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Salvage Archeology in the Missouri River Basin

Archeologists are working ahead of rising reservoirs to rescue 10,000 years of human prehistory.

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Recently in *Science* (*1*) Frederick Johnson ably discussed the history and principles of salvage archeology as a basic national policy. Nearly all archeology is salvage work; few sites, unless protected by park or monument status, are safe from destruction by vandalism, agriculture, or land development. In the last 30 years, however, a special urgency has developed because of the unprecedented expansion of construction of reservoirs, highways, pipelines, and other public and private works. Historic ruins, sites of Indian villages, cemeteries, mounds, and other remains of the past are being destroyed at an ever-accelerating pace. Thus salvage archeology may be defined as the study of materials threatened with early destruction by large-scale construction or development, and the conservation of as many of these materials as circumstances permit. My purpose is to review some problems and accomplishments of a large-scale and continuing archeological recovery program conducted under emergency conditions in the Missouri River drainage basin.

The Missouri Basin comprises about one-sixth of the land area of the contiguous United States, including all or parts of ten states and small portions of two Canadian provinces (Fig. 1). Lying mostly within the northern temperate grassland, topographically it consists of plains, hills, badlands, and mountains. The basin is bisected by the 102nd meridian, which coincides roughly with the line of 20-centimeter summer rainfall that marks the approximate western limit of successful corn agriculture today. Its eastern half, formerly part of the tall-grass prairies, offered climatic and soil conditions favorable for valley-bottom corn-growing by primitive hand methods. Here, in historic times, the permanent villages of such semiagricultural tribes as the Mandan, Arikara, Pawnee, Omaha, and Kansa stood on the banks of the Missouri, Platte, Kansas, and other major streams. In the west, where short grass and sage dominated the native vegetation, a low, uncertain rainfall and high rates of evaporation made corn-growing a precarious base of subsistence, and the native economy rested mainly on a seminomadic bison-hunting and food-gathering lifeway; the Dakota Sioux, Cheyenne, Arapaho, Crow, and Blackfeet were representative tribes.

Because the native peoples here retained their tribal identities and colorful lifeways long after white men entered the region, they have been subjects for observation and study since the early part of the 19th century; the writings of Lewis and Clark, Catlin, Maximilian, Long, and others are well known and still useful. Later scholarly publications of the Smithsonian Institution, American Museum of Natural History, Field Museum, and other scientific and educational establishments include impressive lists of papers dealing with the ethnography of these Plains Indians.

By contrast, before the 1930's there was very little systematically gathered information bearing on the predecessors of the historic tribes. Widely held were the historically conditioned views that the Plains were unfit for human habitation before introduction of the horse and the gun. In Nebraska it was already evident that this was an untenable thesis, and that for some time before the arrival of Europeans there were Indian villages, with unmistakable indications of corn agriculture, pottery-making, and substantial earth-covered dwellings, scattered at least 480 kilometers west of the Missouri River. During the late 1930's, work-relief projects were showing that the numerous village sites along the Missouri in the Dakotas included many that were pre-White in time. Thus there was growing awareness among scholars directly concerned that an abundance and variety of prehistoric materials awaited scientific examination between the Missouri and the Rockies. But the area to be searched was vast; workers were few and the funds available were very limited.

Plains Prehistory in 1940

As broadly visualized in 1940 (*2*), when the outbreak of World War II abruptly ended the field work so-promisingly begun under work-relief programs, Plains prehistory consisted of three stages or time periods. The earliest was the time of the big-game hunters, who made distinctive kinds of weapon points and hunted mammoth and now-extinct forms of bison in the western plains, somewhere between 10,000 and 25,000 years ago on the

