been deposited in the National Archives. Later coverage can be obtained from A.S.C.S. offices in Salt Lake City (U.S.D.A. 1975).

Other conditions being equal, the A.S.C.S. air photos from the late 1930's and early 1940's are probably the cheapest and most useful single source for air photo coverage for most of the Plains. The recent destruction of the negatives for the air coverage for those years for the states of Kansas and South Dakota by the National Archives means that a basic source for Plains prehistory has been lost (Corbyn 1979). Although the National Archives converted the negatives for these states to miniaturized safety film, the low resolution of this film means that prints made from it are all but useless for our purposes. For this reason, repositories or individuals who may own prints made from the original negatives should make special efforts to preserve them. In addition to their other virtues, these prints comprise the earliest systematic air coverage for many areas which have now been heavily modified by all manner of construction, so they reveal data which have been obliterated and can no longer be seen even on the finest modern imagery.

Not only are air photos useful for monitoring past changes, the monitoring of modern storm and flood damage and changes in site visibility is simplified by their use. For example, the loss of historic or prehistoric sites by the collapse of river banks into the stream can be monitored using air photos so that mitigation or preservation can be planned well in advance.

Although most air photos are taken during seasons when crop marks may be the most visible, the opportunity to obtain excellent imagery during the winter should not be overlooked. Several photos taken of the Hidatsa earth lodge villages in the Knife River Indian Villages National Historic Site, in North Dakota, were taken following a light snowfall. Rather than obscuring detail, surface expression at the sites was dramatically highlighted. At Big Hidatsa (Fig. 2), this resulted from the fact that the weed cover surrounding the house depressions partly concealed the snow cover, whereas the snow was more visible in the shorter grasses within the houses and around the village margin. This circumstance, combined with shadow marks, provided very high contrast for surface features. At the nearby Sakakawea Site, which was entirely mantled by short grasses, the blowing snow accumulated in low ridges within the margins of the house depressions, defining them almost as well as if they had been outlined with white paint (Johnson and Wood 1980: Fig. 2).

Even a heavy snowfall does not preclude useful photointerpretation. A gentle snowfall will produce shadow marks at the proper time of day, and drifting snow may accentuate subtle surface expression and/or vegetative cover. In 1955, a privately contracted overflight of the Cross Ranch, on the Missouri River opposite the town of Washburn, North Dakota, was made following a snowfall which left 15 to 20 cm of snow on the ground. Although virtually all ground cover except trees was obliterated in the imagery by the snow, the late afternoon timing of the flight resulted in shadow marks at each of the earth lodge villages along the Missouri River terraces — marks which are pronounced enough that planimetric maps could be produced from them.

Contracting for Air Imagery

A great deal of advice on how to obtain new air imagery exists, but several cautions for those just beginning to use them are given below.

1. Before any decision is made to purchase new imagery for any area, check carefully for existing coverage. Because of the great demand and multiple uses for air photos of every kind, many different sets of black-and-white photos are already on hand for most parts of the United States. Lyons and Avery (1977: 27-31) have synopsized the basic sources for existing imagery and maps. Infrared, false-color, or special map coverage at particular scales must usually be contracted.
2. Once the decision is made to contract with a commercial firm for new coverage, weigh carefully the decision to provide the ground control. There are many hidden costs and problems in providing ground control, and unless you have highly trained personnel, an engineering firm can do the job much faster, and more economically and precisely.
3. Plan your real and potential needs carefully in contracting for an overflight. Have as many kinds of film as possible taken of the subject at the same time. A return flight, for any reason, will be as expensive as the initial one.

The relative costs of on-the-ground mapping versus photogrammetric mapping (although at now obsolete cost estimates) may be found in several papers (see Ebert 1977: 177-185; Ireland 1980; Jorde and Bertram 1976:42-54). For details on a North Dakota example, see Section 6.

Section 2

The Great Plains Landscape

General Geology and Landforms

The Great Plains of the interior of the North American continent is a large regional grassland that extends from central Canada southward to the Rio Grande River in Texas, and eastward from the Rocky Mountains to the western borders of Minnesota, Iowa, and Missouri. The eastern border cannot be well defined since there are no major physiographic landmarks, nor is there a break in topography or vegetation. Rather, the Plains may be characterized as a gentle gradient from the central lowlands of the Midwestern United States to the Rocky Mountains on the west (see Hunt 1967). Although precise bounding is difficult (if not virtually impossible) for the Great Plains Province, our discussion will be oriented toward what is known archeologically as the Central and Northern Plains, which include the eastern portions of Montana, Wyoming, and Colorado, as well as all of North and South Dakota, Nebraska, and Kansas. From a physiographic standpoint, this area includes the Missouri Plateau of Montana and the Dakotas, and the High Plains of the states to the south (Fenneman 1931; Hunt 1967) (see Fig. 3 a—b).

The area under discussion came into existence relatively late in the geological record, principally during late Mesozoic and Cenozoic times (Hunt 1967: 222, 224). Uplift of the Rocky Mountains is in large part responsible for the structural geology of the Great Plains today. The underlying Mesozoic formations of the Great Plains derive from marine sediments deposited during Upper Cretaceous times in a large sea extending from the Arctic Ocean to the Gulf of Mexico. As a result of the continuous uplifting activities that formed the Rocky Mountains, a large outwash plain formed to the east, creating the High Plains (Hunt 1967: 224).

For the most part, the Plains are gently rolling, with Mesozoic and Cenozoic formations being relatively horizontal, although there are several local structural anomalies. Isolated hills and mountains occur in this region, otherwise characterized by little vertical relief, and are located in eastern Montana and Wyoming, and in western South Dakota. These mountains, formed as the result of doming and of laccolithic or other geologic intrusions (Hunt 1967: 222), include the Sweetgrass Hills and the Bearpaw, Little Rocky, Highwood, Moccasin, and Judith Mountains of Montana. The Black Hills are an example of dome mountains resulting from uplift. Additional ranges, such as the Big Horn and the Pryor Mountains, are found along the western edge of the Great Plains adjacent to the Rocky Mountains in Montana and Wyoming.

Other topographic anomalies in the Plains include the badlands and the sandhill regions. Southwestern North Dakota, northwestern South Dakota, and adjacent areas of Montana and Wyoming have badlands regions characterized by heavily eroded shale formations and steep, dissected topography. These areas also contain lignite beds that have sometimes ignited *in situ* and baked the overlying shale, forming a bright red clinker that is similar in weight and appearance to scoria. The sandhills of western Nebraska are another surficial anomaly of the Plains. This region consists of an extensive network of active and inactive sand dunes that provides greater relief for the High Plains than would otherwise be expected.

The principal drainage system in the Central and Northern Plains is the Missouri River Basin. In general, streams flow eastward from the Rocky Mountains and drain into the Missouri River, creating a ladder-like pattern. Streams flowing west

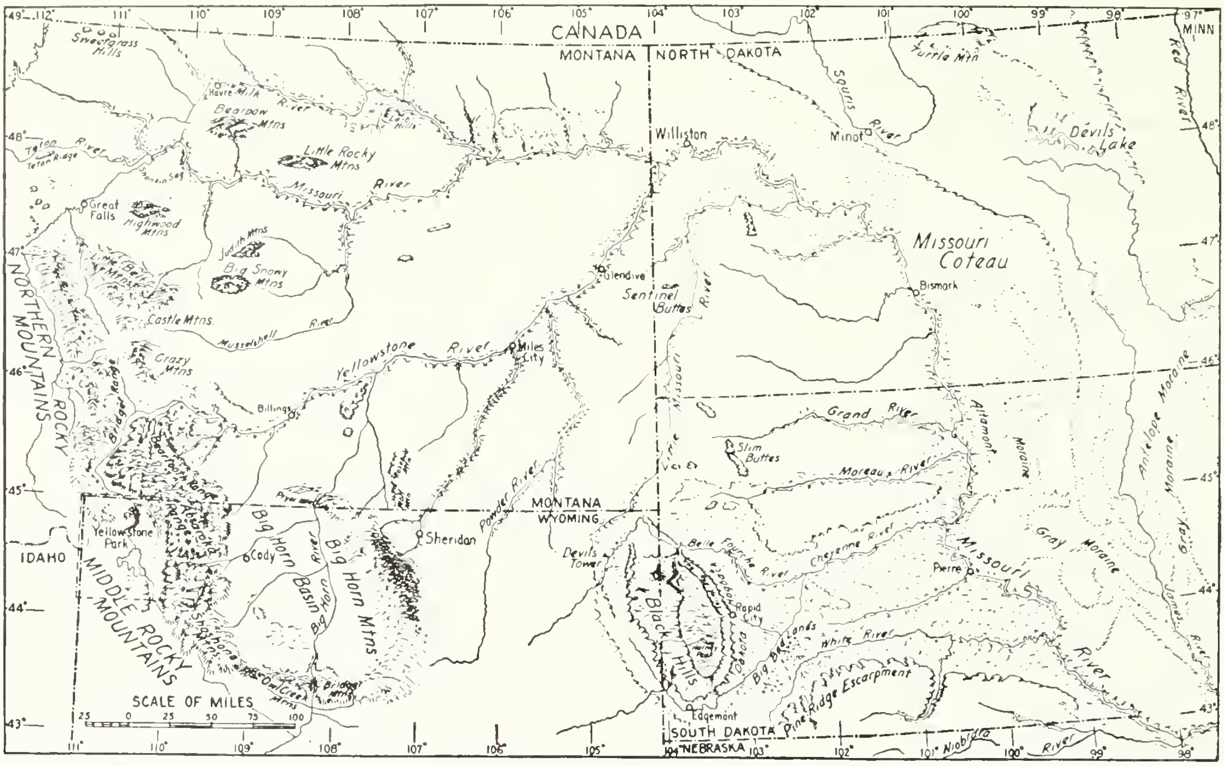


Figure 3a. Physiographic features of the Central and Northern Plains. (From *Physiography of Western United States*, by N. M Fenneman, Copyright 1931. Used with the permission of McGraw-Hill Book Company.) **(top section)**

into the Missouri River are few in number and ephemeral or have a low discharge compared with those flowing east into the Missouri River. Exceptions to the pattern of flowing into the Missouri River are the Souris and Red Rivers that terminate at Hudson Bay, and the Arkansas River that drains directly into the Mississippi River. The Missouri River Valley through North and South Dakota may be characterized as a relatively deep and narrow trench, while in Montana, Nebraska, and Iowa, the river flows through a broader trench. Streams flowing into the Missouri River also tend to have broad valleys with gently sloping bluffs, except where they flow through badlands topography as in the case of the Little Missouri River in southwestern North Dakota.

The Missouri River, prior to glaciation, drained northeastward through northwestern North Dakota, eventually flowing into Hudson Bay, and the ancestral Knife, Heart, Cannonball, Grand, Moreau, and Cheyenne rivers also flowed northeast to Hudson Bay (Burgess et al. 1973: 27; Kelly and Buturla 1967; Lemke et al. 1965: 19). The remaining streams appear to have had as their ultimate destination the Gulf of Mexico. During glaciation, perhaps during Illinoian or early Wisconsinan advances, the Missouri River and other eastward flowing streams were turned southward to their present day drainage system.

Climate: Past and Present

The Pleistocene in North America had at least four major advances of glacial ice which modified landscapes in the northern and eastern Plains. A graphic presentation of glacial limits and glacial drift may be found in Lemke et al. (1965: 16-17). Each glacial advance can be characterized as an oscillating pattern in response to long-term climatic change. In addition, each glacial stage had an associated interglacial period of maximum glacial retreat and relative warmth. The four major glacial stages which identify maximal glacial advances are, from oldest to most recent: Nebraskan, Kansan, Illinoian, and Wisconsinan. The interglacial stages for North America from oldest to most recent are

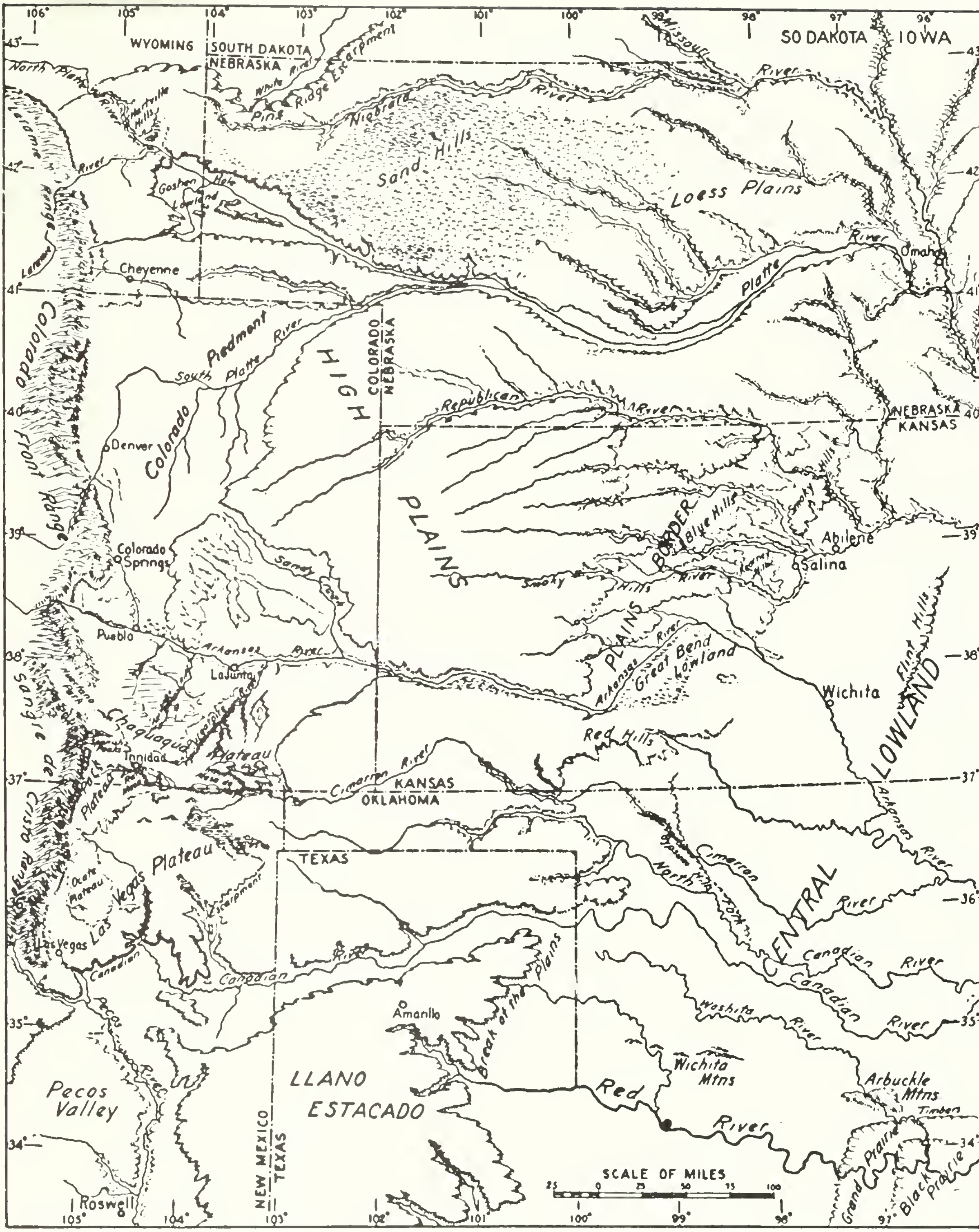


Figure 3b. Physiographic features of the Central and Northern Plains. (From *Physiography of Western United States*, by N. M. Fenneman, Copyright 1931. Used with the permission of McGraw-Hill Book Company.) **(bottom section)**

Table 1. Climatic Episodes for the Holocene.*

Climatic Episodes		Cultural Periods
Late Glacial		
	10,030 B.P. (8080 B.C.)	
Pre-Boreal		Paleo-Indian
	9030 B.P. (7350 B.C.)	(ca. 10,000-5500 B.C.)
Boreal		
	8490 B.P. (6540 B.C.)	
Atlantic		
	5060 B.P. (3110 B.C.)	
Sub-Boreal		Plains Archaic
	2760 B.P. (810 B.C.)	(ca. 5500 B.C.-A.D. 1)
Sub-Atlantic		
	1680 B.P. (A.D. 270)	
Scandic		Plains Woodland
	1260 B.P. (A.D. 690)	(ca. A.D. 1-900)
Neo-Atlantic		
	850 B.P. (A.D. 1100)	
Pacific		Plains Village
	400 B.P. (A.D. 1550)	(ca. A.D. 900-1850)
Neo-Boreal		
	100 B.P. (A.D. 1850)	
Present		Euro-American

* After Wendland (1978: 278-282, Table 3).

Aftonian (post-Nebraskan), Yarmouthian (post-Kansan), and Sangomonian (pre-Wisconsinan) (Butzer 1971, 1976: 195-196; Hunt 1967; Wright 1976a). Maximum glacial ice and drift apparently extended just west and south of the present Missouri River trench in North and South Dakota, northeastern Nebraska, and Montana (Wright 1976a; Wright and Frey 1965). It was probably during the Illinoian or Wisconsinan glacial advance that the Missouri River drainage was turned south.

The importance of glaciation extends beyond direct modification of surface landscapes and river channel changes to the deposition of loess across much of the nonglaciated areas of the Plains. Massive amounts of silts and clays were carried off by glacial melt water streams and eventually left stranded in broad stream beds following glacial recession. Upon drying, the silt and clays, known as loess, were distributed by the wind over much of the Plains and other regions of the Midwest. These loess deposits are variable in thickness (Butzer 1976) and provide a mantle over older strata in the mid-continental United States.

With the end of the Wisconsinan glacial advance,approximately 10,000-11,000 years B.P., a new epoch of the Quaternary began — the Recent or Holocene epoch. In spite of the fact that there were no continental glacial advances during this time, there was climatic fluctuation that affected the distribution of vegetation, fauna, and landforms. The Holocene sequence (after Wendland 1978; Wendland and Bryson 1974) is presented in Table 1. These fluctuations, based primarily on pollen and macro-vegetation data, as well as atmospheric wind circulation patterns, should be considered tentative and subject to further revision as more data are collected. Other statements about climatic conditions in the Holocene have been published (Bryson and Wendland 1967; Bryson et al. 1970; Reeves 1973).

Beginning with the pre-Boreal, there is evidence of a warming trend that culminates with a period of maximal warmth in the Atlantic. During this time, glacial ice has withdrawn to a small ice mass near Hudson Bay and vegetation boundaries are shifting, with midcontinental grasslands expanding eastward (Wendland 1978). The period of maximum warmth in the Atlantic episode is referred to as the Hypsithermal (Wright 1976b), and is a geographically, time-transgressive phenomenon when conditions were generally warmer and/or drier (Wright 1976b). (Also see King 1980; King and Allen 1977; Reeves 1973; Wells 1970; and Wendland 1978, for discussions of the Hypsithermal.) Post-Hypsithermal conditions are not the same as those of the pre-Hypsithermal (King and Allen 1977), but represent a different climatic regime.

From about 4000 years B.P. to modern times, major vegetation boundaries have been approximately stable, although climatic fluctuation has continued to the present. A general deterioration of climate apparently occurred in sub-Atlantic times with a period of warmth following and terminating in the neo-Atlantic (Wendland 1978: 281). While the neo-Atlantic appears to have been a period of greater moisture, the Pacific shows evidence of increasing environmental desiccation into the neo-Boreal (Little Ice Age), when cooler temperatures are evident (Wendland 1978: 281). Since the end of the neo-Boreal and into the present, fluctuations have been noted alternating between drier and wetter conditions (Borchert 1950, 1971; Butzer 1976: 365-374; Lawson 1974). In spite of the fact that the foregoing has outlined major climatic trends, it is necessary to remember that short-term temporal fluctuations, as well as regional fluctuations, also occurred.

The present climate is distinctly continental, characterized by great fluctuations of temperature on a seasonal, as well as an annual, basis. Continental cycles tend to introduce seasonal extremes due to the large landmass, and in mid-latitudes, seasonal extremes become greater than in lower latitudinal positions (Strahler and Strahler 1978: 127-128). In addition, rainfall is slight, ranging between about 25 cm in the west to 63.5 cm or more per annum on the eastern edge of the Plains. Most precipitation takes the form of rainfall and the greatest proportion falls during late spring and early summer.

Several factors are responsible for the extreme seasonal variations of temperature and the lack of precipitation. The mid-latitude and continental position plays a great part. During the winter months, the sun is lower on the horizon and the effect at the earth's surface is less radiation at a more acute angle for fewer hours of the day, resulting in extremely cold winters. On the other hand, radiation strikes at a normal angle for more hours of the day throughout the summer months. The result is extremely hot summers (Borchert 1950; Strahler and Strahler 1978).

The seasonally fluctuating precipitation pattern characteristic of mid-latitude grasslands is also closely associated with the continental character of

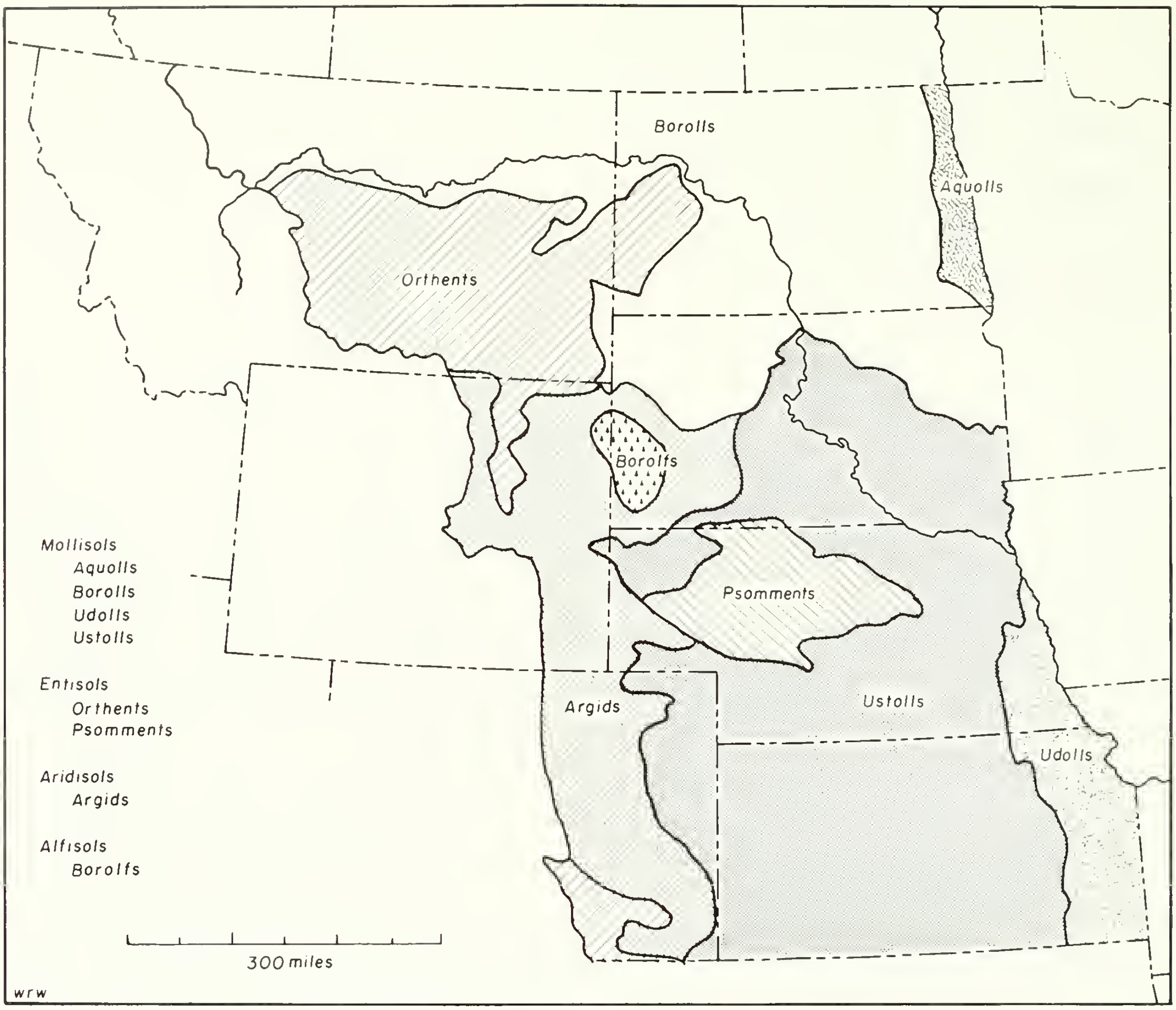


Figure 4. Soil orders and suborders or the Central and Northern Great Plains. (Adapted from Aandahl 1972, and U.S. Department of Agriculture, 1975.)

the region. Plains grasslands occupy a region where westerly winds prevail. From their origin in the Pacific, these winds sweep eastward across the western United States, crossing the Rocky Mountains and moving on to the Plains. In passing over the Rocky Mountains, most of the moisture carried by the westerlies is lost. Since the grasslands are on the leeward side of the mountains, they effectively lie in a rain shadow where conditions range from arid to subhumid. Moreover, two additional air masses (Arctic and tropical) influence temperature and precipitation conditions on the Plains region during the annual cycle. Seasonal contrasts are due, in part, to the domination of maritime tropical air masses originating in the Gulf of Mexico and invading the mid-latitudes of the continent in the summer, while during the winter, the Arctic air masses dominate (Borchert 1950; Bryson and Hare 1974; Strahler 1965: 110, 113).