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basis of geological evidence. Much younger—they were dated only by guesses—were the remains known as the Woodland culture, which represent a period of subsistence economies based on simple hunting and food-gathering. The Woodland people were the first in the region to make pottery, probably buried their dead in earth mounds, and lived in small campsites that are now often deeply buried by alluvial deposits. Still later, but certainly preceding the coming of the first Europeans in the 16th and 17th centuries, were other people who lived in small communities of rectangular, earth-covered pithouses, practiced a maize-bean-squash hoe agriculture, were more accomplished potters than their predecessors, and whose village remains could be found westward from the Missouri River for some hundreds of miles in Nebraska and northern Kansas. These, it was thought, were probably directly ancestral to the Pawnee and other historic semisedentary farming Indians of the eastern plains. As to what lay temporally between the early big-game hunters and the Woodland peoples, there was almost no available evidence except in a few stratified sites in the West. The Smithsonian's work at Signal Butte in western Nebraska (*3*) and that of the Montana Archeological Survey and the Works Progress Administration at Pictograph Cave near Billings, Montana (*4*), strongly hinted at intermediate cultures; but the lack of trustworthy chronological controls and adequate comparative materials made interpretation of the evidence extremely difficult.

Organizing the Salvage Operation

The magnitude of the salvage problem that confronted American archeology became apparent as World War II was drawing to a close and the nation was preparing to convert to peacetime activities. As early as 1944, archeologists learned that the U.S. Army Corps of Engineers and the Bureau of Reclamation had well-developed plans for extensive water-control programs in most of the major river basins of the United States. In the Missouri Basin, five huge dams designed for flood control, power development, irrigation, and other purposes, and ranging in height up to 70 meters, were planned for the mainstem in North and South Dakota. Lesser projects, to the number of 100 or more, were to be widely scattered along the tributaries (*5*). Since the prehistoric and early historic peoples centered most of their community and subsistence activities on or near the stream banks, it was clear that the flooding of hundreds of thousands of hectares of valley lands would inundate many hundreds of sites and forever preclude their scientific study (Fig. 2).

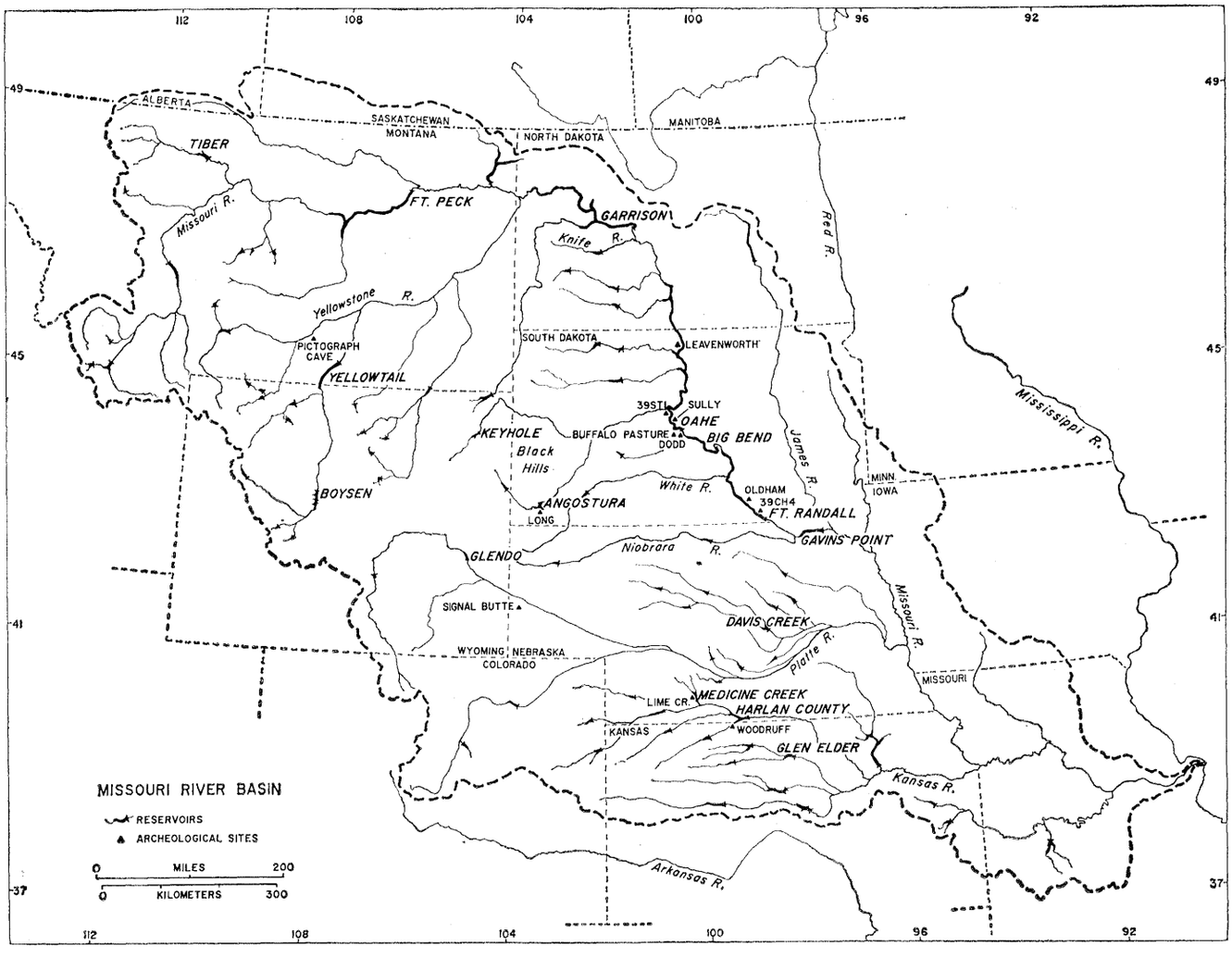

Fig. 1. Map of Missouri River basin (heavy broken line), locating certain certain reservoirs and archeologic sites.

To retrieve as much information as possible before it was thus destroyed, a few far-sighted archeologists concerned themselves with planning for salvage (*1*, *6*). Working through the Society for American Archaeology and with active support from various learned bodies and federal agencies, they brought about formation of the Committee for Recovery of Archeological Remains to assure that "archeological remains threatened with destruction were preserved." Eventually a series of agreements between government agencies established an interagency program for salvage. The Department of the Interior, through the Bureau of Reclamation and the National Park Service, agreed to provide fiscal support for archeologic and paleontologic salvage. The Smithsonian Institution took on the responsibility for organizing and directing the work in accord with accepted standards of scientific investigation and reporting. On an informal basis, the U.S. Army Corps of Engineers cooperated in various ways.

To implement its part of the agreement, the Smithsonian created within its Bureau of American Ethnology an administrative unit designated the River Basin Surveys and headed by F. H. H. Roberts, Jr. When the Bureau was merged into the new Office of Anthropology in 1964, the latter assumed administrative control. Working closely with the National Park Service, the River Basin Surveys has since spearheaded the salvage program in the Missouri Basin.

The first unit to be set up under the River Basin Surveys was the Missouri Basin Project. A field office and laboratory were established in Lincoln on the campus of the University of Nebraska in July 1946. Active field surveys began in August, with a staff of six archeologists, an allotment of $20,000 for the year, no vehicles, and 34 high-priority projects of the Bureau of Reclamation and the Corps of Engineers to survey. Since that modest beginning, from 3 to 12 parties have been active in the field annually, their number, size, and procedures varying with the availability of funds and the changing needs of the basin-wide program.

The program for the Missouri Basin Project was designed to provide for (i) surveys to locate, evaluate, and record all possible antiquities within specified reservoir areas; (ii) systematic excavations at carefully selected sites that promised particularly informative results in relation to the prehistory of the region and of neighboring areas; (iii) preparation of publications on the findings and their significance; and (iv) proper disposition and permanent preservation of specimens, records, and other basic data that were collected. From year to year as the work progressed, the emphasis shifted from exploratory work to more intensive investigation (Fig. 3) at sites and in localities chosen because of their apparently greater promise in the light of the rapidly accumulating information from all parts of the region.