Ecological Zonation: Vegetation and Soils

Soils and vegetation are both closely linked with the environmental parameters discussed above. In general, the major soils that dominate the Plains or steppes of mid-latitude continental posi-

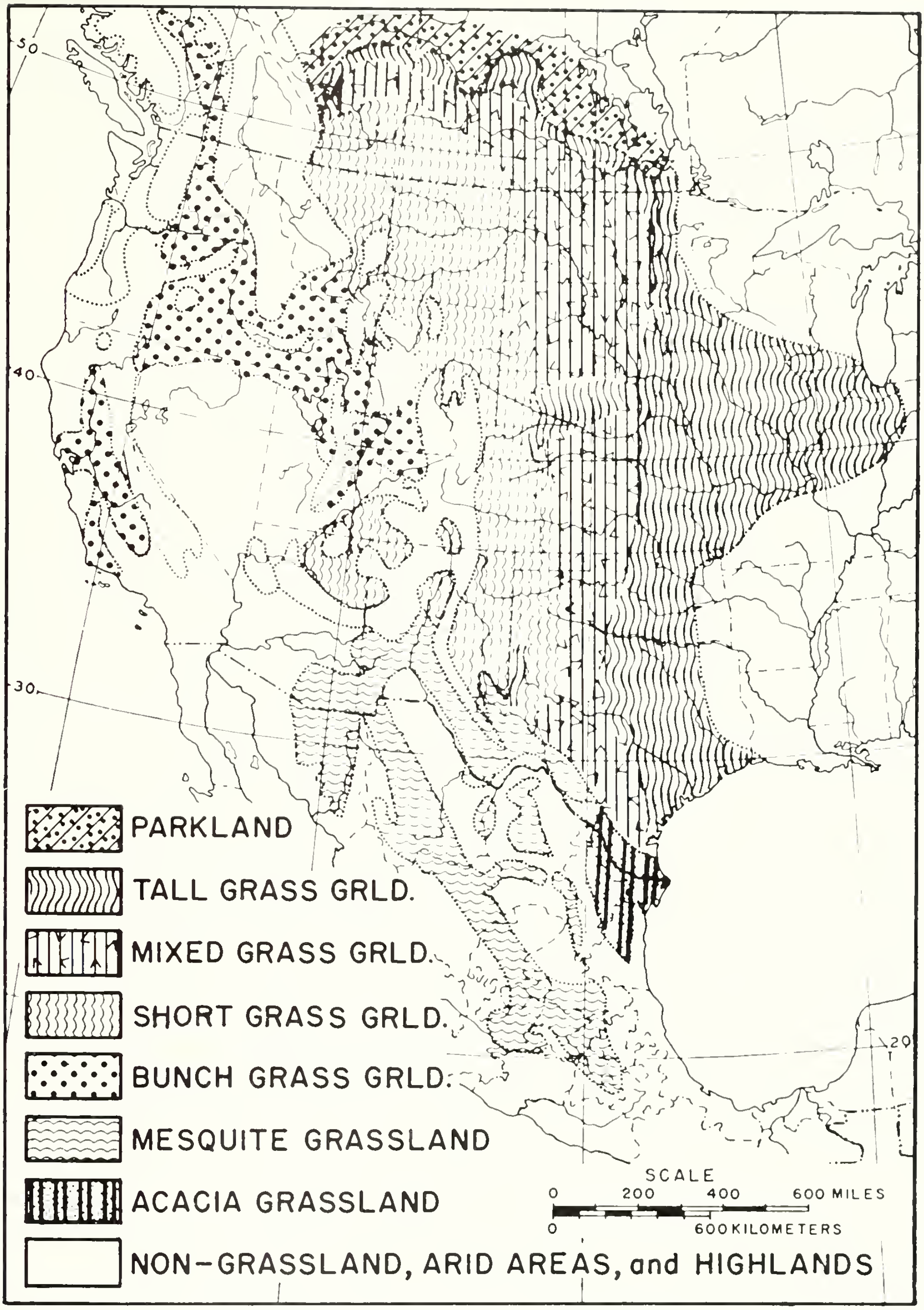


Figure 5. The vegetation of the western United States (from Shelford 1963). Map courtesy of the University of Illinois Press.

tions are the Mollisols (Strahler and Strahler 1978: 223; U.S.D.A. 1975: 271-321), which generally form under grasses in climates with moderate to strongly deficient seasonal soil-water availability. For the most part, Mollisols are dark-colored soils (dark brown to black) and virtually all have a mollic epipedon (U.S.D.A. 1975: 271). Mollisols are among the most fertile soils in the world today. Their distribution and economic importance corresponds to the commercial production of grains, e.g., wheat and corn, and they provide the bulk of grain production in the world (Fig. 4). Prior to the production of grain during Euro-American settlement and later, these soils supported a large regional grassland utilized primarily by large herds of herbivores. (For a more extensive discussion of distinguishing characteristics and subunits of Mollisols, see U.S.D.A. 1975.) Smaller units of Entisols, Aridisols, and Alfisols are also present in the western Plains.

There are two natural vegetation communities in the mid-continental region of the United States: temperate grasslands and northern floodplain forests. The latter community is relatively minor in areal extent and is confined to major stream drainages and their tributaries, with upland forests confined largely to anomalous geographic settings such as the Black Hills. Despite the fact that grasslands occupy positions intermediate between sufficient rainfall to support forests and insufficient rainfall which results in desert forms of vegetation, the floodplain forests exist within temperate grasslands due to surface and subsurface moisture within stream valleys (Kuchler 1964; Shelford 1963) (Fig. 5).

The grassland of North America is one of the most extensive biomes within the continental interior. This biome has two major subdivisions: tall and mixed grass prairies and short grass plains or steppes (Kucera 1978: 199-202; Odum 1971: 388-391; Shelford 1963: 328-347). While these biomes intergrade along an increasing precipitation gradient from west to east, the short grass plains occupy the drier regions west of the 100th meridian, while the mixed and tall grass prairies are in the areas of greater precipitation east of the 100th meridian. The tall grass prairies are, for the most part, beyond the area of concern here.

The plains of the western grasslands have short grasses as the principle species, of which buffalo grass *(Buchloe dactyloides)* and blue grama *(Bouteloua gracilis)* are prevalent species. These grasses are adapted to the seasonal fluctuations of temperature, precipitation, and desiccating winds (cf. Borchert 1950; Tomanek and Hulett 1970). During periods of increased stress, the aboveground portions of these plants dry out and they go into a period of dormancy. When more favorable conditions return, these grasses move out of dormancy and continue their growth cycle. Grasses in these drier areas also tend to bunch or occur in clumps that are sparsely distributed, leaving the ground surface relatively bare. Species in short grass plains are therefore highly adapted to variable moisture conditions within this climatic regime, and also to relatively low moisture availability during late spring and early summer (Borchert 1950: 34).

The mixed grass prairies characterize a transitional zone between the short grasses of the west and the tall grasses of the east. Principal species include big bluestem *(Andropogon gerardi),* little bluestem *(Andropogon scoparius),* needlegrass (*Stipa* spp.), and wheatgrass *(Agropyron* spp.). As indicated above, mixed and tall grass prairies exist along the gradient where precipitation increases, east of the 100th meridian, in a region classified as subhumid (Borchert 1950; Strahler and Strahler 1978: 251). These grasses tend to be deeply rooted and form a thick mat or sod.

Both subbiomes of grassland (short grass plains and prairies) are associated with the Mollisols except in the extreme western Plains, where the Aridisols form in the transition to desert biomes (U.S.D.A. 1975).

Faunal populations are relatively similar for both subbiomes and are characterized by species that aggregate in colonies or herds and are either running or burrowing types (Odum 1971: 391). Included are bison, economically very important to prehistoric inhabitants and early Euro-American settlers, pronghorn antelope, and deer, as well as burrowing rodents such as ground squirrels, prairie dogs, and gophers (Odum 1971: 239, 391). Grassland predators include coyotes, foxes, and bobcats.

In summary, the mid-continental North American grasslands exist in an area of outwash resulting from uplift activities in the Rocky Mountains during late Mesozoic and Cenozoic times. Subsequent modification of land surfaces occurred during periods of glacial advance and retreat during the Pleistocene. In addition, Holocene changes of warming/cooling and relative wetness/dryness helped modify land surfaces, as well as affect prehistoric occupation of the Plains. Today, grasses of various height and adaptability exist along a precipitation gradient, structured by Arctic and tropical air masses and the flow of westerly winds, ranging from semiarid, west of the 100th meridian, to subhumid east of that line. We turn now to a consideration of the prehistoric and historic habitation of the Plains region.

Culture History of the Plains

In this section, we present a brief summary of type sites by cultural period as an aid to remote sensing in the Central and Northern Plains. There is good evidence, with exceptions noted below, that the region under consideration has supported human occupation continuously since the end of the Pleistocene. Each cultural period entails a different, or at least modified, adaptation to prevailing conditions, although some periods are better known than others.

Paleo-Indian sites represent the earliest currently agreed upon occupation in the Plains. These groups represent an adaptation to a subsistence strategy heavily dependent on the acquisition of Pleistocene megafauna.

The Archaic period follows the Paleo-Indian, and although not well known on the Plains, it is representative of a subsistence strategy based on hunting and foraging of a wider range of resources than the previous period.

The next period, referred to as the Plains Woodland is, like the Archaic, not well known, but probably was characterized to some degree by a reliance on bison hunting, small mammal procurement, and foraging. Sites of this period exhibit architectural features in the form of linear and dome-shaped mounds and small temporary encampments. It is also during this period that the first evidence of cultivated plants and ceramic manufacture is recognized.

The Plains Village period follows the Plains Woodland and is known for its large villages composed of earth lodges, and for a subsistence strategy that includes bison procurement and horticulture.

The final period represents the time of settlement on the Plains by non-native groups and is referred to as the Euro-American period.

More detailed discussions and overviews of the Central and Northern Plains may be found in Caldwell and Henning (1978), Frison (1978), Lehmer (1971), Wedel (1959, 1961, 1978), and Wormington (1957).

Paleo-Indian Period (ca. 10,000-5500 B.C.)

Sites of this period have been the object of much research and have aided in the understanding of the antiquity of human habitation on the Plains in particular and the New World in general. Paleo-Indian sites are distributed primarily along the western edge of the Plains, particularly in eastern Colorado and Wyoming. For the most part, sites tend to be buried and without surface manifestation except in cases where materials are exposed through stream channel action. Research has generally focused upon kill sites and butchering sites which appear to be the most prevalent sites located thus far. Attention has been directed toward habitation sites (see Frison 1976, 1978; Irwin-Williams et al. 1973); however, these kinds of sites have low archeological visibility resulting from impermanent encampments, lack of structural remains, and paucity of refuse accumulation. Additionally, archeological visibility is hampered by past geological processes that have resulted in the burial of sites or destruction of sites by stream channel movement, water runoff, and by eolian deposition. For the most part, only the most durable materials survive in the archeological record, including stone tools, lithic debris resulting from manufacturing and/or maintenance activities, faunal remains, and bone tools.

The Paleo-Indian period consists of a number of different complexes distinguished on the basis of lithic tool types and stratigraphic association. Three general complexes are recognized: Clovis or Llano, Folsom, and Plano. The first two have diagnostic projectile points distinguished on the basis of point size and length of flute, while the Plano has unfluted projectile points. Some authors (Jennings 1978: 32; Wilmsen and Roberts 1978: 175) have questioned whether unfluted points postdate Folsom points and have noted that they are found in contexts contemporaneous with fluted points. However, it does appear that unfluted points have a greater temporal span than the fluted ones.

The oldest materials on the Plains are representative of the Clovis complex. Although Clovis sites are better known in areas adjacent to the Plains (e.g., the Southwest and the Southwestern Plains), there are several sites in Colorado (Dent: Wormington [1957]), Wyoming (Colby: Frison [1978]), and possibly Montana (Lindsay Mammoth: Frison [1978]) that appear to have Clovis associations. All of these sites have mammoth bones and radiocarbon dates at about 9000-10,000 B.C. (Frison 1978: 23). The Dent and Colby sites have fluted projectile points associated with mammoth remains, while the Lindsay Mammoth Site has no projectile points (Frison 1978: 85-86). In spite of the sparseness of sites for the Clovis complex, they nonetheless represent the earliest known materials in the Plains. All of these sites may be considered kill sites; no habitation sites have yet been reported.

The Folsom complex represents another group of materials and faunal associations that overlaps with, and postdates the Clovis complex (cf. Irwin 1971; Irwin-Williams et al. 1973). The points characterized as Folsom are finely made, with a large flute running virtually the entire length of a specimen. Projectile points of this type along with other stone tools tend to be associated with procurement of an extinct form of bison *(Bison antiquus)* (see Frison 1978: 143-144; Wilmsen and Roberts 1978: 45-48). The Folsom complex is in part represented by three habitation sites or levels, including Hell Gap Locality 1 (Irwin-Williams et al. 1973: 44) and Hanson (Frison 1978: 115-146; Frison and Bradley 1980) which are both in Wyoming, and Lindenmeier (Wilmsen and Roberts 1978) in Colorado. All date to about 8000-9000 B.C. (Frison 1978: 23).

The Plano complex postdates Folsom, and extends to the end of the Paleo-Indian period at about 5500 B.C. A number of different occupations are referred to here and include point types that are unfluted and associated with later complexes. These points are well made lanceolate forms and include the Midland, Agate Basin, Hell Gap, Alberta, Cody, Frederick, and Lusk. A more detailed discussion of these occupations, dates, and sites may be found in Frison (1978) and Jennings (1978). Representative sites include various occupational levels at Hell Gap in Wyoming, as well as bison kill sites such as Olsen-Chubbuck (Wheat 1972) and Jones-Miller (Stanford 1974) in Colorado, Casper (Frison 1974) and Agate Basin (Frison 1978: 149-168) in Wyoming, and Hudson-Meng (Agenbroad 1978) in Nebraska.

In summary, the earliest complexes representative of the Paleo-Indian period occur in the western portion of the Plains. The Clovis complex came into existence about 10,000 B.C. and apparently represents exploitation of Pleistocene megafauna, notably mammoth, as a major part of the subsistence strategy. Clovis is followed by the Folsom complex where emphasis of the subsistence strategy is on an extinct form of bison. The Plano complexes overlap with Folsom and continue through the end of the Paleo-Indian period in the Plains, terminating at approximately 5500 B.C. Here the emphasis is on bison procurement by specialized means such as bison traps or jumps. Sites of this period tend to be buried and exposed only through stream action or modern earth moving activities.

Archaic Period (ca. 5500 B.C.-A.D. 1)

The Plains Archaic is perhaps the least known and understood period in the Central and Northern Plains. Plains Archaic sites are found along the western portion of the Plains, particularly in Wyoming. In addition, sites occur in extreme eastern Nebraska and Kansas (see Wedel 1978: 195-202). Plains Archaic can be divided into early, middle, and late periods based on radiocarbon dating, and is further differentiated on the basis of projectile point types and subsistence strategy.

The early Plains Archaic corresponds approximately to Hypsithermal times during the Atlantic climatic episode. Originally referred to as the Altithermal (Antevs 1955) and recently changed to the Hypsithermal (see Wendland 1978; Wright

1976b), this period was thought to explain the absence of human occupation as due to extremely arid conditions on the Plains. A compilation of ideas concerning the Altithermal is available in Reeves (1973). As Frison (1975: 295) has noted, evidence for human occupation during this time is found most frequently in foothills and uplifted areas peripheral to the Plains.

Reeves has proposed that the lack of sites on the Plains pre-dating 3000 B.C. may be due to several factors, including:

> (1) The very small sampling of archeological sites in the area. (2) The age of associated land forms and sediments for sampled sites which have yielded components dating ca. 3000 B.C. but no earlier. Aside from Hell Gap, the Angostura Reservoir is the only other locale, to my knowledge, where earlier terraces or sediments have been sampled. (3) The paleohydrological sequence which has destroyed or deeply buried the emergent floodplain surfaces which existed during the interval 5500-3000 B.C. (1973: 1243).

As a result, the Plains Archaic (except for its periphery) is not well known for this time period.

Early Plains Archaic sites, e.g., Hawken and Hawken III in the Black Hills, apparently represent bison kill sites, specifically arroyo traps (Frison 1978: 192-201). Farther west and in higher elevations, cave sites and an open air campsite with a possible structure have been excavated (Frison 1978: 44), but are not well known. Early Plains Archaic sites are characterized by the appearance of side-notched projectile points which are considered diagnostic of the period. The Logan Creek (Wedel 1978: 199) and Coffey sites (Schmits 1978) are probably open air campsites occupied during late Hypsithermal times along the eastern periphery of the Plains.

The middle Plains Archaic follows the early Plains Archaic and is post-Hypsithermal, dating to about 1500 B.C. During this period areas previously unoccupied during the Hypsithermal show evidence of human occupation. Evidence for increased use of plant foodstuffs is represented by grinding slabs and manos, as well as subterranean roasting pits (Frison 1978: 46-49, 352-360). A wide variety of projectile point types has been noted for the middle Plains Archaic including the McKean, Hanna, and Duncan types.

Sites of the middle Plains Archaic period include arroyo bison kills and bison jumps, as well as rockshelters, cave sites (Frison 1968, 1970, 1978), and open air campsites (Reeves 1973). It is also at this time and continuing through historic times that stone circles appear in the Northwestern Plains (Frison 1978). Sites containing stone circles occur in a number of topographic situations ranging from arroyo edges to butte tops, and have a variable number of circles. Although the function of these circles is unknown, they have been inferred to be remains of domestic structures, perhaps tipis (see Frison 1978: 51-53; Kehoe 1960; Malouf 1961). There are usually only a few diagnostic artifacts associated with the stone circles and, whatever their function, it is reasonable to assume short duration of use.

Late Plains Archaic is the final period and terminates at about the beginning of the Christian era. Diagnostic projectile points include corner-notched ones from Pelican Lake, which contrast with side-notched types from the early and middle Plains Archaic. Known sites are open air campsites, bison kill sites including arroyo traps and jumps, rock shelters, and cave sites. Toward the end of this period and slightly later, different and more sophisticated bison procurement techniques appear. The manifestation known as Besant shows evidence of a bison drive lane and corral construction in eastern Wyoming (see Frison 1971 and 1978: 213-233). Here, posts had been cut and placed in the ground to create a lane through which bison could be driven, and at the end of the lane was a pound or corral to hold the animals for dispatching and processing. A ceremonial structure was near the drive lane, as inferred from patterns of postmolds and bison vertebrae and skulls found on the original ground surface (Frison 1978: 200-221).

In summary, the Plains Archaic has been characterized as a time when broad spectrum food procurement strategies were exercised. Early Plains Archaic sites seem to be restricted to higher elevations and uplift areas on the Plains periphery and are assumed to be a response to arid conditions of Hypsithermal times. Middle Plains Archaic sites proliferated on the Plains after the Hypsithermal and greater evidence for foraging activities appears, primarily in the form of grinding slabs and manos. The late Plains Archaic shows evidence of increased sophistication in bison procurement techniques.

Sites of the Plains Archaic include bison kill sites, open campsites, cave sites, rock shelters, stone circles (middle Plains Archaic and later), and bison drives and pounds (late Plains Archaic).

Woodland Period (ca. A.D. 1-900)

The Plains Woodland follows the Plains Archaic period. Sites having Woodland components are best known in the Central Plains, including Kansas and southern and eastern Nebraska, and the Northeastern Plains from the Missouri River Valley eastward. The first evidence for ceramic manufacture and for the construction of mounds on the Plains dates to this period. It is also a time when evidence of domesticated plants begins to appear in the archeological record.

Perhaps the best known Woodland manifestations are those along the Missouri River in the eastern Central Plains (Johnson 1976) in eastern Kansas and, to a lesser extent, in eastern Nebraska (Haas 1980; Wedel 1959: 542-557). Sites in this area, referred to as Kansas City Hopewell or Middle Woodland (Johnson 1976: 7), consist of both large open air habitation sites, as well as smaller campsites located in the Missouri River bottoms and adjacent tributaries (Caldwell and Henning 1978: 123; Johnson 1976). No houses are known but, based on the depth of middens at many of these sites, it has been suggested that site occupation was lengthy (Wedel 1959: 555). Some sites of the Kansas City Hopewell have the remains of cultigens (e.g., maize) (Wedel 1959: 544 and 1978: 204). However, available data indicate a subsistence strategy emphasizing hunting and gathering (Johnson 1976: 8), perhaps supplemented by horticulture. Bluff tops often have artifically constructed mounds that contain burials (O'Brien 1971; Wedel 1978: 204).

Woodland sites are also known in eastern Nebraska (Haas 1980; Kivett 1952) on the Loup and Missouri Rivers, and in western Nebraska on the Loup and Republican Rivers (Kivett 1952), as well as the Platte River. Village sites tend to be deeply buried in alluvial silts, although at least one cave site contains a Plains Woodland occupation (Champe 1946: 49-52). Rockshelters and open air campsites are also known for northeastern Colorado (Scott 1973). Plains Woodland sites outside of the Kansas City area appear to have a hunting and gathering subsistence pattern with an emphasis on bison hunting.

Plains Woodland sites in the Northeastern Plains are known primarily from open air sites and associated mounds (Chomko and Wood 1973; Hurt 1952; Neuman 1975; Wood and Johnson 1973). Open air sites are attributable to Plains Woodland on the basis of ceramic and projectile point types and appear to have a subsistence strategy oriented toward hunting and gathering with an emphasis on bison hunting. The mounds may be dome-shaped or linear, and some are known to contain burials. Linear mounds tend to have a low relief and occur individually or in groups of both linear and dome-shaped mounds.

In summary, Plains Woodland is best known for the Kansas City area. Sites are large open air campsites, small open air campsites occupied for short duration, and burial mounds located on higher points of land. Subsistence is thought to be hunting and gathering of bottomland species of flora and fauna, probably supplemented by horticulture.

Central Plains and Northeastern Plains Woodland manifestations consist of open air campsites, cave sites (in the western Central Plains), and burial mounds. Open air campsites tend to be buried and show little, if any, surface expression. Subsistence strategy is also thought to be based upon hunting and gathering, with particular emphasis on the bison.

Plains Village Period (A.D. 900-1850)

The final prehistoric period on the Plains is the Plains Village and extends from the Plains Woodland period to the time of Euro-American expansion. These peoples had a subsistence strategy based on horticultural activities adapted to riverine or bottomland conditions and activities organized around bison hunting in the surrounding grasslands. Virtually all Plains Village sites are on terraces overlooking bottomlands and consist of remains of substantial earth lodge structures located in permanent settlements, sometimes surrounded by ditches and other fortifications (Lehmer 1971; Wedel 1978: 207-213; Wood 1974).

Plains Village sites are represented by three different traditions distinguished on the basis of the shape of the earth lodge, pottery types, and artifact inventory. These three traditions are geographically distributed in two areas. The Central Plains tradition occurs in eastern Nebraska and Kansas and in western Iowa. The Middle Missouri and Coalescent traditions are located in eastern North and South Dakota, adjacent areas of Minnesota and Iowa, and particularly along the main stem of the Missouri River in North and South Dakota (Caldwell and Henning 1978: 125-136; Krause n.d.; Lehmer 1971; Wood n.d.b).

The Central Plains and Middle Missouri traditions are the two earliest Plains Village period manifestations, although the Middle Missouri persisted later than the former. Several subgroupings within the Central Plains tradition may be discerned, including the Upper Republican, Nebraska, and Smoky Hill aspects (Blakeslee 1978; Blakeslee and Caldwell 1979; Gradwohl 1969; Krause 1970; Wedel 1959: 557–571 and 1978: 209–210; Wood 1969). In general, sites of this tradition have dwellings approximately square to slightly rectangular in outline, contain postmolds outlining an exterior superstructure, and have a four-post pattern of interior supports. Subterranean storage pits, while not common, occur in dwelling units. Communities tend to be small and unfortified, and located along major drainages and tributaries, particularly in Nebraska and Kansas (Krause 1970; Wedel 1959: 557–571; Wood 1969: 104–105). Central Plains tradition sites are thought to have been abandoned sometime around the fifteenth century, perhaps in response to what has been interpreted as widespread drought conditions (Bryson and Baerreis 1968: 1–34; Wendland 1978: 281).

The Middle Missouri is coeval with the Central Plains tradition, and most sites are found along the mainstem of the Missouri River (Lehmer 1971: 65-105, 121-124). This tradition has been divided into three subdivisions, or variants: Initial (ca. A.D. 900-1500), Extended (ca. A.D. 1200-1500), and Terminal (ca. 1500-1675) (Lehmer 1971). Each of the three variants is distinguishable on the basis of cultural content (e.g., ceramic rim decoration), age, and geographic distribution. The Initial Variant sites are located in central South Dakota from the White River on the south to the Cheyenne River in the north. Sites outside the Missouri River trench that are grouped with the Initial Variant were on the lower James and Big Sioux Rivers in South Dakota and adjacent Iowa. Sites of the Extended Variant of the Middle Missouri tradition are in two concentrations. A southern group is in central South Dakota between the Bad and Cheyenne Rivers, while the northern group is concentrated primarily between the Cannonball and Knife Rivers in North Dakota (Lehmer 1971: 64, 67).

These two variants of the Middle Missouri tradition represent the earliest village peoples in the Northern Plains, and they are contemporaneous for nearly 300 years prior to development of Coalescent sites on the Missouri River. The Terminal Variant postdates the Initial and Extended Middle Missouri variants and is relatively localized geographically. Terminal Variant sites represent a severe reduction in geographic distribution, with relatively few villages north of the Cannonball River to north of the Heart River in North Dakota (Lehmer 1971: 121). While geographic distribution is reduced, however, site area increases on the average. For example, while more than 20 houses are rare at Extended Variant sites, the Terminal Variant Huff Site had a total of 103 houses (Wood 1967: 23). Initial Middle Missouri villages, on the other hand, contained from 15 to 50 houses (Wood n.d.b : 19).

Subsistence strategies for this tradition were based upon floodplain cultivation of corns, beans, squash, and sunflowers, as well as upon hunting activities, principally involving bison. Houses are a distinguishing feature of the Middle Missouri tradition. These structures are long and rectangular, having postmolds around the perimeter outlining a superstructure, and a series of postmolds along the center line indicating a main interior stringer for support. Subterranean pits are common and occur both within and outside the confines of structures. Villages tend to be on the terraces of major drainages overlooking floodplains. Finally, many of the villages, particularly those of the Terminal Variant, were fortified by ditches with bastions and other defensive works, such as palisades (Lehmer 1971; Wood 1967; Wood n.d.b : Fig. 4).

The final tradition attributable to village dwellers of the Northern Plains is the Coalescent tradition and is considered to have four variants: Initial (ca. A.D. 1400-1550), Extended (ca. A.D. 1550-1675), Post-Contact (ca. A.D. 1675-1780), and Disorganized (ca. A.D. 1780-1862) (Lehmer 1971: 111-179). The latter two variants represent villages that postdate Euro-American contact with native populations on the Missouri River, beginning with the introduction of trade items.

The variants of the Coalescent tradition, like those of the Middle Missouri tradition, are distinguishable on the basis of cultural content (e.g., change in ceramic decoration and the presence or absence of European goods), age, and geographic distribution. Sites assigned to the Initial Variant have a very localized distribution between the White and Bad Rivers of central South Dakota in the Big Bend Region (Krause n.d.; Lehmer 1971: 112). The

Initial Variant of the Coalescent, thought to derive from the Central Plains tradition (Lehmer 1971: 111), appeared on the Missouri River at a time when Initial and Extended Middle Missouri villages still existed in the area. The Extended Coalescent Variant is thought to have developed directly from the Initial Variant and has a much greater geographic distribution on the Missouri River, ranging from the White River in central South Dakota to the present border between North and South Dakota. Post-contact sites are distributed from the White River to the Grand River in South Dakota and from the Heart River to the Knife River in North Dakota. The final variant, Disorganized Coalescent, is confined to a few villages near the mouth of the Knife River. The Northern Plains Village period ended with the removal of village-dwelling Indians to Like-A-Fishhook Village at Fort Berthold in North Dakota in the mid-1800's (Bruner 1961; Smith 1972).

Subsistence strategies were equivalent to the Middle Missouri tradition populations, when the emphasis was on horticulture and bison hunting. Houses in this variant are circular, having postmolds around the superstructure perimeter, and generally a four-post pattern of interior structural supports. Subterranean storage pits are common inside and outside of houses. Fortification ditches and palisades are known for the Coalescent tradition sites, and villages are on terraces overlooking river bottoms (Krause n.d.).

During the Plains Village period, new populations from farther east moved onto the Plains, developing a nomadic lifestyle organized around bison hunting. These groups, like those of the Northwestern Plains beginning during the middle Plains Archaic, apparently left sites consisting of the stone circles that are ubiquitous in the Northern Plains grasslands.

In summary, horticultural groups living in relatively permanent villages appeared during the tenth century along major river valleys in the Northern and Central Plains. The remains of the villages (in contrast to the earlier periods) are highly visible surface phenomena.

Euro-American expansion on the Plains has also left remains in the form of distinguishable sites and has stimulated much archeological research. Examples of sites include military installations (e.g., Smith 1960), trading posts (e.g., Woolworth and Wood 1960), riverboats (Petsche 1974), and homesteads, roads, cemeteries, and abandoned towns (e.g., Weston et al. 1980).

Summary

The human occupation of the Plains is continuous from the end of the Pleistocene to modern times. Plains prehistory is divided into four cultural periods: the Paleo-Indian, Plains Archaic, Plains Woodland, and Plains Village periods, and is followed by a Euro-American historic period. Each entails an adaptation to conditions prevalent at the time of its existence, ranging from hunting of Pleistocene megafauna, through broad-spectrum foraging activities, to settled, relatively permanent village life employing mixed-strategy horticulture and bison hunting. Prior to the Plains Woodland period, there is little if any surface manifestation of archeological sites due to past geological, hydrological, and climatological processes. Sites later in the prehistoric and historic record are well represented as surface phenomena.

Section 4

Mapping Environmental Variables

Environmental Data

Air imagery can be used to study changing human land use patterns, as well as changes in landforms at a very small scale, and in great detail. Although most cultural resource management projects are relatively modest in scope, some large-scale projects demand the use of remote sensing techniques (Ebert 1978), for example, the assessment of the National Petroleum Reserve in Alaska (Brown and Ebert 1978). Both air photos and space imagery are invaluable in sampling and stratifying procedures in such projects, when it is patently impossible to survey or assess the entire area.

Environmental data are routinely used by archeologists, but rather than using the imagery directly, they are more likely to use the maps or other data obtained from remote imagery by scientists in other disciplines. Many studies that are basic to archeological research are now being done by soil scientists, botanists, wildlife managers, and others. To cite only a few examples, ERTS (Earth Resources Technology Satellite) imagery has been used to map sand dune areas In Wyoming (Kolm 1974) and soils in the sandhills of Nebraska (Lewis et al. 1975); groundwater sources in prairie settings are being studied by airborne remote sensing devices (Chase 1969). Wildlife habitat mapping, inventory, and evaluation, as well as censuses of mammals, birds, and fish for management studies, are also being done on a routine basis using aerial imagery.

Geologists use air photos as a matter of course for many different purposes, including geomorphological studies (Ray 1960). Along the Mississippi River, for instance, air photos can be used to determine the sequence of meander scars so that relative dates can be obtained for archeological sites on the former river banks. Landform changes over the time for which air photo coverage is available can also yield important data for projecting environmental variables into the past.

Even when no significant changes have taken place in the actual ground surface, massive changes have been induced in the vegetational patterns in most areas since Euro-American settlement. These changes must be understood before projections into the archeological past can be successfully accomplished.

Modern baselines for distributional studies of vegetational communities range from fully ground-based survey to mapping from satellite imagery (Drager 1980). Vegetation on the Plains, for example, can be mapped and monitored using ERTS imagery (Rouse et al. 1973). Large- and small-scale air photos are often used to map vegetational data either in the field, or in the laboratory without actual fieldwork, depending on the kind of data required.

In many areas, increasing use is being made of Government Land Office (GLO) survey data as an aid in projecting modern landscapes into the past. Most of continental United States was subdivided into townships, ranges, and sections by GLO surveyors between 1815 and 1910 (Bourdo 1956). Data accumulated by the surveyors include notes on and descriptions of the vegetation of the areas they covered, particularly that of forests. This information permits the construction of vegetation maps for periods of more than a century ago, when modern disruption of native vegetation was still minimal. The effects of past climates (Wood 1976) and of the native use of fire (King 1978) must nevertheless be taken into account in interpreting the information in the GLO records.

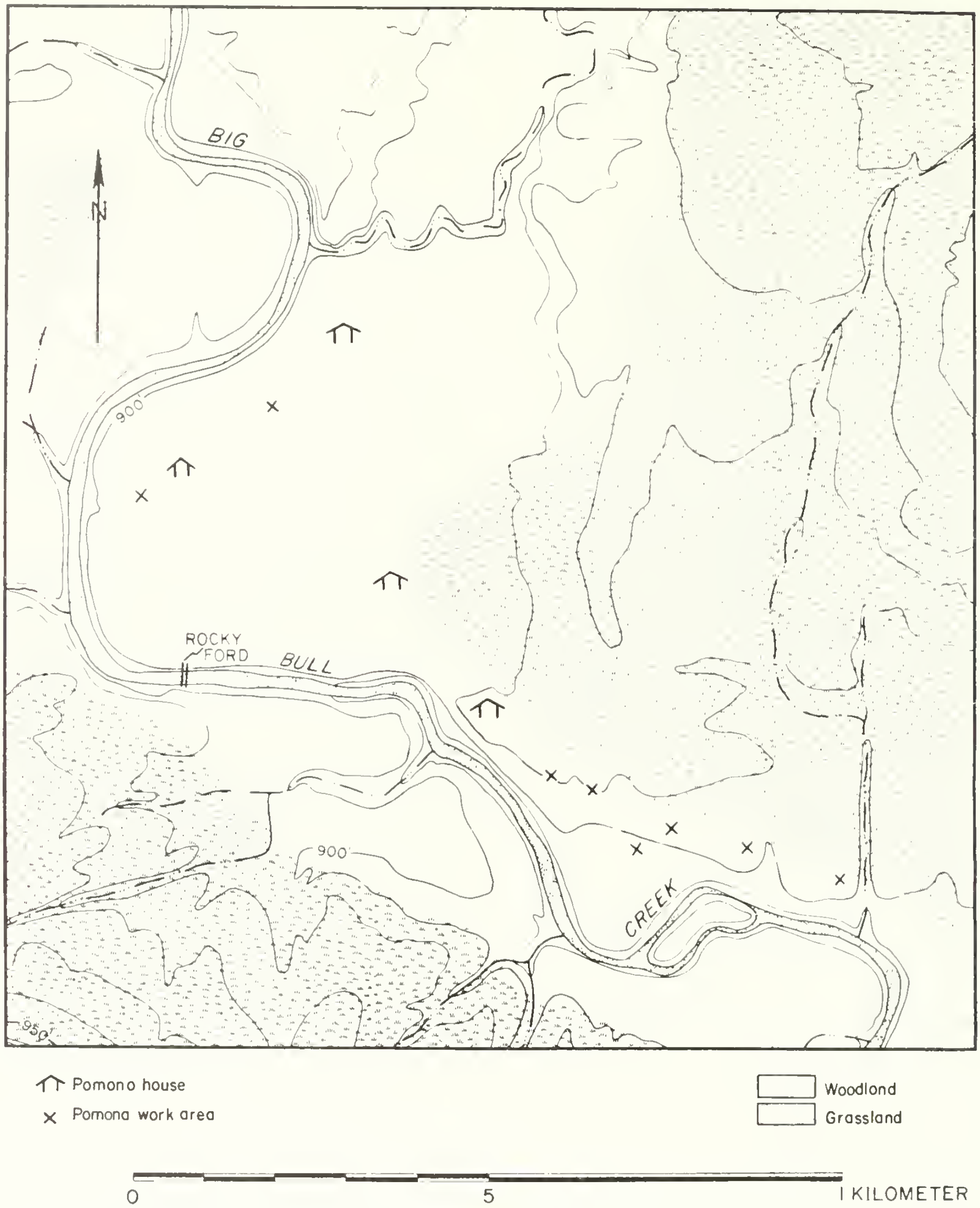


Figure 6. Pomona Phase settlements near Rocky Ford, in the Hillsdale Reservoir, eastern Kansas. Contour interval is 3 m (from Blakeslee and Rohn n.d.: fig. 38).

Remote sensing is consistent with the modern conservation ethic, in the sense that it is nondestructive of nonrenewable resources. The nondestructive approach advocated by Lyons and Scovill "emphasizes the acquisition and sophisticated analysis of a variety of remotely sensed imagery and data as the primary tools of exploration, discovery, and recording" (1978: 5). In the Plains, however, the use of remote imagery still tends to be an adjunct to standard archeological fieldwork, especially in studies of settlement-subsistence systems.

Settlement-Subsistence Systems

As the preceding discussion illustrates, imagery can be used to (a) define and map environmental areas or zones, as well as to (b) understand the distribution of archeological sites in terms of these environmental variables. Such maps and data are needed to devise stratified sampling schemes, to postulate settlement-subsistence systems, and for demographic studies of past human populations (Aikens et al. 1980: 1). Human settlements are not randomly distributed, but are patterned, and a variety of environmental (as well as cultural) factors are responsible for that patterning.

The application of remote sensing to settlement-subsistence systems can therefore yield important conclusions concerning the distribution of human settlements across the landscape.

In one study in the Hillsdale Reservoir, in Miami County, east central Kansas, Soil Conservation Service air photos were used by Samuel Hertha to map forest and prairie soils. The forest soils are lighter in tone than the prairie ones, so they can be readily distinguished on air photos — a differentiation that has been verified on the ground. This distinction is possible because the local streams are entrenched, so that meandering has not interrupted the development of the forest soils along the stream. The forest-prairie margin here appears to be edaphically produced and maintained, so the present distribution of soil types probably reflects very old vegetational patterns. In any event, all of the archeological sites in the reservoir appear to have been located in the forested areas immediately adjoining the stream; none is in the prairie settings away from the channel (Fig. 6). Air photo interpretation of the local soils therefore provides a powerful tool for studies of settlement and subsistence in this part of Kansas (Blakeslee and Rohn 1982, Vol. 1: 80–83).

The physical settings preferred as sites by prehistoric, as well as many historic groups are often dictated by two considerations: topography and vegetation. Topography is an important seasonal consideration, especially in an area such as the Plains where protection from the wind is at a premium in so many locales, and where access to water demanded settings near streams which, in so many parts of the west, are widely separated. The importance of vegetation in providing food and shelter for game animals, as well as providing vegetal produce for direct human consumption, means that vegetation zones are equally important to human settlement.

In a recently completed study in Wyoming, Charles A. Reher has used satellite imagery (Fig. 7) to derive a basic regional environmental stratification for developing certain aspects of his survey sampling design in the western Powder River Basin in the northeastern part of the state. In certain settings, lower level imagery was used to investigate the patch distribution of vegetal resources (Reher 1979).

Reher discovered that the Wyoming Geological Survey County Resource Series maps, based on satellite imagery, yielded detailed data on vegetation and landforms. Although they were useful in early stages of the survey for coding certain information for specific sites, the archeological survey demanded either more specific data or, occasionally, less data than these maps provided. Consequently, Reher devised a stratification of local vegetation, which was refined by his colleague Clayton B. Marlow. This provided

> detailed data on edible species abundance . . . . The final schemata should have a great deal of utility for interpreting the archaeological record (Reher 1979: 180).

The western Powder River Basin provides a steady differentiation in plant kinds and composition from the basin floor to the peaks of the surrounding mountains. Most of Reher's study area consists of a patchy ecotone between a pure shortgrass plains and cool-desert shrubland, bounded on the west by low mountains. Five main strata subdivide the area from east to west: basin ridges, basin grasslands, foothills, mountain conifer, and subalpine These five:

> vegetative-topographic zones were mapped on U.S.G.S. 1:250,000 topographic maps, using ERTS color infrared satellite imagery and color-infrared U-2 imagery (on 1:1,000,000 and 1:120,000 scales). Areas for each zone [were] calculated using a polar planimeter . . . . Control over environmental parameters was done by detailed vegetation sampling by Marlow, coding of [County Resource Series maps and Western Powder River Basin] data in the field, vegetative mapping using satellite, U-2, and Bureau of Land Management 1:34,000 color infrared photos, sketch maps and segment analysis by crew members, use of U.S.G.S. topographic maps, and several other

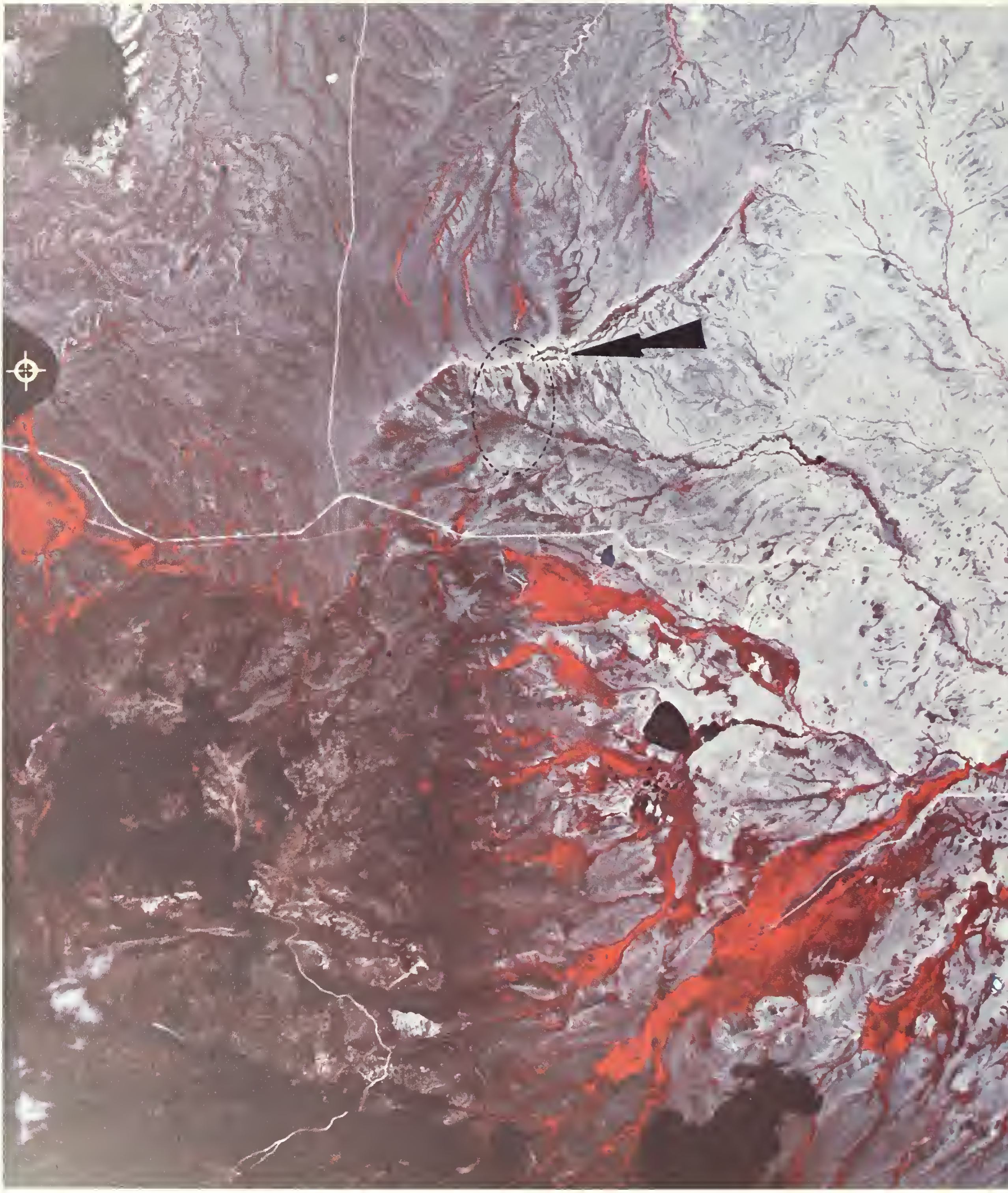
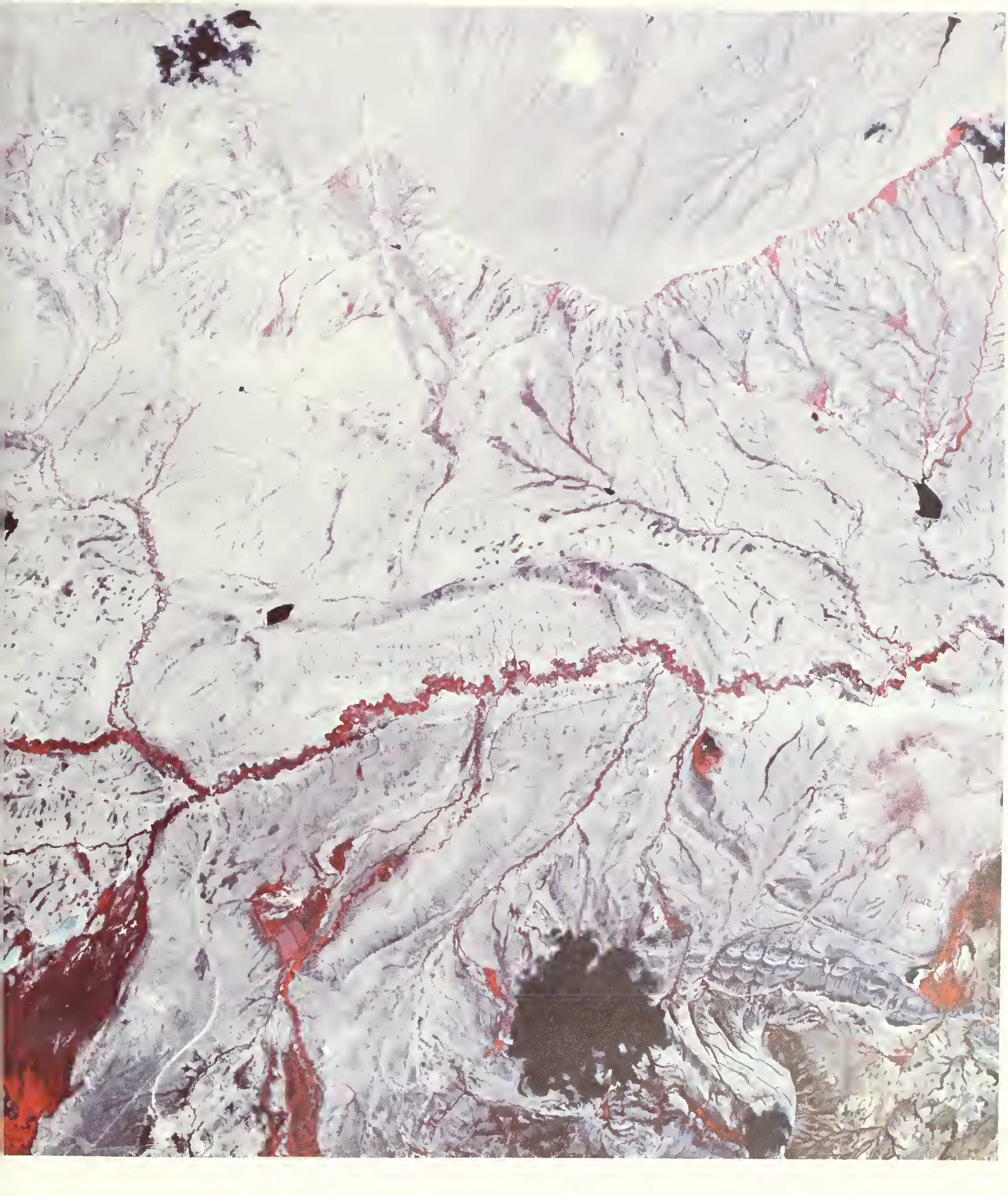


Figure 7. Color infrared U-2 photograph (about 15,240 m) of the Shirley Mountain-Shirley Rim area, Wyoming. Darkest tones are conifer forests; bright red is lush meadow grasses; lavender tones are good shortgrass forage areas; and white to very light lavender tones are more barren sagebrush or greasewood dominated zones. Location of the Besant Muddy Creek site complex (about A.D. 200) is indicated, including four stone tipi rings, a stone-covered burial tumulus, and a bison pound. The drive lane of the pound is still visible as a small, V-shaped white patch. Photograph courtesy of Charles A. Reher.