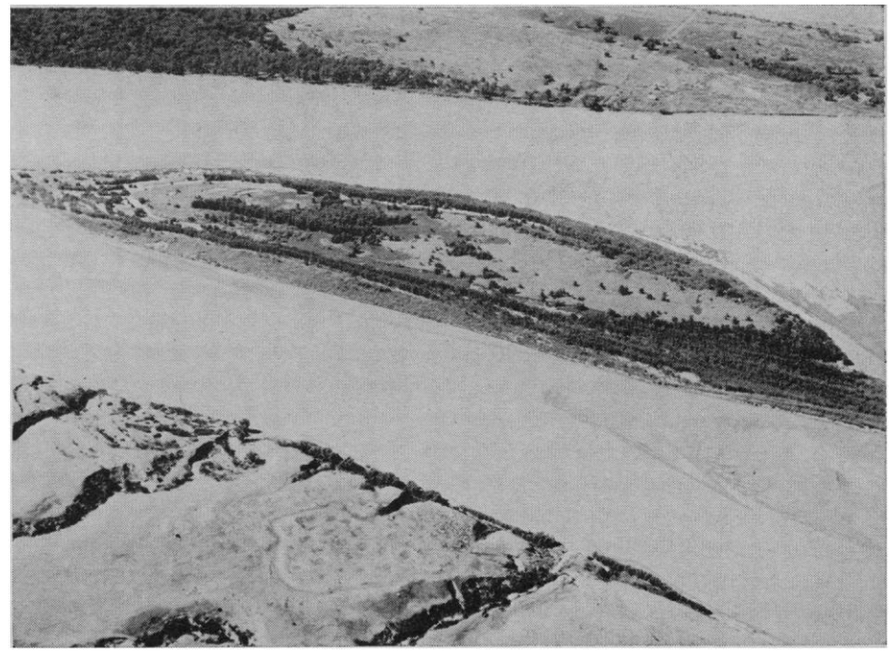

Fig. 2. Aerial view of Buffalo Pasture village site (bottom center), showing 18th-century circular house pits enclosed by fortification ditch near Pierre, South Dakota; Missouri River in background. This is one of many sites flooded by Oahe reservoir.

It was evident from the beginning that the federal agencies concerned had neither the means nor the manpower

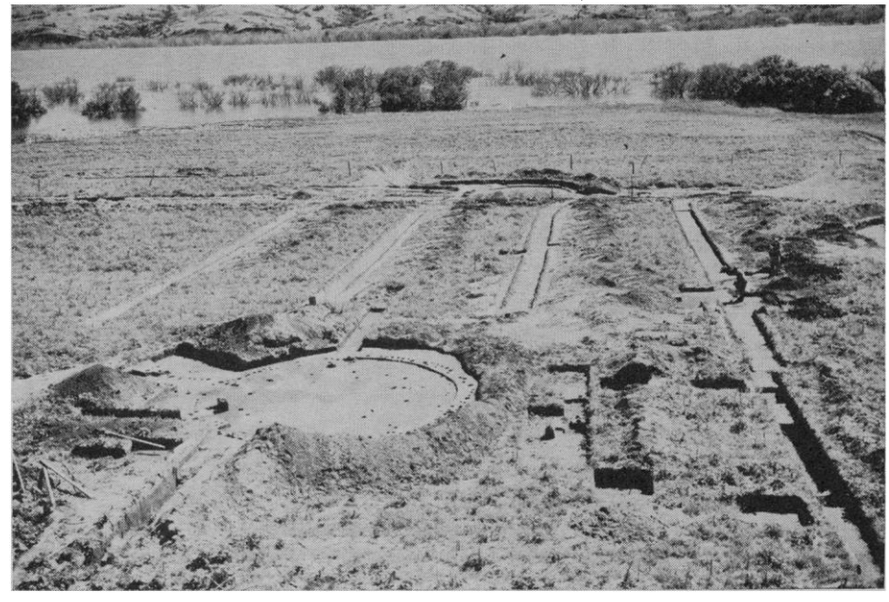

Fig. 3. Postholes outline the floor of a circular earthlodge ruin at Oldham village site near Platte, South Dakota. Rising waters of Fort Randall reservoir (background) now cover the site.