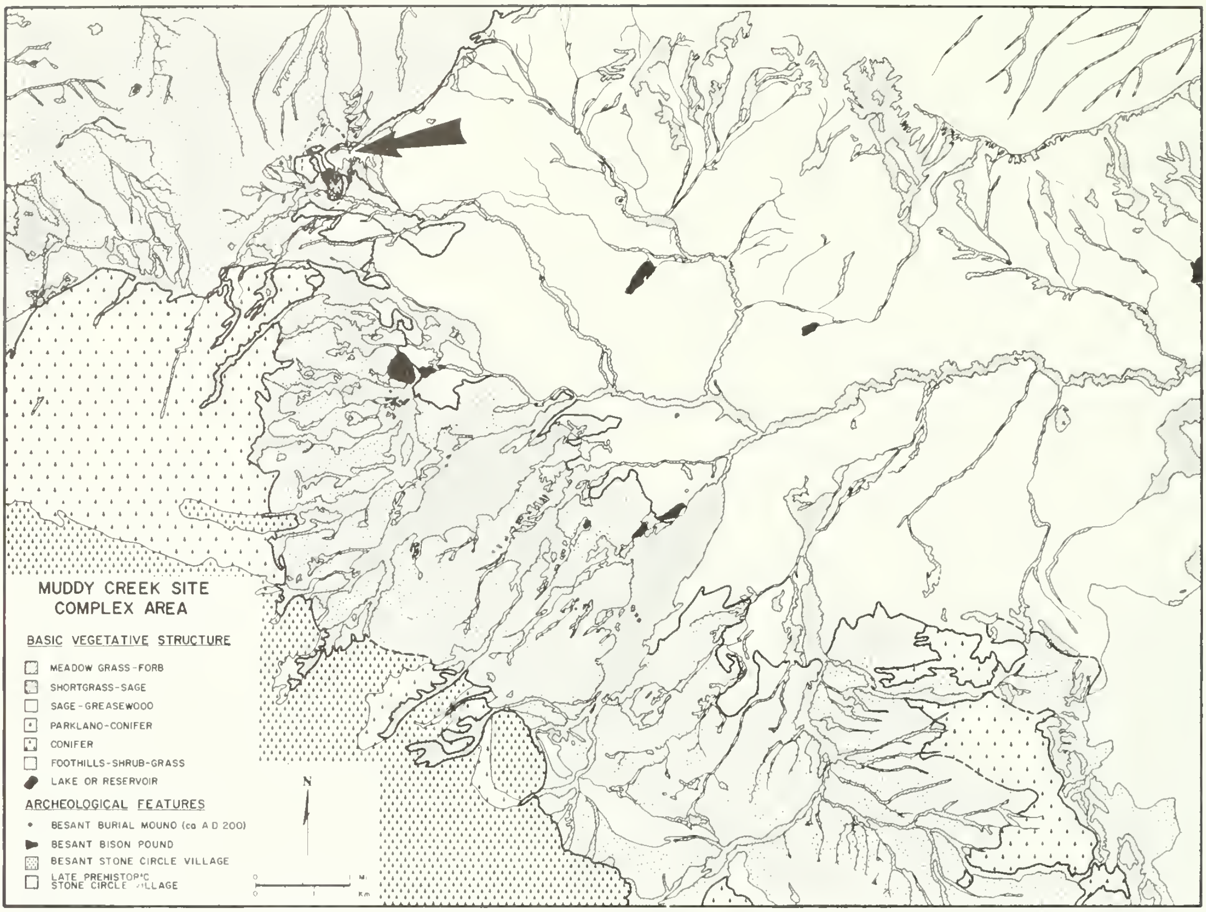


Figure 8. Map of the basic vegetative structure of the Shirley Mountain-Shirley Rim area. The shortgrass and meadow grass zone along the mountain front is thought to be the gathering basin exploited by the builders of the Muddy Creek bison pound. Photograph courtesy of Charles A. Reher.

means (Reher 1979: 181, 190).

The surveys across these environmental zones (Fig. 8), following two transects, document significant changes in site density across the landscape.

> These densities can be correlated with changes in environmental context, and the results generalized to similar contexts in the rest of the study area . . . although the small sample size precludes prediction on the detail that should ultimately be possible (Reher 1979: 292).

In as yet uncompleted studies elsewhere in Wyoming, Reher has used remote sensing in an ever larger role. One such study is of the Muddy Creek Site, a large late Archaic (Besant) bison pound and village near the rim of the Shirley Basin in the southeastern part of the state. Both satellite and U-2 imagery are being used, both utilizing color infrared, with the U-2 imagery taken from an altitude of 15,240 m. Reher is using the imagery to study the distribution of forage types and their densities in the gathering areas he has hypothesized for the site. The V-shaped drive lane for the pound is clearly visible on enlargements of the air photos (Fig. 7). The gathering basin exploited by the builders of the Muddy Creek bison pound was probably in the shortgrass and meadow grass zone along the mountain front (Fig. 8). In other parts of Wyoming, students at the University of Wyoming are using a variety of imagery scales to map basic vegetative patterns.

Section 5

Site Discovery and Documentation

Until very recently, site discovery and documentation were the principal focuses for remote sensing efforts in the Central and Northern Plains. Because of the size and nature of many Plains sites, and because so much of the area remains in grassland, air photography is more useful for site discovery here than in the eastern United States. In the western parts of the area, vast regions have never been touched by the plow. Thousands of acres of grassland were plowed under in the years preceding the great drought of the 1930's; however, much of that land was returned to pasture following the drought. Although a great deal of damage was done to some of the more fragile remains — such as tipi rings — other structures, such as mounds, can still be seen in some of these old fields.

Because of the conspicuous relief on the surface of many Plains sites, and because of sharp differences in the soil moisture and nutrients in the archeological features in many of the native village sites, they appear clearly in air photos even though the area has been under cultivation for years. Crop marks, soil marks, shadows, and relief (singly or in combination) may reveal their presence even after drastic land modification. Except where site locations have been favored by Euro-Americans as town or construction sites, some traces of many known village sites can be detected on air photos.

In the eastern parts of the Plains, long-continued cultivation has so obscured the already low-profile sites there that air photos are generally of limited use, since actual site evidence is normally obliterated; however, topographic indicators for site locations can of course be identified. Abandoned meanders, isolated natural levees, terraces, and other physiographic features are readily detectable, but contour maps sometimes use such large intervals that subtle undulations in the ground surface are not apparent. Photos also give clues to recent channel straightening or reveal old borrow areas associated with road construction, and which may not be readily identifiable during a pedestrian survey. Time could be wasted checking a channel which has little or no antiquity (Thomas A. Witty, personal communication, 1981).

There is another problem in cultivated areas. The use of fertilizers to improve land productivity proves to be a real handicap by obscuring what was a traditional way of spotting some kinds of sites. In Kansas, for instance, the use of fertilizer has all but obliterated modern crop marks in some fields by enriching the soil so that the subtle differences in soil nutrients are totally masked by uniformly luxuriant vegetation (Thomas A. Witty, personal communication, 1981). This is surely a major factor to be considered in air photo interpretation in those parts of the United States where fertilizing croplands to increase production is important.

The Missouri River Basin Program and Air Photo Interpretation

The spectacular air views of archeological sites in the American Southwest which Colonel Charles A. Lindberg took in 1930 came to the attention of pioneer Plains archeologist William Duncan Strong soon after they were taken. Strong, among others, tried to get Lindberg to fly up the Missouri River to photograph earth lodge villages in the Dakotas, but World War II began while their efforts were still in progress, and the plans were abandoned (Waldo R. Wedel, personal communication, 1981). It was to take nearly two decades before a similar plan was undertaken.

No effective use of air photography was made in the Plains before the U.S. Department of Agriculture began to provide air photo coverage in the late 1930's and early 1940's. Even then no *systematic* use of aircraft as an aerial photographic platform predates the establishment of the Smithsonian Institution's Missouri River Basin Surveys (MRBS) office in Lincoln, Nebraska, in 1946. The beginning of serious air photo exploitation dates to the mid-1940's, and the individual most responsible for it was Thomas E. Huddleston, then with the U.S. Army Corps of Engineers, in Omaha, Nebraska. In about 1945, his

> attention was drawn to the fact that a number of locations along the upper Missouri River, which are marked ''Ancient Indian Village'' on the 1890 Corps of Engineers Maps, presented a very singular appearance on aerial photographs (Huddleston 1948: 5).

In the pioneering paper just cited, Huddleston also provided Plains archeologists with many ideas they were to continue to develop through the years. He recommended that air photos be used to prepare planimetric maps of sites, and further, recommended that the 1938 air photos taken by the U.S. Department of Agriculture be used, despite the fact that the photos taken more recently are usually technically superior. The reason is that during the drought of the 1930's, moisture accumulated in the earth lodge depressions and, combined with the buried ash, charcoal, and other debris in house and midden areas, provided a greener and more luxuriant plant cover than in other parts of the site.

Huddleston provided the fledgling MRBS office with air photos illustrating his findings, as well as a list of sixty archeological sites he had located on air photos. This collection of air photos provided Waldo R. Wedel and Paul L. Cooper and their successors at the MRBS with the nucleus for their own air photo archive. The MRBS continued to accumulate air photos, and used them extensively and systematically. Eventually, they obtained almost complete coverage of the Missouri River Valley in the Dakotas for their use, since this is where the major Pick-Sloan dams were being built. Paul L. Cooper systematically scrutinized them and recorded the resulting data, or impressions, on site forms, and virtually every MRBS archeologist used them (or similar air coverage) to plan excavations and to choose sites for excavation.

Probably nowhere else in the Great Plains would air photos prove to be as useful as they would here. A succession of late prehistoric to historic, sedentary, village-dwelling Indians had built hundreds of communities along the Missouri River, most of them on high, grassy terraces where the ruins of their earth covered dwellings, often fortified by deep ditches, were readily visible, even from great altitudes.

In privately chartered aircraft, Waldo Wedel flew over the Medicine Creek Reservoir, in western Nebraska, in the mid-1940s to obtain the low oblique air photos of the Upper Republican sites being excavated there (see Kivett 1949: Fig. 69a). He also photographed several of the major village sites in the lower Oahe Reservoir area, in central South Dakota. The photographs of the Buffalo Pasture Site (39ST6) and the Sully Site (39SL4) were very dramatic ones. The Sully Site was probably the largest of the earth lodge villages in the Plains, and this view was used time and again to illustrate salvage program pamphlets and other publications resulting from the work (Wedel 1961: Pl. IX). MRBS archeologists, and those working with collaborating institutions across the Plains, made several hundred individual flights to illustrate or otherwise document archeological sites of interest.

The Solecki Flight of 1952

In the summer of 1952, the Smithsonian Institution authorized an aerial photographic survey of selected sites in eight reservoir areas in Nebraska, South Dakota, North Dakota, and Wyoming.

> Although individual supervising archeologists occasionally used light airplanes for photographing particular sites from the air, no over-all coordinated archeological survey of this type had been attempted in the United States prior to the summer of 1952 . . . (Solecki 1952: 43).

During that summer, about one-third of the total number of archeological field projects within the continental United States were being carried out in the Missouri River basin, many of them along the mainstem of the Missouri where large (and photogenic) earth lodge villages were being investigated.

Ralph S. Solecki, accompanied by an accomplished cameraman, Nathaniel L. Dewell, completed three air photo missions over sites in the eight

Missouri basin reservoirs, flying more than 8047 airline kilometers (Fig. 9). Sixty-two sites (or related features) were photographed at oblique angles in both black-and-white and in Kodachrome film from altitudes of 150 to 250 m. These views are a valuable resource, as most of the sites are now permanently inundated or the site setting is drastically altered. Although the photographs are not cited as Solecki/Dewell products in most publications, they can usually be identified by their high quality and by the 1952 date. They have been used to illustrate dozens of articles and monographs on Plains prehistory. Solecki later published useful early articles on air photo interpretation in archeology (Solecki 1957; Solecki et al. 1960), and contributed to the first edition of the *Manual of Remote Sensing* (Reeves et al. 1975: 1999-2060).

First Experiments in Remote Sensing in the Plains

During his tenure as Chief Archeologist of the National Park Service, John M. Corbett closely followed new research interests and techniques in archeology. He not only recommended that new techniques be used in various areas of the National Park Service, he sometimes subsidized especially innovative ones, as he did an aerial study of part of the Missouri River Valley in central South Dakota. This study, conducted in 1965 by the Itek Corporation, concentrated on two areas: a 12.9-km (8-mile) section along the west bank of the river near Fort George Island, and a 9.7-km (6-mile) section along the opposite bank of the river near Dores (or Dorion) Island, in Stanley and Hughes Counties, respectively.

Fourteen sets of air photos were taken at different times, using various films and filters and photographic scale, and the relative utility of each set was evaluated by Itek photointerpreters. They concluded that:

> panchromatic black-and-white film, exposed through a minus-blue filter at a scale of 1:10,000, contained essentially all of the information derived from the study of the 14 sets of photographs.
>
> It was also determined that the . . . small amount of additional detail that could be detected in true-color, false-color, and infrared black-and-white photography, and in photography at a scale of 1:5,000 and 1:3,000, does not justify the added expense of obtaining it (Itek Corporation 1965: 2).

Although these and other conclusions have been superseded, this experimental study was conceptually and operationally a landmark one, at least a decade in advance of its time. For two unfortunate reasons, however, it had little influence on future work in the Plains. First, Itek personnel made overenthusiastic and unsupportable claims for the utility and reliability of their study; and second, MRBS archeologists in Lincoln overreacted defensively to their claims. Mutual collaboration by the photointerpreters and archeologists could have resulted in an important pioneer paper in remote sensing. Corbett's efforts to initiate such studies in the Plains were thus thwarted, but his contributions toward the founding of the Remote Sensing Laboratory of the National Park Service in Albuquerque (Obenauf 1980) has substantially enriched our knowledge of remote sensing in archeology in general.

A major lesson to be learned from the preceding is that the photointerpreter should be an archeologist intimately familiar with the history and terrain of the area under study. The aftermath of the Itek study provides a good case in point, for when one of the Itek photointerpreters published a summary of the work, several erroneous claims were made. It was alleged that the photointerpreters had "found every site which had been found by professional archaeologists on the ground, [so that] field exploration which may otherwise take months to conduct can be performed in just a few hours..." (Strandberg 1967: 1155, 1157). In fact, however, only about 30 percent of the previously recorded sites were rediscovered by photointerpreters. Unfortunately, the author went on to claim that one of these former sites (39HU61) had been "discovered by photoarchaeology," and implied that it was a Norse community contemporary with the Kensington Stone (Strandberg 1967: 1152, 1155) — an unsupported speculation that is perpetuated in at least one popular photographic technical manual (Eastman Kodak Company 1972: 17). This site, 39HU61 (Grannie Two Hearts), is a two-component site, the earliest of which is the fortified enclosure so conspicuous on air photos, and is a component of the Initial Middle Missouri tradition (Terry Steinacher, personal communication, 1981).

Experimentation with various films, filters,

Figure 9. Nathaniel Dewell and Ralph Solecki preparing for a photography mission, 1952. The camera is a Folmer Graphic Aero Camera K-10. Photograph courtesy of Robert L. Stephenson and the National Park Service.

and other factors is still rare in the Plains states. One major exception was the study, by Leslie Davis and his colleagues, of sites in parts of western North Dakota and in selected parts of Montana (Davis et al. 1977). This study, sponsored by the Bureau of Land Management, was an effort to see if 1:80,000 color infrared photographs were useful for surveying cultural resources of large areas. Whereas the scale of the imagery meant that large-scale features, village sites and quarries, could be detected, it was found to be of little value as a device for *prospecting* for most kinds of sites. Nevertheless, it led to the accumulation of a body of data on which Leslie Davis, Robert Carroll, and their associates continue to build in the Northwestern Plains (e.g., Davis and Aaberg 1981; Davis and Carroll 1981; Davis et al. 1980).

Use of Air Photos in Field Reconnaissance: A Recent Example

Air photo interpretation was used during the three seasons of fieldwork conducted by the Division of Archeological Research, University of Nebraska-Lincoln, in the Big Bend Reservoir area, South Dakota, in 1978-1980. The following notes on this phase of the field work were provided by Terry L. Steinacher. Photos were used for site identification, verification, locational control, site parameter definition, and site mapping. Three sets of air photos were used:

U.S. Department of Agriculture 1938-1939 photos (scale 1:8,100)

Two sets provided by the Omaha District of the U.S. Army Corps of Engineers, flown in 1968 and 1974 (scale 1:24,000)

Before on-the-ground survey, each set was inspected for evidence of unrecorded sites. Additionally, known sites were examined to determine if further information on size and site pattern could be discerned. Visual inspection of the photographs was aided by the use of 5X, 10X, and 60X magnification. Where overlapping coverage was available, stereoscopic examination was also done. Each site of interest on the air photos was marked on U.S. Geological Survey 7.5 minute quadrangles and was subsequently field checked during the pedestrian survey of the project area.

This procedure resulted in the discovery of a number of sites by ground surveillance teams, including one fortified earth lodge village (39HU242) and at least five historic sites (39BF33 and 36, and 39HU90, 110, and 118). A number of suspected areas turned out to be natural vegetation irregularities, such as old haystack rings and topographic aberrations.

The air photos were also used to supplement the existing maps and to provide control for site locations prior to location by precise surveying procedures. The aerials were further employed to plot the outlines of subsurface features. Finally, the air photos were useful in establishing site boundaries necessary for National Register nominations.

Each of the three sets of air photos was used for different purposes. The 1974 set was perhaps the best of the series technically; however, due to the time at which it was taken, it generally showed less detail of the surface features than the other two. The 1968 set was therefore used for site identification, locational control, and site mapping. The 1938-1939 series, although technically the least satisfactory, showed the greatest detail of subsurface features, because it was taken at what is probably a near-optimum scale; prior to much of the commercial, governmental, and private development of the area; and at a time of optimum environmental circumstances. Because of the extreme variation in the factors of vegetational cover, precipitation, and season, as many series of air photos as are available should be consulted. Steinacher's experience was that photos taken in the early spring or late summer — especially during dry years — are the most useful, and that infrared photos taken under these conditions would be especially valuable.

Plains Features Visible on Air Imagery

As far as we now know, aboveground structures which may have been constructed by Paleo-Indian and Archaic populations on the Plains were too small or ephemeral to leave traces detectable by present means of remote sensing from the air. Byproducts of the quest for good quality chert did, however, leave evidence in the form of quarry depressions, as a later section of this paper documents.

Mounds. Beginning in Woodland times, substantial structures were built which can be detected on air photos, specifically, earthen mounds of varying form. Such tumuli are to be found throughout the eastern part of the Central and Northern Plains, especially along the margins of watercourses. The number of mounds which may have been built in valley bottomland settings is uncertain, since they would have been seriously damaged by cultivation; in any event, most known mounds on the Plains are on high points overlooking the floor of an adjoining stream valley.

Because upland cultivation frequently ceases a short distance from the river's bluffs, mounds often remain in the uncultivated strip between the bluff's edge and the field. In eastern Kansas, dome-shaped burial mounds can almost always be located on air photos, or verified on them after ground discovery. Because these mounds are on hilltops along streams, they can usually be distinguished from natural or other features by their topographic setting, size, plant cover, and color (Thomas A. Witty, personal communication, 1981). Generally, mounds can be detected even at scales of 1:24,000 (Stallard and Witty 1966: 16).

A number of natural features in the Plains and elsewhere in the United States, however, simulate the surface appearance of aboriginal mounds. Thomas A. Witty (personal communication, 1981) has found, especially in the Osage Plains area in eastern Kansas, that trees have pushed up earthen mounds around their bases, 6 to 9 m in diameter, especially in upland slope areas. When the tree dies and decays, a mound is left which retains (in younger mounds) rotted wood near its center. Other forms of mounds are left by the action of trees, especially in areas where the soil is thin and root

Figure 10. A low oblique air photograph of the Molstad Site (39DW234), South Dakota, showing the fortified sector of the site. Photograph courtesy of the National Park Service.

systems are not deeply buried. When a tree is toppled by wind or some other agency, a pit may remain by its side where the roots have been torn from the ground. When the tree decays, a mound is often left by the earth which adhered to its roots, so that a low knoll is left adjoining a shallow depression, resulting in cradle-knoll topography where this process is common (Wood and Johnson 1978: 329-331).

Still another form of natural mound may be confused with aboriginal ones. Known as "prairie" or as "pimple" mounds in the Midwest and Plains areas (and as "mima" mounds in the west, especially in the Puget Sound area), their genesis is a matter of debate, although they probably result from several different processes. They consist of groups of low, dome-shaped hummocks, usually in upland prairie settings, and their resemblance to artificial mounds is quite convincing (Fairbridge 1968: 888-890).

Aboriginal earthen mounds are widely distributed in the eastern Plains; in the Dakotas, they extend as far west as the Missouri Valley. At least, earthen mounds do not appear to occur in Colorado, Wyoming, and Montana, although burials appear to have been placed in some rock piles in Wyoming. Most of the mounds in the Dakotas, like those in Kansas and Nebraska, are dome-shaped.

In eastern North Dakota, as well as in adjoining parts of Minnesota and Manitoba, there is another major form of earthen mound (linear mounds), often with a dome-shaped mound on one or both ends or located nearby. The use of air photos recently led to the discovery of a large cluster of linear mound sites near the mouth of the Knife River, on the Missouri River above the city of Bismarck, North Dakota. In 1969, only one such mound was known in the area, and a visit to the structure aroused Wood's curiosity as to whether there might be more of them. A systematic inspection of 1:7,920 scale 1938 air photos between Garrison Dam and Square Butte Creek was undertaken. Following the discovery of a complex of linear mounds north of the town of Stanton, and its verification on the ground by Wood and by Donald J. Lehmer, no fewer than eight mounds or mound groups were located nearby, containing more than one linear mile of linear mounds (Chomko and Wood 1973; Stanley A. Ahler, personal communication, 1980). These mounds had not been detected previously because they represented a new form, to which local fieldworkers had not yet become sensitized. In fact, Wood had not only walked, but driven a vehicle over one of them several times before his air photo interpretation identified it as a native structure. This experience should emphasize the fact that the real advantage in using remote imagery is in the change in perspective, as well as the greater perspective offered by such imagery.

Village Sites. No other single set of archeological manifestations on the Great Plains is more conspicuous than the village sites of the semisedentary gardening tribes who lived along the Missouri and Platte Rivers and along their major tributaries (Fig. 10). Some of these villages are so large and prominent, especially on air photos taken during the late 1930's, that they resemble bombing ranges with clusters of well defined craters (Fig. 11). Even when they have been plowed, crop and soil marks commonly reveal their presence and the existence of ditch fortifications to the initiated (Johnston 1967).

Beginning in the 1940's, a number of people began to use light airplanes as photographic platforms. Russell Reid, in North Dakota, photographed the Huff Site and other villages along the Missouri River, and in the mid-1940's, Waldo R. Wedel, as we have already seen, photographed many of the Upper Republican settlements along Medicine Creek in western Nebraska. He and others of the MRBS, and collaborating institutions in the Plains states, began to use air photos as a means of documenting not only the site and its excavations but of recording it in its physical setting.

Most of the village sites in the Dakotas are along the Missouri River proper; only a few of them are on its tributaries or along other streams, e.g., Biesterfeldt, on the Sheyenne River in southeastern North Dakota. The Mitchell, Brandon, and other village sites are on the James and Big Sioux Rivers in southeastern South Dakota. Earthworks (resembling, if they are not in fact, ditch fortifications) of a size large enough to be conspicuous on air photos of 1:7,920 scale do, however, occur in other parts of the Northern Plains, although the presence of dwellings within the enclosed areas is rarely documented. Such sites include the White Earth Creek Site (32MN2) in Mountrail County, North Dakota, the Smiley-Evans Site (39BU2), on the Belle Fourche River near the north edge of the Black Hills of South Dakota, and a few others. A systematic scanning of air photos along other streams in both eastern and western North and South Dakota is likely to reveal still other such sites, although it is unlikely that they will be found to be common.

Several "ceremonial circles" have been discovered in McPherson and Rice Counties, eastern Kansas, where they are ascribed to the Great Bend aspect, dating to about A.D. 1500 to 1600. These sites consist of a circular ditch 27.4 to 54.9 m in diameter; the ditch may be continuous or consist of five or six sections. These circles can be identified in both undisturbed and cultivated settings at scales of 1:12,000 (Stallard and Witty 1966: 19-22, 28).

The study of another type of village site on the Plains can also profit by the use of air imagery. The villages of some of the Late Woodland (Graneros focus) peoples, as well as some of the late prehistoric Southern Plains Village tradition peoples in southeastern Colorado, would be amenable to remote sensing discovery and mapping, although no such work has yet been done in this area. The Graneros focus pithouses are several meters in diameter, and are large enough to be visible on air photos as small as 1:7,920. Furthermore, late prehistoric villages of the Apishapa focus and of the Upper Purgatoire complex in the same general area consist of single isolated houses and small settlements, and contain surface masonry dwellings. Some of these small communities are built in defensive settings behind stone walls (see Campbell 1976: Fig. 5). These communities are related to those of the Panhandle aspect to the southeast, which also used masonry dwellings.

The southeastern Colorado area, especially such areas as the Chaquaqua Plateau, would be an ideal setting in which to conduct air reconnaissance;

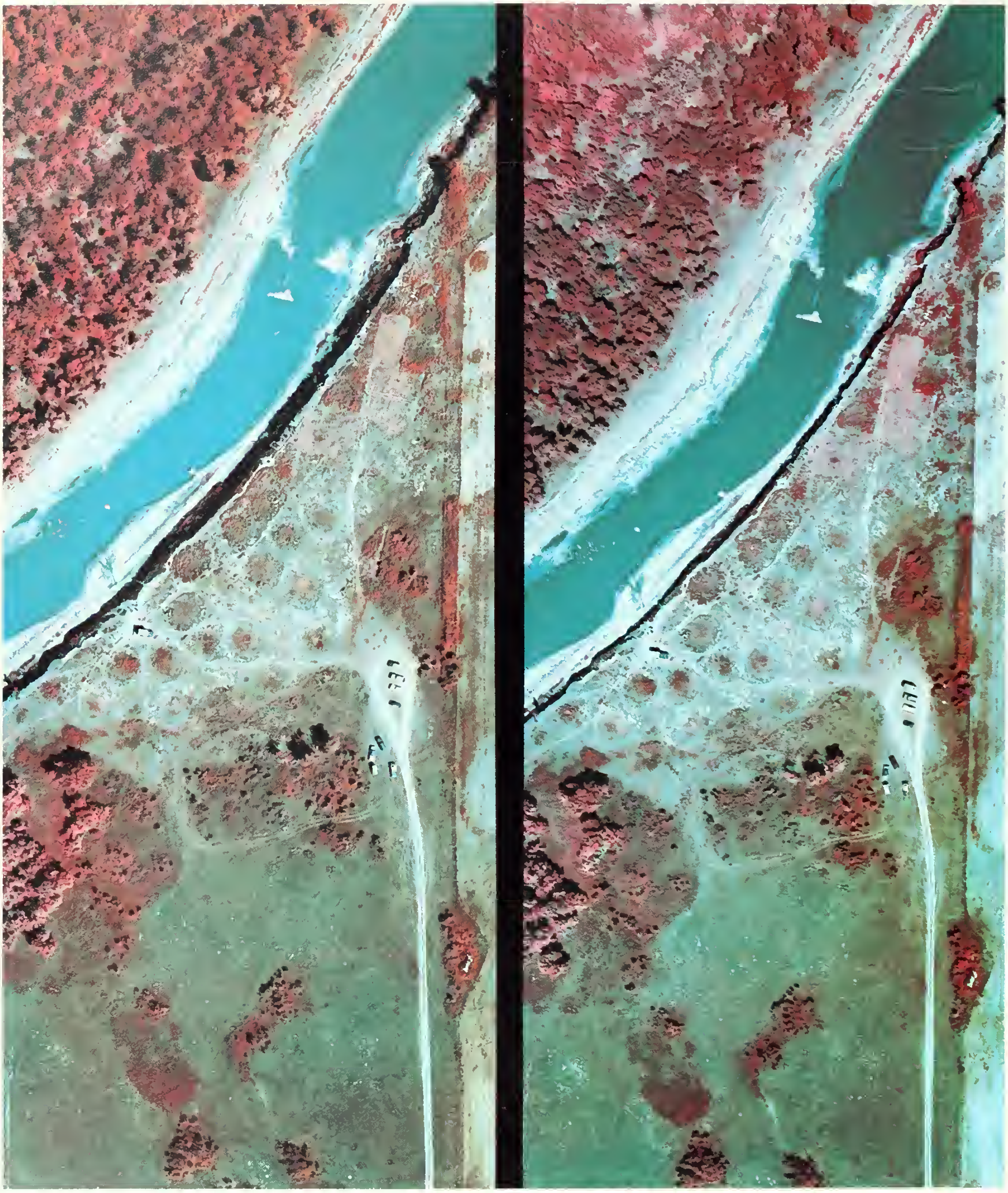


Figure 11. A false-color infrared stereo pair of the Sakakawea Site (32ME11), North Dakota. Photographs courtesy of the National Park Service.

there are few roads, and the country is exceedingly rugged, making foot reconnaissance a very slow and expensive process. The thin soil and vegetation cover in this area, combined with the fact that many of the sites, especially some of the Apishapa focus ones, were built on bedrock, suggests that shadow marks would probably be most informative in pinpointing village sites (Stephen J. Ireland, personal communication, 1981).

Aboriginal Quarries. A common problem in studies of lithic technology is determining the source of different kinds of raw materials, especially those used for chipped stone tools. Preferred raw materials may sometimes be obtained from such settings as stream beds, where the material has been transported, often for some distance. Because of the deleterious effects chemical and mechanical weathering has on flaking qualities, however, many Native American groups obtained some raw materials directly from bedrock exposures or from other *in situ* sources.

Remote sensing is proving to be a powerful tool in determining the source of some materials. In eastern Montana, for example, distinctive raw materials — porcellanite and non-volcanic natural glass — occur in sediments metamorphosed by burning lignite coal deposits. Porcellanite refers to fused shales, most of which are shades of grey and red, while non-volcanic natural glass is a slag formed at points where the burning coal reached the highest temperatures. Although these two materials are among the preferred ones for flaked stone tools, not all of the metamorphosed sediments are desirable for this purpose.

In eastern Montana and adjoining areas, porcellanite is widely used. In some prehistoric assemblages, as much as 95 percent of the chipped stone tools are manufactured from this material. It is especially common in the Powder River basin, where thick seams of coal of the Tongue River member of the Fort Union formation have been burned. There are vast outcrops of porcellanite there, many of which reveal evidence of prehistoric exploitation. Mapping these outcrops is practical only by the use of remote imagery.

The upper layer of burned sediments is generally composed of materials reddened by the heat of the burning coal, and is known as "scorio" or "scoria." Seams of this material may be up to 120 feet thick and, because these metamorphosed beds are harder than the surrounding materials, they tend to form the tops of ridges and hills. On false color infrared imagery, this red material appears as distinct yellow hues, usually in linear patterns following ridges. It is therefore a simple matter to map the coal burn outcrops by transferring these patterns from 1:80,000 color transparencies (used by the Bureau of Land Management in Montana) to 1:126,720 scale map overlays.

Not all of the burn outcrops visible on the infrared imagery, of course, contain knapping-quality porcellanite. Surface examination is needed to verify that any given outcrop was in fact used as a quarry area. Nevertheless, the data accumulated to date clearly illustrate the extent of the coal burn areas, and provide a solid point of departure in trying to understand the use and distribution of this raw material (Gerald R. Clark, personal communication, 1981).

The Knife River, in west central North Dakota, is believed to have obtained its name from the local Indians who obtained raw material for chipped stone knives from quarries along its middle reaches, in Dunn and Mercer Counties. Before 1968, only five such quarries were known, principally the Dodge and Crowley quarries; the latter is now a North Dakota State Historic Site.

During a reconnaissance study of Pleistocene geology in Dunn County in 1968, 24 additional quarry sites were located by geologist Lee Clayton on air photos (Clayton et al. 1970), and ground survey in western North Dakota has revealed still others. These quarry pits are easily visible on air photo stereopairs at a scale of 1:20,000, as they are circular pits about 6 m in diameter and some 0.9 to 1.2 m deep, with quarry areas covering from 0.8 to 32.4 hectares (2 to 80 acres), some of which contain several hundred quarry pits. These quarries appear to have been in use for many thousands of years, with the products traded as far away as Ohio, Missouri, and Colorado, beginning in paleo-Indian times.

Quarry sites in Montana, also characterized by depressions surrounded by rubble, have also been detected on air photos (Fig. 12). The Schmitt and Helena quarries, near the town of Three Forks, western Montana, were both photographed at nominal camera scales of 1:6,000 and 1:30,000, and both sites are recognizable as such at both scales. Such "quarries are among those kinds of sites which are identifiable on [color infrared] at any scale to as small as 1:80,000" (Davis et al. 1977: 68).

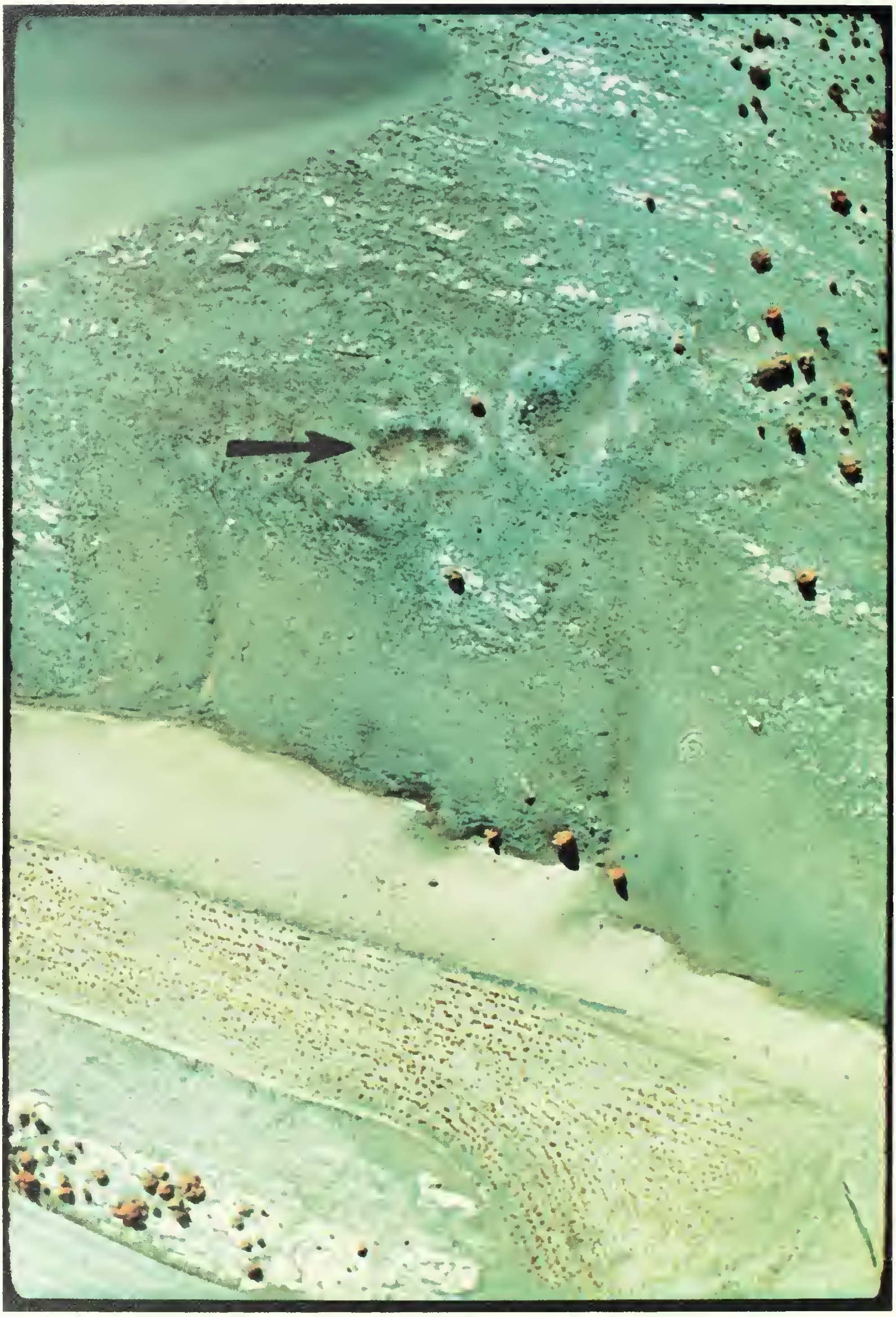


Figure 12. A false-color infrared oblique view of prehistoric quarry pits of the Schmitt chert mine complex (24BW559), Montana, excavated in a limestone matrix. Scale of photo is 1:2,000. Photograph courtesy of Robert E. Carroll of ECON, INC., Helena, Montana [Davis et al. 1977].

Figure 13. A low oblique view of Fort Sully II (1866-1894), a military post in Sully County, South Dakota. Photograph courtesy of the National Park Service.

Historic Euro-American Sites and Structures. Euro-American fur trade and military posts, as well as townsites in the Plains, tend to appear prominently on air photos for several reasons: their large size, their common use of stone, and the recency of construction (Fig. 13). Although it is seldom necessary to resort to air photos to find such large and documented sites as forts and towns, smaller-scale structures are not as well documented. The University of Kansas, for instance, has found that air photos are useful in discovering and interpreting nuclear farmsteads, and for discovering midden areas associated with abandoned ones (Ricky L. Roberts, personal communication, 1981). John Taylor, with the Bureau of Land Management in Montana, informs us (personal communication, 1981) that BLM personnel are able to use air photos in range management studies to locate historic homesteads.

Sandra Laney, University of Nebraska-Omaha, finds that parts of the Nebraska City Cutoff of the Oregon Trail are visible on air photos, and hopes to identify "road ranches" (private dwellings catering to freighting traffic) along the trail. Even smaller scale discoveries are also possible: the base for the flagpole at Fort Union Trading Post National Historic Site was detected on a low-oblique air photo (Douglas D. Scott, personal communication, 1981).

Steamboats. Although it is an inland area, the presence of a great waterway, the Missouri River, provides a significant regional resource for underwater archeology. During the nineteenth century, when steamboats plied the river in great numbers, from its mouth to Fort Benton, Montana, literally hundreds of these craft sank in the treacherous waters of the Missouri. The hulls of most of these boats have long since been destroyed by the river, but a number of them remain entombed in river silts and sands, either in the present channel, or in former ones.

Some of these boats can be seen from the air, at least during times of low water. In 1977, using a North Dakota National Guard helicopter, Norman Paulson and Frank Vyzralek flew along the

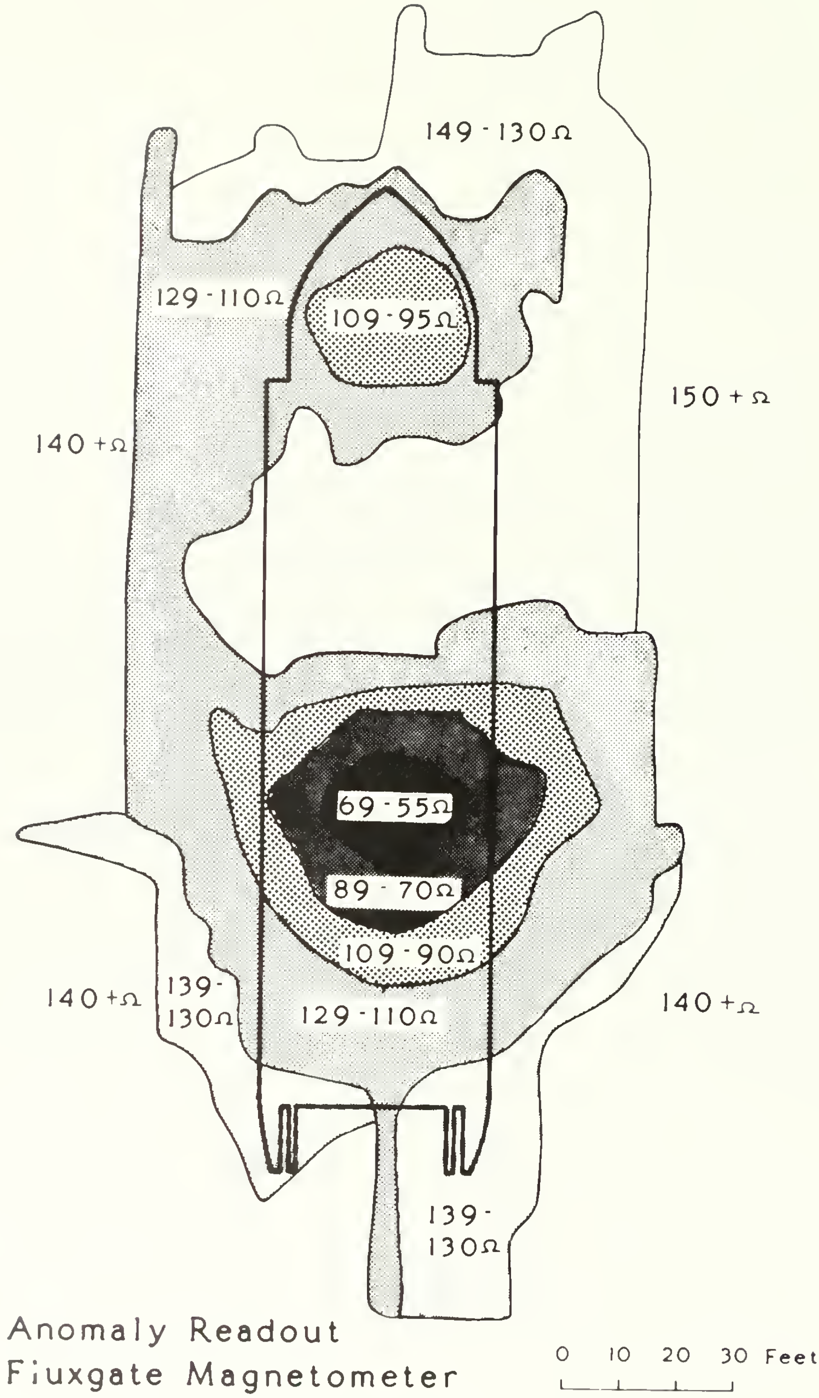


Figure 14. Map of the fluxgate magnetometer values relative to the actual location of the steamboat *Bertrand*, below surface. The patterns are based on readings taken at 5-foot intervals. The lowest values correspond roughly to those areas in which most of the iron and steel were found. (After Petsche 1974: fig. 18).

Missouri River north of Bismarck at altitudes of 30.5 to 61 m, and located and photographed the remains of the *Abner O'Neal,* which sank near Painted Woods in 1893 (Sperry 1977: 37, and photograph). The hull of the boat is clearly visible because the Missouri River at this point is quite clear, its sediment load having been deposited in the Garrison Reservoir, a few kilometers upstream. Another steamboat, near the city of Bismarck, was visible at low water a few years ago, but has since been covered by shifting sandbars. Garvey C. Wood, of Loma, Montana, has also discovered (personal communication, 1981) that the remains of steamboats could be seen from the air in the Missouri River in the vicinity of Fort Benton (Wood 1977).

In 1865, the steamboat *Bertrand,* enroute from St. Louis to Fort Benton, struck a snag and sank in DeSoto Bend, on the Missouri River some 40 km north of Omaha, Nebraska. In the years following its demise, the river bed shifted and the former channel became silted over, burying the remains of the boat. The general location of the boat was determined in 1967 by the combined use of old and new maps, newspaper accounts, and modern air photos, and the next year its location was pinpointed by the use of a fluxgate magnetometer. By that time, the remains of the vessel lay below the water table some 8.5 m below the surface. The boat was subsequently exposed and excavated, although it was not feasible to raise or remove the boat itself for preservation or display (Petsche 1974: 1, 28, Fig. 18). The surface anomalies detected by the magnetometer left little doubt as to the exact position of the vessel (Fig. 14).

Further Applications

A wide variety of studies exploiting air photos are possible, potentially opening many new areas of study. For example, V-shaped fish traps, or weirs, of stones laid across streambeds occur from the Atlantic Coast to the eastern Plains. They are known in north central Missouri and in southeastern Iowa (Shields 1967; David L. Cook, personal communication, 1981). These features are normally visible on air photos, at least at times of low water. Thirty-six such Colonial and/or Indian traps were found in eastern United States on 1:10,000 black-and-white air photos, photographed using a Wratten 15 filter, which permitted maximum penetration into the water. These traps were all but impossible to detect either from the shore or on the water, since they are easily confused with natural shoals (Strandberg and Tomlinson 1970). Only one such structure is presently known in the area covered by this supplement; it is on the James River in northeastern South Dakota near the town of Redfield, where it appears to be associated with a historic Dakota earth lodge village (R. Alex 1980). A systematic check of air imagery, especially in the eastern Plains, will probably detect more of these features.

Loose and Lyons (1976) have used air photos to interpret aboriginal fields at Chetro Ketl, in Chaco Canyon, New Mexico, and Melvin Fowler has made a good case for the possibility of detecting aboriginal field patterns from air photos, based on his studies of two archeological sites in Illinois (Fowler 1969). Although the Plains Indians' gardens differed from those detected by Fowler, is it not possible that field sites might also be seen on air photos of the valleys of the Platte and Missouri Rivers, i.e., sites of the historic Pawnee, Arikara, and Mandan-Hidatsa and of their prehistoric predecessors? We know of no one who has ever looked for such fields. Of course, many of the likely areas for such fields, at least in the Dakotas, now lie beneath various reservoirs and are not amenable to ground truth testing, but other areas are available for study. Other possibilities for exploiting air imagery should occur to regional specialists.

An Eastern Montana Enigma

Not all features visible on air photos are capable of ready interpretation, as is documented by the following data, provided by Robert E. Carroll of ECON INC., a private consulting firm in Helena, Montana. Beginning in August, 1972, ECON INC. biologists working in eastern Montana began noticing a series of "circles" or rings on the ground at two locations which are visible only at certain seasons of the year. The size, regularity and location of the rings suggested a possible cultural origin, so three field trips were undertaken in an effort to determine whether the rings were natural or cultural in origin.

ECON biologists examined the rings during midsummer and found that the dominant vegetation making up the visible outlines of the rings was *Taraxacum officinale* (dandelion) and *Bromus tectorum* (cheatgrass brome). These plant species are indicative of some form of disturbance, but are seasonal in growth, which accounts for the rings being visible only during late spring and early summer. During this time, the rings can be seen from ground level if the observer is aware of exactly where to look for them. They are also visible to the eye from an airplane. They can be seen in most detail, however, when photographed from the air with false-color infrared film (see frontispiece). A 30 degree arc is lighter (or missing) from many of the circles; this arc is always on the east rim of the ring.

On September 4, 1974, the rings and immediately adjacent areas were examined for cultural materials actually or potentially associated with them, by Leslie A. Davis, Thomas E. Roll, and Stephen A. Aaberg. Location A produced extensive evidence of prehistoric activity: large quantities of stone toolmaking by-products of procellanite, non-volcanic glass, and chalcedony, limited amounts of animal bone and freshwater mussel remains, a hearth, and scattered fire-cracked rocks. There is no doubt that the location is the site of numerous visits over time by prehistoric hunters.

Location B yielded no persuasive evidence of prehistoric activity. A small fire-burned zone was observed on the west bank of the arroyo that abuts this location to the west, and several bone fragments (presumably of bison) protruded from this same stratigraphic unit a few meters downstream. Tailings from rodent burrows and ant pilings revealed no materials of prehistoric origin. This location also differs from Location A in having randomly distributed shallow depressions of widely differing diameters. The depressions seem to occur predominantly near the rings.

Discreet inquiries among local residents revealed that the rings' presence is well known locally in both locations, and apparently has been since the earliest Euro-American permanent settlement in the area. There was no mention of any local speculation or legend concerning the origin of the rings.

ECON prepared photo materials from which field investigators could locate precise ring points by triangulation from given land features. Investigators went to the ring locations on October 19, 1974, for further evaluations. At location A, a ring edge was located by triangulation, since there was no surface evidence of the ring's presence. The outer edge of the ring was estimated to be 1.4 to 1.8m across. A trench, measuring 3m long, 25cm wide and 50cm deep was dug to cross section the edge of the ring. The trench was dug to extremely compact subsoil and discontinued. No differences were noted in the sediments exposed beneath the weak A_h horizon, in either color or structure. There was no evidence of any prior excavation or surface modification that might account for the presence of the rings; the surface appears to have been stable for several thousands of years.

The rings at Location A range from 55 to 58m in diameter. Ten rings have been identified, most of which overlap, along a north-south axis. Only one "free" feature is present, somewhat apart from the others. The entire group is contained in an area of about four hectares.

There are eleven distinguishable rings at Location B. One ring appears to be bisected by an arroyo. All of the features at this location can be contained within an elliptical area of approximately 3.5 hectares. Persons unknown had dug three crude pits in the outer edge of one ring in an attempt to solve the mystery of the rings. The exposed cuts of the pits showed evidence neither of earlier surface disturbance nor of sediment discoloration or soil structural anomalies. Nine of the rings overlap, but seldom in the regular adjacent-concentric linear relationship noted at Location A.

ECON specialists have been observing these rings every year for eight years now, and they never change. The field examinations rule out a cultural origin for the rings. Although a biological origin for the rings can be determined, their age and the reasons for their genesis remain unknown.

Section 6

Site Mapping and Evaluation

Planimetric and topographic maps of archeological features can be prepared directly from air photos. This can be done rather quickly from either vertical or oblique photos, although both time and cost increase proportionately with the need for greater precision. Computer systems, for example, have been developed to transfer information from oblique air photographs of archeological sites to maps (Scollar 1978). Photogrammetric mapping in archeology is synopsized by Lyons and Avery (1977: 68-83). Wolf (1974) is an excellent general reference for photogrammetric techniques.

One of the first air photos of a prehistoric Plains village site to be published was one taken by Russell Reid of the State Historical Society of North Dakota. Reid's photograph of the Huff Site, on the Missouri River just south of Mandan, was published in 1942 under the title, "A Remarkable Photograph of a Mandan Village" (Kruse 1942). This photograph appears to have been the basis for an uncontrolled sketch map of the site published a few years later (Will and Hecker 1944: Pl. 2, bottom). This was probably the earliest (though inaccurate) use of air photography for mapping a Plains archeological site.

A more accurate, but still imprecise, application was the mapping of the Huff Site from a low-level vertical air photo provided by the North Dakota Air National Guard (Wood 1967: 28, Map 4). A detailed site map was prepared, although without correction for parallactic displacement, after only a few hours had been spent on the ground checking surface details against the imagery. This technique was practical at Huff because of the outstanding clarity of the surface features at the site, for all features visible on the ground were equally visible on the air photo.

Details can also be added to maps based on air imagery. The site map for the Buffalo Pasture Site (39ST6) in South Dakota was prepared by Wood from a vertical air photo, using one of the low level oblique views of the site taken by Solecki and Dewell in 1952 (Lehmer and Jones 1968: Fig. 1, Plate lb) to elaborate on details that were not clear on the much smaller scale air photo (1:7,920).

Modern techniques for reducing air imagery to planimetric or topographic maps are capable of yielding almost any reasonable degree of precision. The most sophisticated site mapping in the Plains has probably been done at the Deer Creek Site in Kay County, northern Oklahoma, and at the Knife River Indian Villages National Historic Site in North Dakota. The Deer Creek Site was photographed in color from an altitude of 366 m by a commercial map service in Tulsa, subsidized by the Tulsa District, U.S. Army Corps of Engineers. Another map firm, in Oklahoma City, then produced a topographic map at one-foot contour intervals according to national map standards. Ronald C. Corbyn, using the same photographs, also prepared a planimetric map of the site, illustrating surface cultural features from crop and soil marks and surface expressions (Corbyn 1974 and 1976: 20-21, Fig. 1). The photogrammetric work done at the Knife River Indian Villages is discussed at greater length later in this chapter.

Because many of the early Euro-American settlements in the Plains tend to be in areas which are lightly occupied today, and have never been cultivated, some of them appear on air photos with enough clarity that they can be easily mapped. This is especially valuable when written records on the sites are inadequate. About two-thirds of Camp Cooke, on the Missouri River at the mouth of Judith River in north central Montana, has slumped into the Missouri River. John Taylor has been able

Figure 15. A low altitude ladder platform for oblique or vertical views, a once familiar sight on the Plains. Photograph courtesy of the National Park Service.

to use U.S. Department of Agriculture air photos from the late 1930's to map the parade ground and other features which cannot now be reconstructed from historic documents (personal communication, 1981).

Ricky L. Roberts and T. H. Lee Williams have used air photos to map and interpret the abandoned town of Chelsea (about 1868-1878) in the El Dorado Reservoir, in Butler County, eastern Kansas (personal communication, 1981). A review of air photos revealed road and street patterns. A town plat was superimposed over the air photos to provide increased data for interpretation, and this was followed by ground truth excavations. Color infrared in this instance was superior to the black-and-white imagery in revealing road and street scars.

In addition to their value as finding aids, air photos can serve many othr purposes, some of them quite practical. Lehmer and Wood, for instance, included as part of the site records an 8½ by 11 in photocopy of that part of their 1:7,920 scale air photos, to illustrate each of the sites in their files for the upper Knife-Heart Region, North Dakota. The photocopies were useful for quick reference, and for estimating site size, the number of houses, site setting, etc. Such information was easier to retrieve on such photocopies than from the bulky and much smaller scale 1:7,920 full size (24 by 24 inch) prints.

Site documentation using vertical air photos has taken many forms over the years. For decades, a standard practice on the Plains for recording excavated dwellings, large-scale features, or general excavations was to photograph them from the top of a tall ladder. Successfully done, this yielded good floor plans for earth lodges, as almost any Plains village site report from the 1940's to the present is likely to reveal. At least one broken neck and a variety of lesser injuries were incurred in using this technique — one which demanded a more adventurous spirit than many people were able to muster. Swaying at the top of a 9 m (30 foot) ladder while manipulating one or more cameras was sometimes as exhilarating as it was productive (Fig. 15). Today, the use of cherrypickers, the Swedish "turret" (Straffin 1971), the Whittlesey bipod (Klausner 1980), or ballon-borne cameras is preferred. Dennis Stanford of the Smithsonian Institution has used the Swedish turret to produce photo-mosaics of the bison bone bed at the Jones-Miller site in northeastern Colorado (Klausner 1980: 297).

Features Now Being Mapped from the Air

Stone Features. Many kinds of features on the Northern Plains were built using stone. These include stone circles (tipi rings); individual piles or piles in alignments; cairns; medicine wheels; effigies; rock piles over burials; mosaics; fortifications; vision-quest structures; and bison drive lanes (Davis and Carroll 1981). Most of these features normally have very low profiles, rarely being more than a few centimeters in height, but they contrast with the surrounding soil or vegetation sufficiently to be visible several hundred meters above the surface. Several techniques, however, may be used to enhance or highlight these features so they may be mapped or detected from greater heights.

These stone features present a special problem in detection since they are composed of field stones, often in a setting containing many other surface stones. Their presence is therefore often camouflaged by this naturally distributed stone as well as by the presence of lichens. Except when the stones are heaped up, they present targets ranging from 10 to 30.5 cm^2, so that surfaces as small as 100 to 930 cm^2 must be visible in the imagery. Under ideal conditions, stone features of this size have been detected at scales as small as 1:30,000, but at a scale of 1:500 (1 cm = 5 m), objects as small as about 15 cm in diameter are readily visible (Davis and Carroll 1981).

Detection of stone features is simplified by the fact that most of the stones are white, although shadows, patterns, and vegetative surroundings provide additional clues. Davis and Carroll (1981) have found that false-color infrared normally "affords the skilled interpreter a greater range of information upon which to make his interpretive decisions" (1981: 12).

A number of "medicine wheels" are known in the Northwestern Plains. They occur in different styles and sizes (see Wedel 1961: Figs. 23-24), and interpretations of their functions are correspondingly debated. These features consist of circles of stones with varying numbers of "spokes," sometimes also associated with low piles of stones. Most of these "wheels" are visible at relatively low elevations, but Stephen A. Chomko (personal com-

Figure 16. The Demijohn Flats Tipi Ring Site (24CB736), Montana, showing the whitewashed stone circles. Photograph courtesy of Lawrence L. Loendorf.

munication, 1981) has found that the medicine wheel in the Big Horn Mountains east of Lovell, Wyoming, is visible from commercial airliners 6,700 m above the mountain top on which it is built.

Other rock structures in the Northwestern Plains include "fortifications," usually consisting of low stone walls, and human as well as animal outlines, commonly turtles (Kehoe and Kehoe 1959: Figs. 1-3; Wedel 1961: Figs. 16-20). Stone alignments of several different kinds are known; significant among them are the stone piles associated with bison drive lines and with aboriginal trails across mountainous areas.

Although boulder arrangements appear to be most common on the Northwestern Plains, they are by no means restricted to that area: such structures also occur in the northeastern periphery and in the Central Plains. Perhaps the most prominent example of such native constructions is the Tie Creek Site, on the Winnipeg River in southeastern

Manitoba, which is one of the largest aboriginal boulder arrangements in North America. This large complex of figures, many of them connnected to one another by lines of stones, is set on a massive, flat granitic outcropping near the southwestern edge of the Canadian Shield (Steinbring 1970). Although some of the figures and stone lines may be concealed by forest cover, most of them are set on flat bedrock exposures. For this reason, the site is especially suitable for low altitude photographic mapping.

Similar boulder arrangements are rare in the Central Plains. The figure of a man was outlined in small pieces of limestone on a high hill south of Beaver Creek, in Harlan County, south central Nebraska (King 1963: 107), although it was dismantled for building stone sometime after its discovery in 1869.

Tipi Rings. Scattered throughout the Northern and Northwestern Plains are large numbers of features usually known as "tipi rings." These rings, ranging up to 9 m or more in diameter, consist of stones set in the ground at varying depths. They often occur in clusters of up to several hundred rings. The usual explanation for them is that they represent the stones that were used to secure the base of a tipi to the ground. Some of the circles are obviously too large, or too small, to have served this function, so that each feature must be individually interpreted. We might warn that the unwary observer might confuse some of these rings with "patterned ground," the sometimes circular patterns in stone which result naturally from freeze-thaw cycles in periglacial environments (Loendorf 1969: 74; Wood and Johnson 1978: 344-346).

One characteristic feature of the Plains Indians is said to be the "camp circle," i.e., a large circular arrangement of tipis (Wissler 1941: 94). It is therefore curious, despite the fact that thousands of tipi rings have been recorded, that none of the sites conforms to this pattern, intimating that perhaps the camp circle is a very late (perhaps historic) development on the Plains.

Tipi ring sites are often quite large and scattered, and ground-level mapping is time-consuming and expensive. One alternative is to whitewash or lime the stones and to photograph them from the air. An especially graphic example of this treatment was carried out at the Demijohn Flats Site (24CB736), south of Red Pryor Mountain in Carbon County, Montana, which consisted of over 230 rings. This site was so large that it could not be encompassed in one photograph from the air, since at the elevation necessary to include the entire site in one frame the individual stones in the rings were not visible. A dramatic and informative oblique air photo of the site was obtained after whitewashing the stones (Loendorf 1969: 88-92, Fig. 8). The resulting pattern remained visible from the air and was even used as a landmark for airline pilots for several years after the stones were painted (Fig. 16), a circumstance which prompts Loendorf to caution that a less durable marking medium should be used. Agricultural lime has been successfully used to outline effigy mounds in northeastern Iowa to enhance their visibility in air photos (Mallam and Mount 1980).

Leslie Davis and his colleagues in Montana have been doing a great deal of experimentation in the Northwestern Plains with different film types at various scales. Much of this work has been done with tipi rings, but other kinds of sites are also being investigated. One tipi ring site in Montana is the Madison Tipi Ring Site (24MA556). Because of their uniform diameter,

> the 4 m (average) diameter stone circles are easily visible at 1:6,000 scale, and the threshold of visibility . . . [is] at 1:13,000 scale . . . under general conditions, tipi rings will be visible at 1:12,000 and larger scales and, at optimum conditions, at scales as small as 1:14,000 (Davis et al. 1977: 71).

Medium-scale, 35mm true color, black-and-white, and false-color infrared air photos were taken at the conclusion of excavations in 1980 at the Pilgrim (24BW675) stone circle site in Montana for two reasons: to document the archeological work completed there (Fig. 17), and to map environmental factors, specifically, data on soils and vegetation, which had been independently recorded on the ground. This photography appreciably supplements the site records by graphically documenting the site in its natural setting, which is the intermediate zone between the Elkhorn Mountains and the Townsend Basin, south of Helena, Montana (Davis and Aaberg 1981).

Prehistoric stone circles (as well as bison drive lines) exist in some numbers at the Ulm Pishkun State Monument in central Montana. Medium-scale, 35mm true color, black-and-white, and false-color infrared air photos were taken at different seasons and years to document extant features at this site. These features had previously been

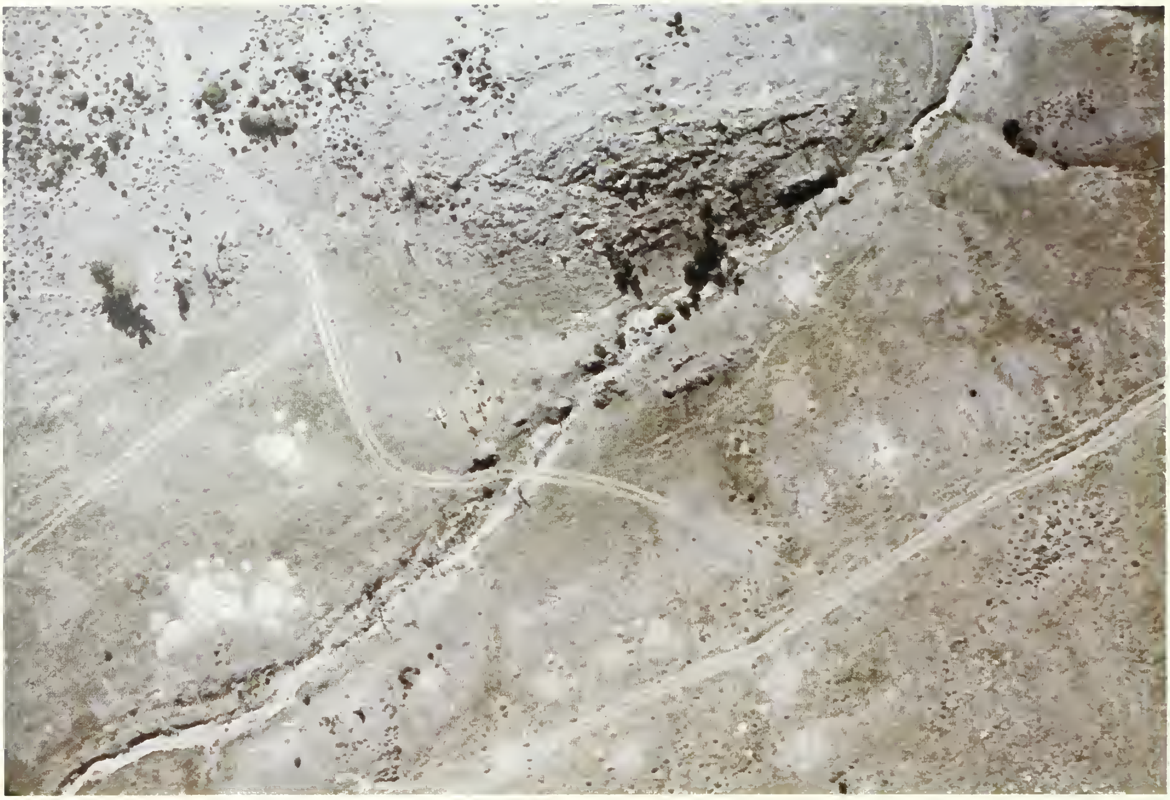


Figure 17. The Pilgrim Site (24BW675), Montana, during excavations in 1980, from an Ektachrome view taken at 305 m. All of the circles in this view have been excavated, with the individual stones remaining in place. Note the crater formed by an exploded military round in the lower left near one of the circles. Photograph courtesy of Robert E. Carroll of ECON, INC., Helena, Montana [Davis and Aaberg 1981].

mapped on the ground as a control. Comparisons against various kinds of imagery will yield data on the preferred films and image sizes to use in recording such information (Davis and Carroll 1981).

Buffalo Jumps. A common practice among many High Plains tribes was to force bison, in large groups, into traps or corrals, to be killed later at the convenience of the hunters. Another technique was to manipulate the bison into a position whereby they could be stampeded, within specified drive lanes, over a high bluff or precipice where they were killed by the fall. Both methods involved the use of V-shaped drive lanes, which were often augmented by low piles of stone behind which hunters could stand or crouch and drive the animals in the desired direction. Such piles of stone are common in the Northwestern Plains; for example, there are more than 500 rock piles in the drive lanes at the Head-Smashed-In bison jump in southwestern Alberta (Reeves 1978: 154, Fig. 17.3).

Larger cairns may either be isolated or built in conjunction with other features. The Upper Muddy Creek Cairn, in Carbon County, Wyoming, north of the town of Medicine Bow, is a circular feature about 3.5 to 4 m in diameter and 120 cm high. It is associated with numerous stone circles and small rock piles on a bluff edge overlooking the Muddy Creek bison jump. The cairn is large enough and contrasts sufficiently with the surrounding vegetation that it is visible on air photos on a scale about 1:6,000 (Stephen A. Chomko, personal communication, 1981).

Under certain circumstances, the bone bed resulting from a bison jump may appear in air photos. The Madison Buffalo Jump (24GA314), northwest of Bozeman, Montana, produced a prominent color signature on color infrared film; the soil, enriched by bone and other nutrients, yielded a chartreuse colored signature which would probably be detectable on any color infrared "photographic scale currently in common use, including 1:80,000" (Davis et al. 1977: 73, Fig. 74).

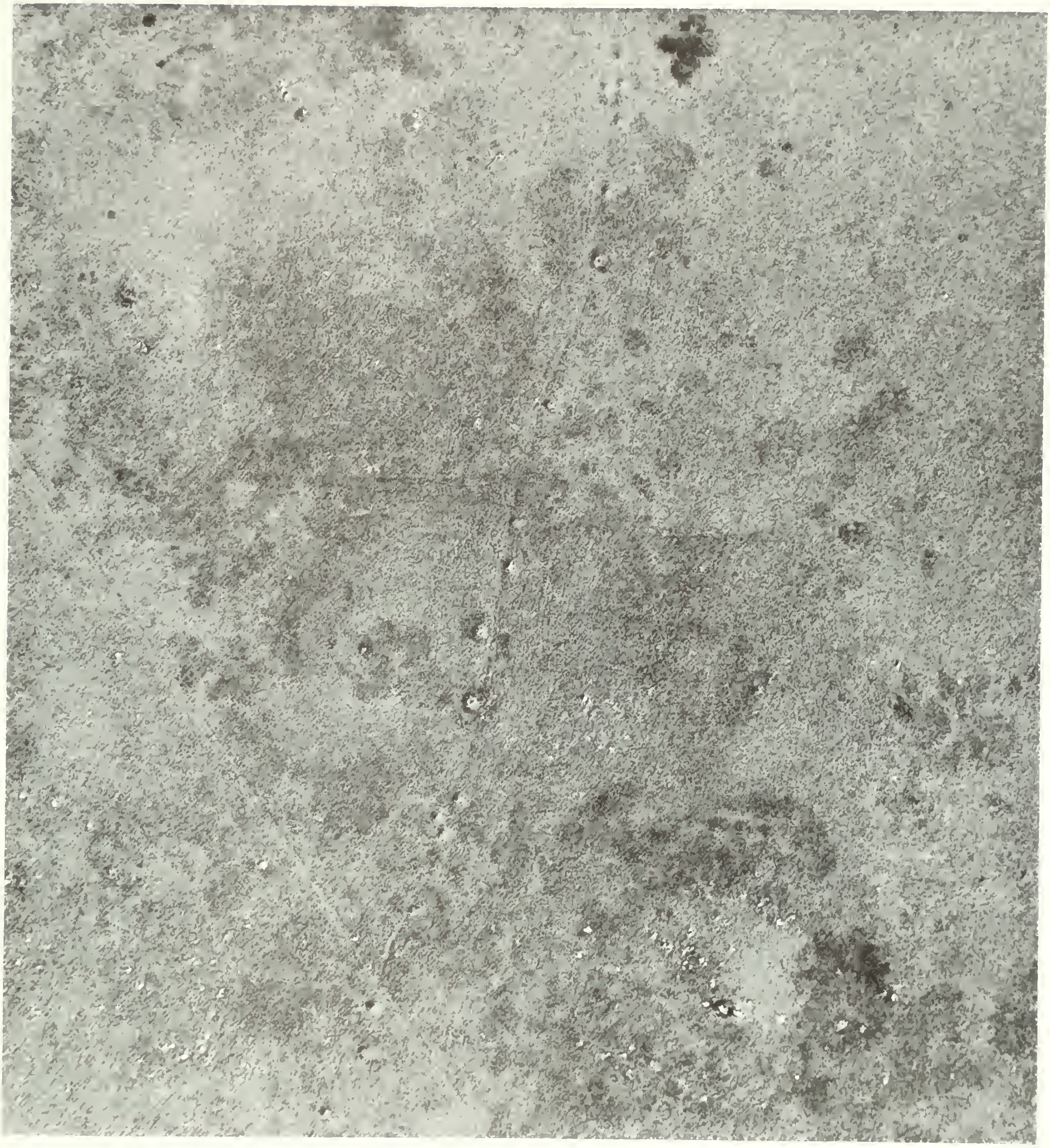


Figure 18. Vertical air photograph of part of the East Bearspaw Slope Aboriginal Trail, Montana, showing 347 m of trail, marked by the linear depression and by 18 stone cairns. Photograph courtesy of Robert E. Carroll of ECON, INC., Helena, Montana [Davis et al. 1980].

Trails and Roads. Historic Euro-American features which are especially amenable to mapping using air photos are trails and roads. The Oregon Trail, for instance, has been plotted from Independence, Missouri, to Laramie, Wyoming using air photos (Morley 1961). Although the technique has not been widely applied, it could be usefully employed, for example, to confirm or refine the many hundreds of miles of military and pioneer trails mapped by Dana Wright in North Dakota, such as the Sibley Trail of 1863 (Wright 1962). Albert G. Hahn, a former air photo interpreter, has studied air photos for southeastern Colorado, and has seen what he believes to be alternate routes for the Santa Fe Trail near Bent's Old Fort. The trail itself can be traced rather easily, although it is disturbed somewhat by modern roads. He also finds that the Taos Trail, a branch of the Santa Fe Trail, can be traced in part on air photos (Hahn, personal communication, 1981).

The Red River Metis, in the Northern Plains, made regular trips into North Dakota and Minnesota in the mid-1800's. The ruts cut by their two-wheeled Red River carts, for the most part, have vanished beneath the plow. Remnants of several of these trails are still visible, although a recent comprehensive study of them does not mention that air photos would be useful in tracing them (Gilman et al. 1979).

Late prehistoric and historic Indian trails are known in many parts of the West. In some instances, these trails left tangible traces. The East Bearspaw Slope Aboriginal Trail consists of a linear depression 3.2 km long created by foot travel, and marked by a series of stone cairns, in the Bearspaw Mountains of northern Montana. Davis et al. (1980) obtained medium-scale, 35mm, vertical true color and large-scale, oblique, black-and-white air photos of this trail as a first step in documenting this Indian feature (Fig. 18). Using the maps and photogrammetry, an appropriate field investigation can be designed to explore its construction, use, and antiquity. Bad Pass Trail in the Pryor Mountains of southern Montana is likewise marked by cairns, and could be investigated using the same techniques (Lawrence L. Loendorf, personal communication, 1981).

Distinct, well worn trails are also known to have existed between adjoining Indian villages in the Northern Plains. In 1806, Alexander Henry visited the Mandan and Hidatsa communities at the mouth of the Knife River, and in riding between two of the villages, he "proceeded on a delightful hard, dry road," the heat of the sun, he said, having made it as hard as "pavement" (Coues 1965, Vol. 1: 344). Such "roads" were still sufficiently distinct that some of them were mapped in 1908 by A. B. Stout and a party from the State Historical Society of North Dakota (Wood n.d.a : Fig. 15). Some of these roads are discernible today on 1938 U.S.D.A. and later air photos, particularly those in the vicinity of the Big Hidatsa Site (32ME12). A three-tracked trail, very probably a travois track, can be found on the ground today northwest of the Fort Clark Village Site (32ME2), which may also be visible on air photos (C. L. Dill, personal communication, 1981).

Other kinds of trails, which are likely to be less distinct than tracks for travois or wheeled vehicles, include the major cattle trails from the Southern to the Central Plains (Athern 1961). Important cattle trails ended at Ogallala, Nebraska, and at Dodge City, Ellsworth, Abilene, and Wichita, Kansas. Of these, the Dodge City and Ogallala trails (about 1876-1884) are the more western, lying principally in grassland, so that the chance that they left detectable remains is somewhat enhanced.

Other trails of interest to Plains specialists are those made by game animals, especially bison, which appear to have left traces detectable by remote imagery. Several studies suggest that bison trails are identifiable on air photos (anonymous 1967; Babcock and Clayton 1976; Clayton 1975; Harksen 1968), although some features which superficially resemble bison trails are believed to be settling lines over fracture zones in the earth's crust (Zakrzewski 1965).

Photogrammetric Mapping at the Knife River Indian Villages

Remote sensing has been a very important part of the research program carried out by the Midwest Archeological Center of the National Park Service and by the University of North Dakota at the newly established Knife River Indian Villages National Historic Site in Mercer County, west central North Dakota. This national historic site consists of 486 hectares (1200 acres) of river bottomland (terrace and floodplain) just north of the mouth of the Knife River and the town of Stanton. Three conspicuous Hidatsa village sites (Lower Hidatsa, 32ME10; Sakakawea, 32ME11; and Big Hidatsa, 32ME12), as well as a number of less prominent sites, are within the park. In fact, the entire park area is almost one continuous site area, a fact which has complicated planning for park development.

Park planners established the boundaries of the park, in part, using information from oblique and vertical air photos of the area. Among the photos studied were those taken by the North Dakota State Highway Department which had been taken following a light snowfall (see Section 4 and Fig. 2).

Before the authorization of the park by Congress in 1974, the area had been investigated only casually by professional archeologists, although each of the three large village sites in the park had been mapped earlier in the century by one or more investigators. Detailed contour maps of the entire park, and of the three major villages in the park were needed by both the archeologists and the park planners for use in developing the area. The high cost of conventional on-the-ground surveys necessitated finding an alternative, e.g., the preparation of contour maps by photogrammetric techniques.

In 1976, following consultation between Thomas R. Lyons (Remote Sensing Division of the Southwest Cultural Resources Center, National Park Service, Albuquerque) and F. A. Calabrese (Midwest Archeological Center, National Park Service, Lincoln), several sets of vertical air photos were taken of the Knife River Villages for photogrammetric purposes. These included 40 9 by 9 inch black-and-white photos of the major archeological sites in the park taken at a scale of 1:1,800 by an engineering firm in Albuquerque in 1976. Color infrared photos covering the entire park were also taken by the same engineering firm in 1977, providing 177 9 by 9 inch transparancies. Black-and-white air photos of the entire park were also taken by an engineering firm in Grand Forks, North Dakota in 1978, providing 39 9 by 9 inch prints. Finally, a black-and-white high altitude photo of the entire park and its immediate environs was taken in 1978 by the Grand Forks firm.

Individual Site Maps. Three individual village site contour maps were photogrammetrically produced by the Albuquerque engineering firm from the 1:1,800 black-and-white imagery obtained in 1976. They depict the Lower Hidatsa Site, the Sakakawea Village, and Big Hidatsa. The site map for Sakakawea illustrates the level of detail obtained in this set of maps (Fig. 19). These maps have a 15 cm (or about a one-half foot) contour interval, and are to a scale of one inch to 30 feet, or 1:360.

These maps were basic to the archeological work planned in the park for several reasons. First, existing maps of these villages had been made in 1906 and 1911, and they were unreliable and in too small a scale. Second, new ground-based maps could not be made soon enough to be useful, because lead time demanded that the maps be made at a time when the National Park Service owned only a small part of the park, and had limited access to other parts of the park. Mapping from the air was the only practical option remaining.

Photogrammetric control was based on existing ground landmarks, as well as on temporary targets placed on the ground by National Park Service personnel. At Sakakawea, it was possible to set the targets at points on a grid later used for archeological purposes. The detailed site maps are valuable not only for plotting archeological data obtained from surface collections, but for correlating surface relief with magnetic and resistivity surveys, as is described later.

Overall Park Map. A general map of the park was needed by park planners and as a base map for archeological work, as well as the surveys required by Executive Order 11593 for a cultural resource inventory of the park area. A contour base map of the park was photogrammetrically produced by the Grand Forks engineering firm using the black-and-white air photo coverage taken in 1978. This base map consists of a set of 22 sheets (and an index sheet) drawn to a scale of 1:1,000, with a contour interval of one-half meter. The kind of detail it yields may be determined by comparing a section of this map (Fig. 20) with the 15 cm contour map of the Sakakawea Site (Fig. 19).

The completed base map for the 486-hectare (1200-acre) park was produced for $10,000, including ground control, at a cost of $8.33 per acre (1978 prices). The three individual site maps were produced for about $1500 each. Because they were done at a 6 inch (or 15 cm) interval, they depict three times the detail of the one-half meter map for the park, so that cost-per-acre comparisons between the two sets of maps are meaningless.

Subsurface Mapping Techniques. Several non-photographic tools for the investigation of ar-

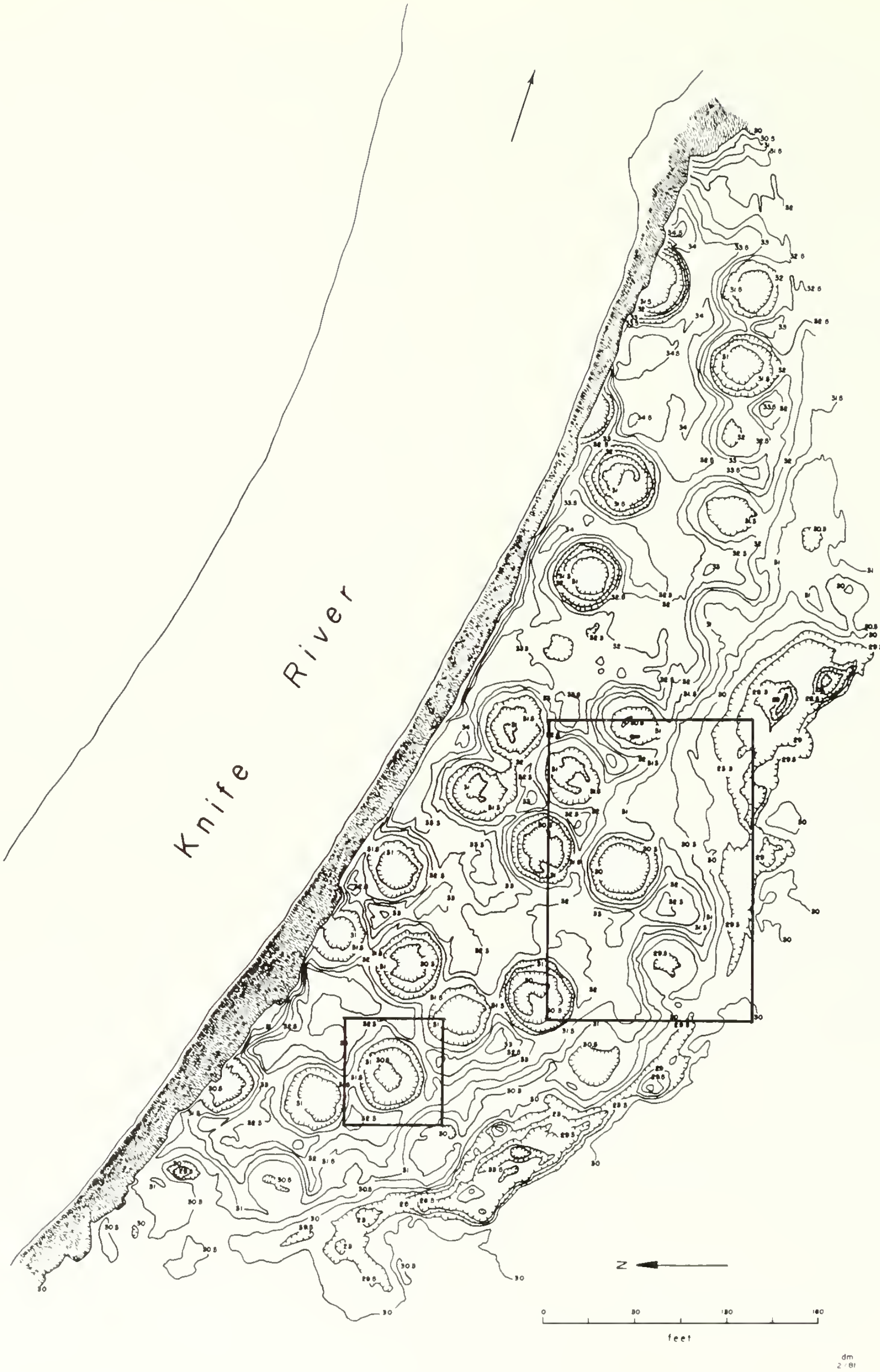


Figure 19. Fifteen centimeter contour map of the Sakakawea Site, North Dakota, photogrammetrically produced from low level air photos. The large rectangle bounds the area shown in Figure 28; the small rectangle, the area shown in Figures 29-30. Map courtesy of the Midwest Archeological Center.

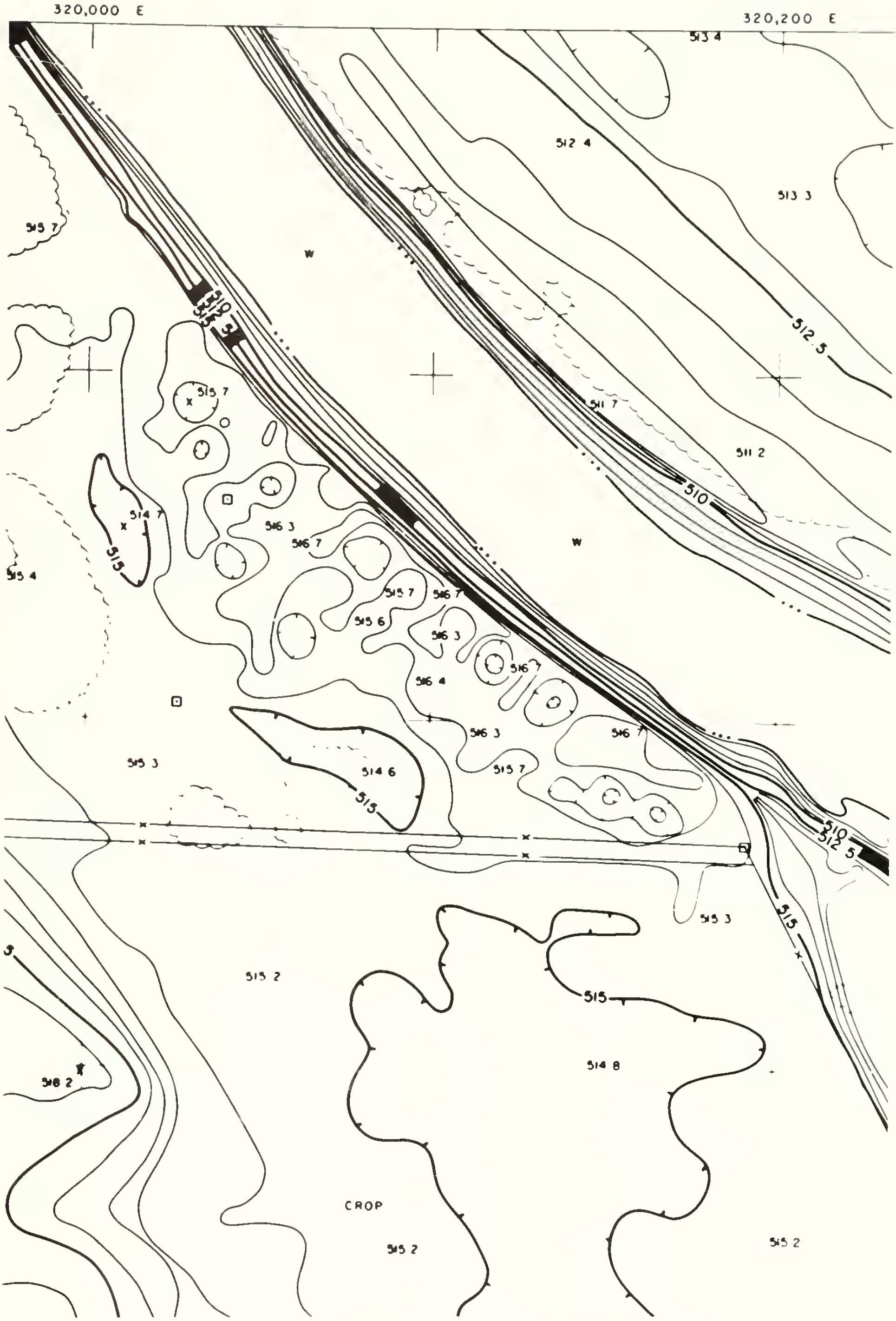


Figure 20. Half-meter contour map of the Sakakawea Site, North Dakota, photogrammetrically produced from low level air photographs. Map courtesy of the Midwest Archeological Center.

cheological sites have been briefly introduced in the *Remote Sensing Handbook* (Lyons and Avery 1977: 40-42) and in the second supplement (Morain and Budge 1978: 24, 37-38). These techniques are consistent with a model of cultural resource management which has developed in the last few years: the preservation and protection of the resource, while at the same time obtaining data by nondestructive means for both scientific and management needs (Calabrese 1979: 7). Presently, three techniques are most often applied to the detection and analysis of buried features: magnetometry, soil resistivity, and ground-penetrating radar. Except for ground-penetrating radar, Aitken (1974) provides the most comprehensive discussion of ground-based sensing devices. The three most common techniques differ significantly in the cost of the necessary equipment, the amount of time required to cover a given area, and the nature of the archeological features which can be detected.

Traditional soil resistivity instruments depend primarily upon moisture differences in order to distinguish between a feature and its matrix. Because of this, both short- and long-term fluctuations in precipitation can make resistivity data difficult to predict and to interpret. However, resistivity can be effective in locating stone and masonry features and has been successfully employed for locating ditches and pits, particularly on historic sites. Christopher Carr (1977) has provided an excellent discussion of the problems associated with the detection of small features typical of many of those found in prehistoric sites in the Plains.

Our experience with magnetometry and resistivity has indicated that the collection of resistivity data requires two to four times as long for a unit of area. One of the advantages of resistivity surveying, however, is that the data are not greatly affected by adjacent modern developments (e.g., buildings, fences, parking lots), but perhaps the greatest advantage is that the requisite equipment is relatively inexpensive (about $500) and simple to operate. The measurements can be recorded by hand and small amounts of data may be hand plotted. A single individual can place the probes, adjust the meter, and record the values.

Ground-penetrating radar is the most recent of the subsurface techniques to be developed for application to archeological sites. The instrument transmits a short pulse of radio-frequency energy into the soil and then records the echos from soil and rock interfaces as well as from metallic objects (Bevan and Kenyon 1975; Vickers et al. 1976). Radar seems particularly well adapted to locating structures and metal artifacts on historic sites. Radar contrasts with the two other techniques in the high cost of the equipment ($20-40,000). As a result, most archeologists who wish to use radar will do so by contracting for the services of a commercial specialist. Although the equipment is rather bulky, it may be operated by one or two individuals and the rate of ground coverage is often quite high.

Magnetic surveying is presently the most frequently applied of the ground-based sensing techniques. Several types of magnetometers have been used by archeologists, and Tite (1972) and Aitken (1974) provide good contrastive statements on these various devices. North American archeologists are likely to have to choose only between the proton magnetometer and the less common caesium magnetometer, both of which are used to measure local increases or decreases in the strength of the earth's magnetic field.

Local changes in the magnetic field can be caused by both artificial and natural deposits that either contrast with their matrix in susceptibility to induced magnetization or possess sufficient permanent magnetization. Increase in susceptibility to induced magnetization occurs frequently but not always with the incorporation of organic material into the fill of an archeological feature. Permanent magnetization frequently occurs when soil or rock is subjected to intense heat. Other more subtle mechanisms may result in detectable anomalies, such as the apparent alignment of the magnetic domains of fine soil particles which settled out of ponded irrigation water. This permitted the detection of prehistoric garden plots in Chaco Culture National Historical Park (Loose and Lyons 1976).

Commercial magnetometers have a calculator-type display and the values are amenable to hand-recording. The present cost of equipment for magnetic surveying ranges from $3-4,000 for a proton magnetometer to $9-12,000 for a caesium magnetometer. There are less expensive alternatives (Morrison et al. 1970; Steponaitis and Brain 1976), but these cannot be recommended unless a member of the crew has a good background in electronics. Normal magnetic surveying methods require two or three individuals.

Partially because these devices extend our abilities to sense variation in archeological deposits, special data-processing tools are frequently required. Ground-penetrating radar is available as a

Table 2. Principal Magnetometer Surveys Conducted in and Near the Study Area.

Site Name	Site No.	Site Type and Age	Data Collection*
KANSAS			
Fort Larned National Historic Site		Historic nineteenth-century fort	MWAC 1977
NEBRASKA			
Flat Rock Site	25BF210	Prehistoric earth lodge	NEBCAR 1973
Fort Atkinson State Park	25WN9	Historic nineteenth-century fort	NEBCAR 1975
Rock Creek Station	25JF17	Historic nineteenth-century stage and pony express station	NEBCAR 1980
NORTH DAKOTA			
Amahami Site	32ME8	Historic Hidatsa village	NEBCAR, MWAC 1976
Fort William and Fort Union Trading Post National Historic Site		Historic nineteenth-century forts	MWAC 1977
Huff Site	32M011	Prehistoric village site	MWAC 1977
Knife River Indian Villages National Historic Site:			
Buchfink Site	32ME9	Prehistoric village site	NEBCAR, MWAC 1975
Lower Hidatsa Site	32ME10	Prehistoric Hidatsa village	NEBCAR, MWAC 1977
Sakakawea Site	32ME11	Historic Hidatsa village	NEBCAR, MWAC 1976-77
Big Hidatsa Site	32ME12	Historic Hidatsa village	NEBCAR, MWAC 1977
Poly Site	32ME407	Prehistoric village site	NEBCAR, MWAC 1977
OKLAHOMA			
Deer Creek Site	32KA3	Protohistoric village site	NEBCAR 1979-80
SOUTH DAKOTA			
Jake White Bull Site	39C06	Prehistoric village site	MWAC 1977
Walth Bay Site	39WW203	Prehistoric village site	NEBCAR, MWAC 1974
Smiley-Evans Site	39BU2	Prehistoric village site	SDARC 1980

Table 2 (Continued)

Site Name	Site No.	Site Type and Age	Data Collection*
WYOMING			
Ward and Guerrier Trading Post (Fort Laramie National Historic Site)		Historic trading post	NEBCAR, MWAC 1976
Fort Laramie Cemetery		Historic cemetery	OSA-W 1980
South Pass City		Historic town	OSA-W 1980

*** KEY TO TABLE 2**

NEBCAR = Nebraska Center for Archaeophysical Research, University of Nebraska-Lincoln; John W. Weymouth, Director.

MWAC = Midwest Archeological Center, National Park Service; Robert K. Nickel, Field Director.

SDARC = South Dakota Archeological Research Center, Fort Meade, SD; Robert Alex, State Archeologist.

OSA-W = Office of the State Archaeologist, State of Wyoming; George C. Frison, State Archaeologist.

package of instruments to generate the pulses, receive the echos, record these data on magnetic tape, and provide a printout of the results. At the present time, this is the only option available for storing and presenting the results of radar surveys. Both resistivity and magnetometry can produce data that may be evaluated by simple inspection or by simple manual plotting techniques (Breiner 1973: 13-15). More often, the volume or complexity of the data will require computer processing. The use of even an inexpensive micro-computer will permit the application of mathematical techniques which may be necessary to reduce variation in the data which does not relate to archeological features (Scollar 1969).

Applications in the Plains. The application of these ground-based techniques to Plains archeological sites is quite recent. The earliest known tests were conducted by John Weymouth in 1972 (Weymouth 1976). Ground-penetrating radar has only been applied to a few sites on the margins of the study area. Bruce Bevan (1979) has conducted two seasons of work at the Deer Creek Site in extreme north-central Oklahoma, and has also worked with the Wyoming Recreation Commission in the study of historic remains at South Pass City in Wyoming (Fawcett and Larson 1980).

Resistivity has had equally limited application in the Plains. It has been used to investigate a single earth lodge at Knife River Indian Villages National Historic Site in North Dakota; the resulting print-out (Fig. 29) is discussed later. The Nebraska Center for Archaeophysical Research has recently tested two types of resistivity devices at the Deer Creek Site (John W. Weymouth, personal communication, 1981). This study was conducted in conjunction with an extensive program of magnetic surveying. When the final reports by Bevan and Weymouth are completed, the Deer Creek studies will provide the best comparative evaluation of these three techniques for application to prehistoric and protohistoric sites in the Plains.

Magnetic surveying has been much more widely applied to archeological sites in the study area, and a summary of magnetic surveys is presented in Table 2. The list includes several historic sites which range from cemeteries to trading

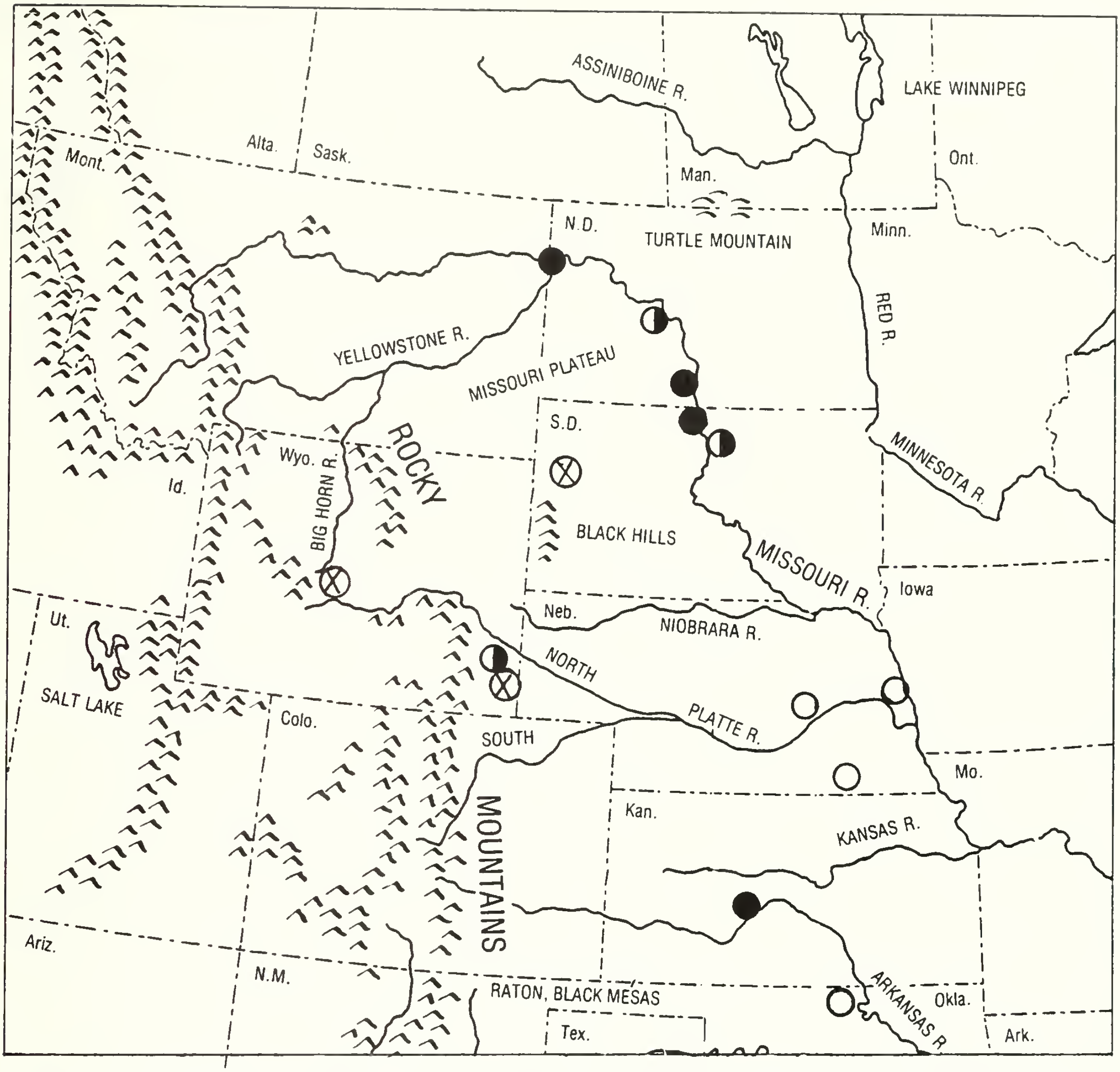


Figure 21. Localities where proton magnetometer mapping has been done in the study area by the University of Nebraska (open circles); by the Midwest Archeological Center (black circles); by joint operations by the two institutions (split circles); and by other groups (circled Xs). Refer to table 2. Map courtesy of the University of Nebraska Press.

posts (Fig. 21). A number of prehistoric sites, primarily those of village Indians, have also been investigated. The results of these surveys have been used to evaluate plans for the placement of modern developments (Ahler 1979) and have been incorporated into complex site sampling strategies (L. Alex 1980). Other projects are still in progress. L. Adrien Hannus, at the State University of South Dakota, is presently experimenting with both resistivity and magnetometer surveys in areas between tipi rings in a quest for exterior features. These sites are in northeastern South Dakota along the right-of-way for the Northern Border Pipeline Project. Hannus, in collaboration with Kenneth Deaver, also plans to experiment with both techniques at tipi ring sites in Montana.

Results of limited magnetic surveys at two Middle Missouri tradition sites serve to illustrate methods of analyzing these data. The Jake White Bull Site (39C06) and the Huff Site (32M011) are in extreme north central South Dakota and south central North Dakota, respectively. Both were on the

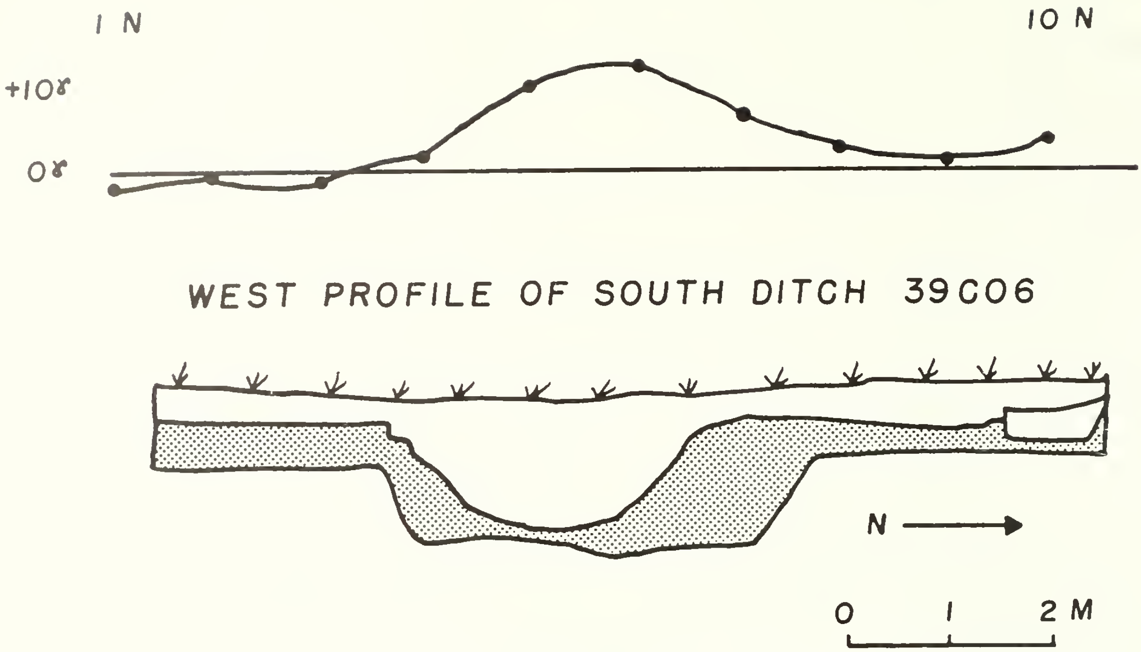


Figure 22. Magnetic and archeological profiles of the fortification ditch at the Jake White Bull Site, South Dakota. Courtesy of the Midwest Archeological Center.

banks of the Missouri River, now the Oahe Reservoir. Following preliminary investigations at the Jake White Bull Site (Ahler 1977), magnetic data were collected on a series of paced traverses and within a 20 by 40 m block. Three of the traverses crossed the southern part of the fortification ditch (Ahler 1977: Figs. 5, 7). The profile plot of one of these magnetic traverses is presented together with a simplified ditch profile (Fig. 22). The signature of the ditch is evident as a prominent (10-20 gamma) increase in the magnetic field strength. The Jake White Bull fortification ditch illustrates the type of archeological feature which is suitably surveyed by pacing traverses and for which hand-plotting of the data is adequate.

At the Huff Site, a single house was magnetically mapped (Figs. 23, 24). House 19 was selected to provide data from a location near the center of the site, because a contour map of the house was already available, and because the floor plans for the houses at this village were well known (see Wood 1967: Maps 8, 15). Two computer plotting routines were used to map the magnetic data and one was also applied to the topographic data. The Harvard University SYMAP program (Dougenik and Sheehan 1975) was used by Weymouth to prepare a plan view plot of the magnetic data (Fig. 25). The house is centered in the area shown in the SYMAP plot, with the entry passage (A) toward the bottom. The floor area is marked by a group of low values (B) which contain localized highs (C). The low contours have rectilinear lines as one would expect from other excavated houses at Huff. There is a high anomaly offset toward the entrance on the long axis of the house (D) which is the appropriate location for a primary fireplace (Wood 1967: 32).

The second plotting program is an orthographic routine which produces a false perspective plot. The program runs on a desk-top computer. It was used to create a projection equivalent to a low oblique view of the house. Two accompanying illustrations depict the topographic values collected by Wood (1967: see Fig. 26), and the magnetic data collected by Nickel (Fig. 27). As in the SYMAP version of the magnetic data, the floor area is seen as a group of low values with roughly rectangular limits.

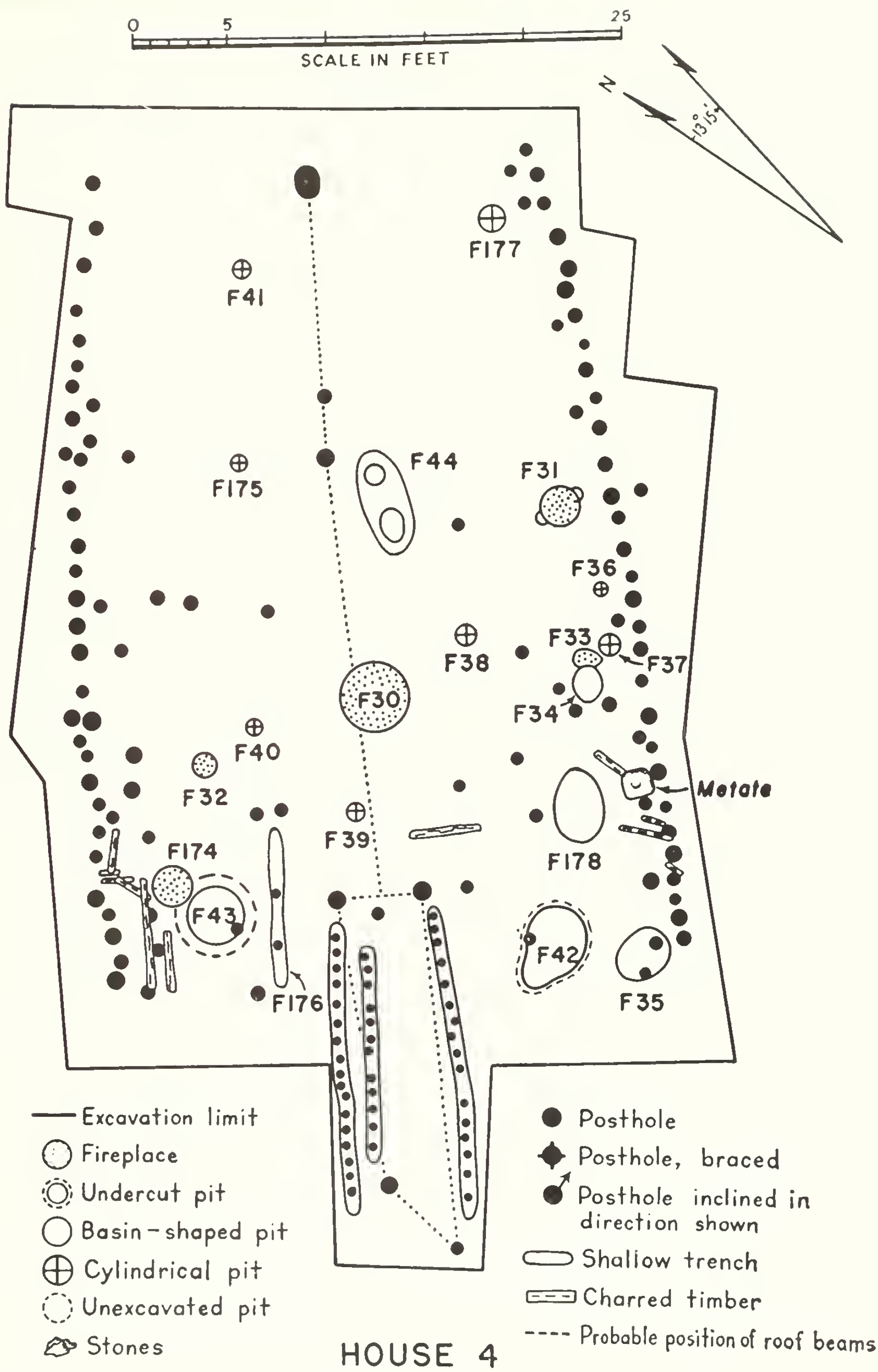


Figure 23. Floor plan of House 4, Huff Site, North Dakota (from Wood 1967: Map 8).

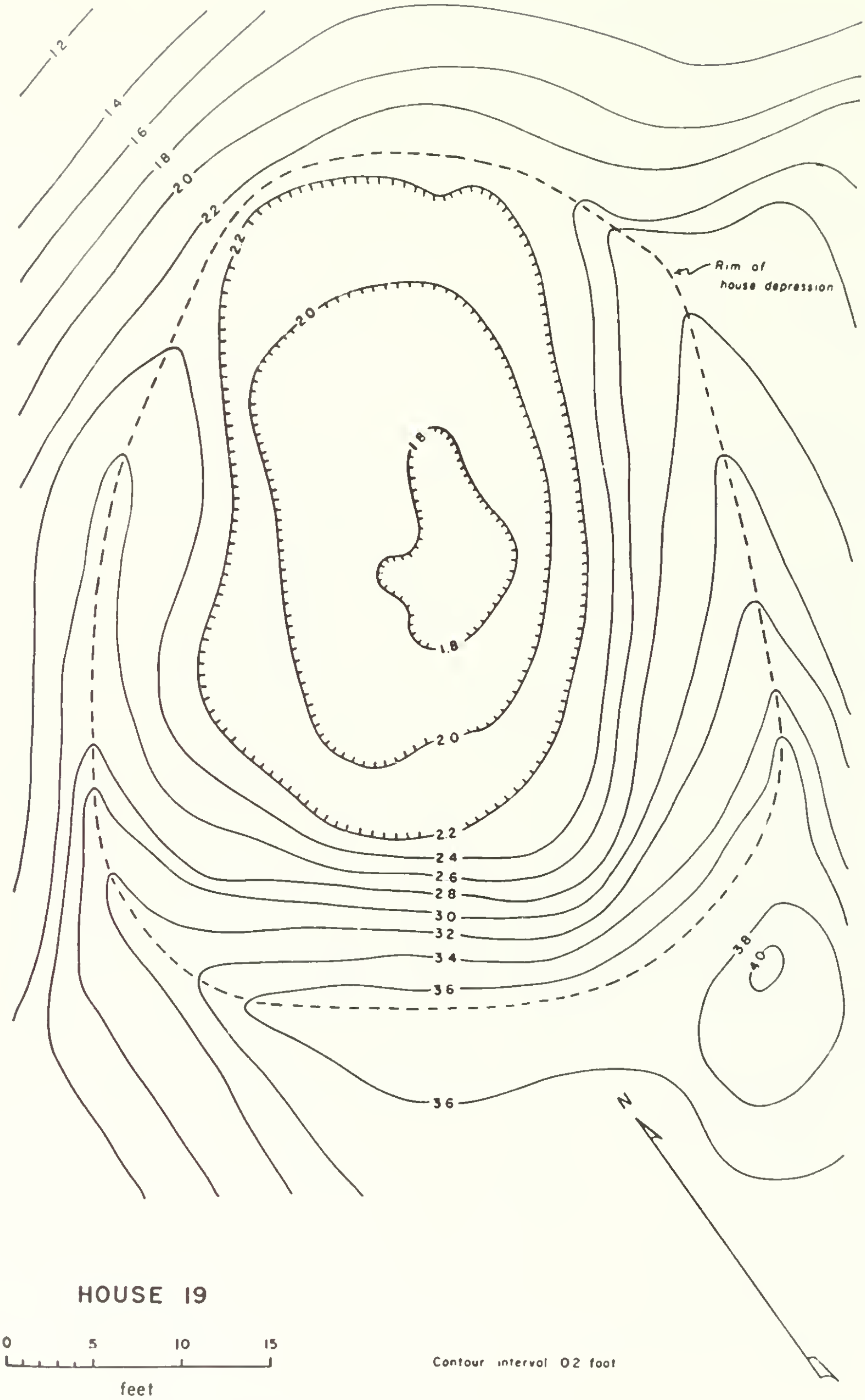


Figure 24. Contour map of House 19, Huff Site, North Dakota. See Figures 25 and 26 for topographic and magnetic data for this unexcavated house (from Wood 1967, Map 15).

Figure 25. Magnetic map of House 19, Huff Site, North Dakota, produced by Harvard University's SYMAP program. Contour interval is 2.2 gamma. Courtesy of John W. Weymouth.

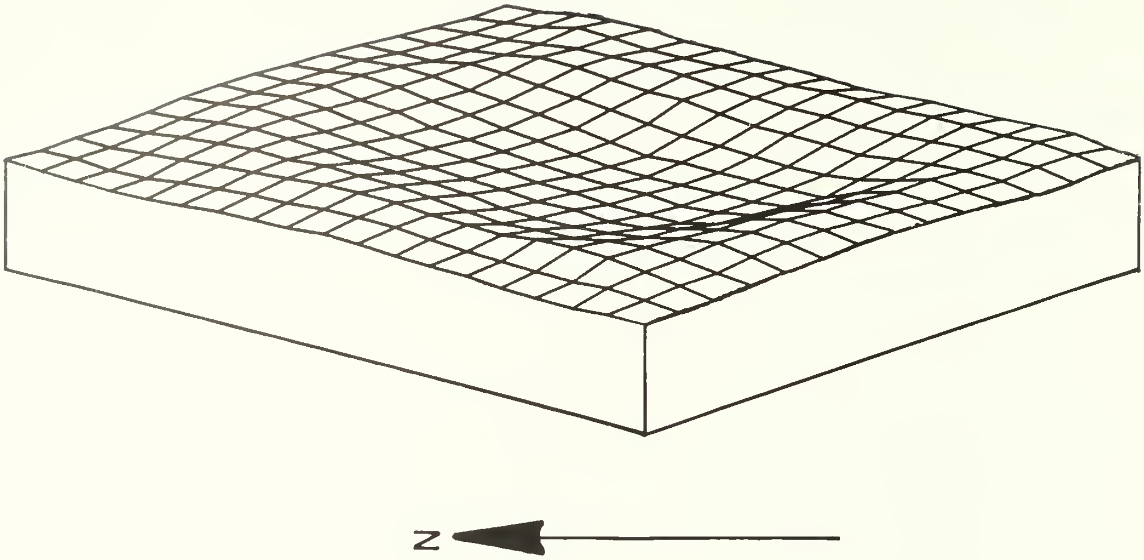


Figure 26. Topographic data, House 19, Huff Site, North Dakota. Low oblique projection based on data from Figure 24. Plotting based on Midwest Archeological Center computer program. Courtesy of the Midwest Archeological Center.

In this view, the entrance is toward the lower right and the anomaly caused by the primary fireplace can be seen along the center line of the house. This plot makes particularly obvious the groups of high values along the walls and outside the east corner of the house. The area which included House 19 (and about half of an adjacent house, or 400 m^2) was surveyed in about one and one-half hours. Although this block of 441 values could be hand-contoured, the repeated adjustment of contour intervals to maximize the interpretability of various subsets of the data would be burdensome without computer assistance.

The Knife River Program. The archeological remains to be found at the Knife River Indian Villages National Historic Site provide an excellent means for testing and refining magnetic and other subsurface mapping techniques for Plains village sites. The surface expressions of subsurface structures are exceptionally clear, so the archeological excavations which were to follow should permit the identification of some of the anomalies detected by the magnetic field work. These identifications can be readily correlated with the anomalies on the maps obtained from the photogrammetry program in the park.

A proton magnetometer survey was conducted on portions of Sakakawea village (32ME11) in the summer of 1976, when 0.42 hectare (1.04 acres) was surveyed. Additional smaller units were surveyed at a number of other sites in and near the National Historic Site (Weymouth and Nickel 1977). The instruments were standard proton magnetometers with ± one gamma sensitivity. The results of the survey, particularly at Sakakawea village, were remarkable.

The 10.5 survey blocks contained the obvious depressions of 11 houses. These features were easily recognized in the field and could be identified on the photogrammetrically-produced topographic map (Fig. 19). A careful examination of the magnetic maps revealed clear signatures of 13 houses. A plot of 6 of the 10 blocks is illustrated (Fig. 28), showing portions of Houses 11, 12, 16, 17, 18, and 22. This magnetic map indicates that one of the lodges (not clearly represented by a surface depression) is located immediately east of House 16. The signature of this house is incomplete, with its western portion truncated by the signature of House 16. The implications are that the hidden house is earlier and that House 16 was built over part of the earlier structure. Other examples of such superimposition of houses can be seen in the

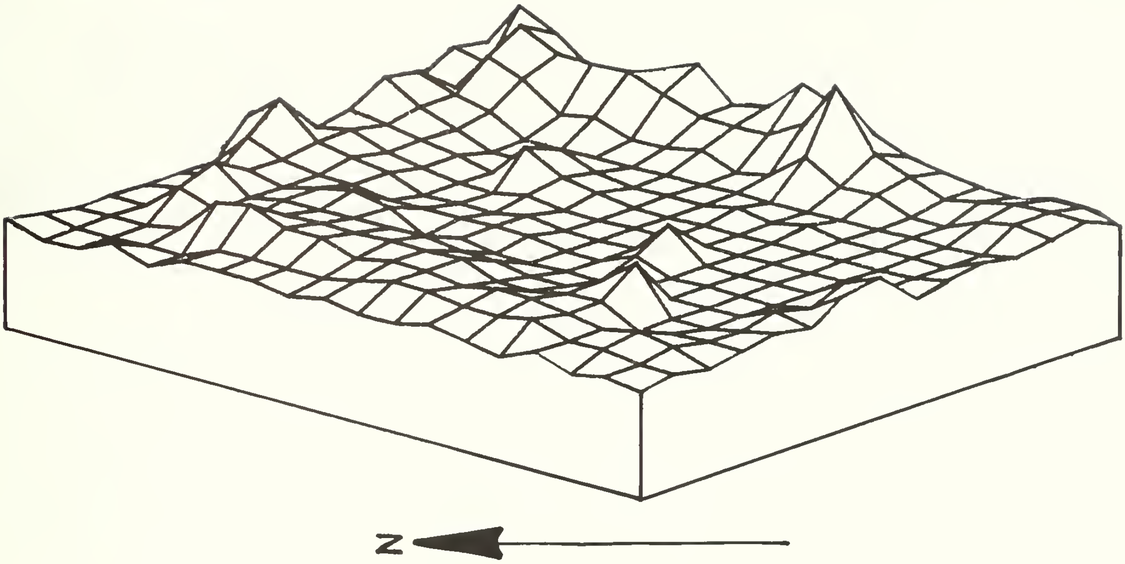


Figure 27. Magnetic data, House 19, Huff Site, North Dakota. Projection of magnetic field strength of values associated with this unexcavated house. Plotting based on Midwest Archeological Center computer program. Compare with the topographic expressions shown in Figures 24 and 26. Courtesy of the Midwest Archeological Center

Figure 28. Magnetic map, Sakakawea Site, North Dakota; the block measures 40 by 60 m. Six earth lodges are visible on the surface in this area (Houses 11-22; house numbers directly below the central hearth of each house). One house (X) has no surface expression. Block location is shown in Figure 19. Courtesy of John W Weymouth and the Midwest Archeological Center.

Figure 29. Soil resistivity map, House 6, Sakakawea Site, North Dakota; for its location in the site, see Figure 19. North is toward the top of the map. Courtesy of John W. Weymouth and the Midwest Archeological Center.

eroded bank along the Knife River. Also included in the extreme lower right of the same illustration (Fig. 28) is a portion of a feature which has been previously interpreted as part of a dry-moat type fortification ditch. There is, however, no clear surface relief discernible at this time that would indicate the presence of a ditch, and the magnetic data do not indicate the presence of a buried feature.

Most of the archeological features at the Knife River Indian Villages are no more than two meters below the ground surface. The use of a small diameter hand-operated coring tool has been sufficient in most cases to verify the sources of the magnetic anomalies with minimal impact to the sites (Weymouth and Nickel 1977: 117, Fig. 8). As a further consequence, it has been possible to test other instruments on the same areas which have

Figure 30. Magnetic map, House 6, Sakakawea Site, North Dakota; for its location in the site, see Figure 19. North is toward the top of the map. Courtesy of John W. Weymouth and the Midwest Archeological Center.

been subjected to both magnetic surveys and limited verification testing. House 6 at Sakakawea village provides an excellent benchmark for such testing. This house contains several well defined features and has been surveyed by magnetometers several times to assess replicability and to gather data on the vertical gradient of the magnetic field.

House 6 was surveyed in 1978 with a conventional soil resistivity meter. Representations of the resistivity data (Fig. 29) and of the magnetic data (Fig. 30) for this house are offered for comparison. Both of these data sets are discussed in greater detail by Weymouth (Weymouth and Huggins n.d.). By comparing the two figures, it can be seen that the magnetic map documents greater variation than the resistivity survey. In particular, it reveals the location of the central hearth, an iron object, several floor features, and major features in the midden areas outside the house. By contrast, the resistivity map records two major features in the floor area. Similar anomalies are present in the portions of the floors of the two other houses present in the lower left and lower right of the map (Fig. 29). The resistivity survey revealed little variation in the midden areas to the northeast, north, and south of House 6. In general, the more easily collected magnetic data appear to contain more information on archeological features at the Knife River Indian Villages. However, it should be noted that both data sets contain more information than can be shown in a single map.

In sum, magnetic surveying and similar techniques can produce a substantial amount of information on the nature and distribution of subsurface archeological features. This information may be used to guide more traditional archeological investigations, or it may be used as a planning guide in the placement of construction features. In the former case, the archeologist should be able to make a more critical selection of units to excavate. This should enhance the potential for collecting data relevant to the primary project goals, and also may result in reduced field and laboratory costs. When used as an aid to planning construction projects, it should be possible to make more adequate selection of alternatives. Both the relative magnitude of the impact and the scope of salvage operations should be better understood. When judiciously applied, these tools provide both archeologists and land managers with an economical source of information without unnecessary ground disturbance.

Section 7

Sources of Technical Assistance

The following list cites the major university-based organizations in the Central and Northern Plains states that are capable of providing assistance to those interested in initiating remote sensing projects, or assistance in carrying out such projects. Many privately owned, commercial firms in those states also have these capabilities, as well as numerous firms elsewhere which work in the Plains. In addition, state highway departments, geological firms, and photogrammetric engineering firms can provide assistance in one or another aspect of remote sensing.

KANSAS

Remote Sensing Laboratory
Center for Research, Inc.
207 Nichols Hall
University of Kansas
Lawrence, Kansas 66045

Director: Fawwaz T. Ulaby
(913) 864-4832

NEBRASKA

Remote Sensing Applications Laboratory
Department of Geography and Geology
University of Nebraska-Omaha
Omaha, Nebraska 68182

Director: Jeffrey Peake
(402) 554-2726

Nebraska Remote Sensing Center
Conservation and Survey Division
113 Nebraska Hall
University of Nebraska-Lincoln
Lincoln, Nebraska 68588

Director: Lee Miller
(402) 472-3471

Nebraska Center for Archaeophysical Research
Department of Physics and Astronomy
204 Brace Hall
University of Nebraska-Lincoln
Lincoln, Nebraska 68588

Director: John W. Weymouth
(402) 472-2775

NORTH DAKOTA

Remote Sensing Division
Department of Geography
Gillette Hall
University of North Dakota
Grand Forks, North Dakota 58202

Director: R. D. Mower
(701) 777-4246

SOUTH DAKOTA

Remote Sensing Institute
Winona Hall
South Dakota State University
Brookings, South Dakota 57007

Director: Victor Myers
(605) 688-4184

WYOMING

Remote Sensing Laboratory

Department of Geology
University of Wyoming
Laramie, Wyoming 82071

Director: Ronald Marrs
(307) 766-2330

University instruction in many aspects of remote sensing and photogrammetry is also available in each of the Plains states with which we are concerned. Nealey (1977: 263-275) provides a state-by-state listing of colleges and universities in both the United States and Canada, together with the department offering the course(s). For example, as of 1977, six institutions in the state of Colorado offered from one to thirteen courses in remote sensing or photogrammetry. Nealey (1977: 278-279) also lists those universities having general programs in remote sensing or photogrammetry; they include Colorado, Kansas, and North Dakota.

The Remote Sensing Applications Laboratory (RSAL) at the University of Nebraska at Omaha has just commenced the publication of a newsletter, *New Frontiers;* Volume 1, No. 1 was issued in September/October of 1980. It is designed to inform the applied remote sensing community of the activities of that laboratory.

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.