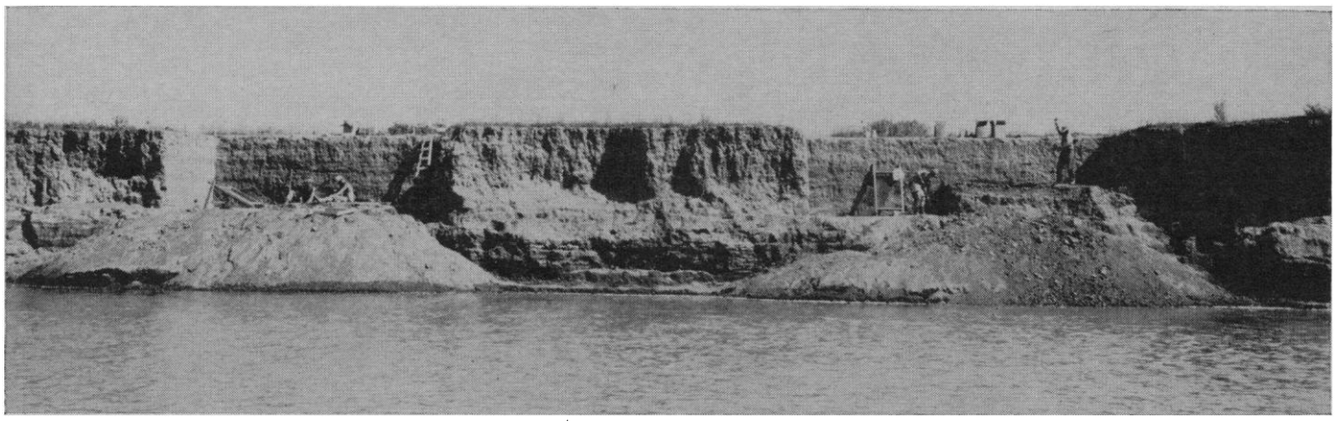

Fig. 4. A late-prehistoric campsite 2.4-meters underground is being excavated just above the Tiber reservoir pool on Marias River, Montana.

to carry out the intended operations unaided. The cooperation of state universities, historical societies, and other interested organizations was accordingly solicited, and more than a dozen such have actively participated in the salvage program in the Missouri Basin—some at sacrifice of their own research plans. At first their work was supported by their own funds; since 1950 it has been materially expanded through contractual arrangements with the National Park Service. Their activities have always been planned and carried out in coordination with the broader salvage procedures and objects of the River Basin Surveys and the National Park Service.

Unlike the work-relief programs of the 1930's, the salvage operations since 1946 have not had to concentrate in localities having heavy unemployment and abundant labor, regardless of the archeological possibilities. Instead, charged with responsibility for locating and evaluating any and all sites that would be endangered by reservoirs and appurtenant works, trained archeologists were able to make spot checks, followed (if necessary) by more thorough investigations, of innumerable localities which very often would not normally have been investigated for many years. The broad sampling thus made has touched nearly every section of the Missouri Basin and has tested native man's use of a wide variety of local environments. The remains investigated have run the gamut from sites of the early big-game hunters, 7000 to 10,000 thousand years old, through those of the pre-pottery and pottery-making peoples, to others of the historic period of the fur-trade and western expansion. Since the initial surveys indicated that the threat to paleontologic materials was far less severe, the interagency work on salvage has been concerned primarily with archeologic remains.

Achievements of the Work

Since 1946, more than $2,500,000 has been expended by the Smithsonian River Basin Surveys in the Missouri Basin; this figure does not include the cost of publications stemming from the operations. The amount spent by cooperating agencies is not a matter of public record so far as I know. Unquestionably, much more archeologic fieldwork has been done during the last 20 years in the basin than in all previous time, and the program ranks as one of the largest ever undertaken in the United States. A vast amount of recorded information has resulted, including field notes, site and locality maps, standardized information sheets giving detailed data on specific features within particular sites, photographs, and other supporting data. Great quantities of artifacts and important collections of skeletal material have been gathered under controlled conditions; and rigidly selected representative samples, with full provenience data, have been added to the national collections. Lesser amounts of records and artifact materials have enriched the collections of the nonfederal cooperating agencies, there to furnish important resources for study, information, and education.

What else has been accomplished? Archeologists faced with a common problem—loss of their basic working materials—have coordinated their efforts regionally much more effectively than ever before. A direct outcome of the salvage program has been development of a uniform system of trinomial designation of sites, applicable throughout the entire Plains region and beyond. Time pressures on the archeologists have encouraged extensive utilization of aerial photos to locate sites and to determine their extent and nature. Heavy earth-moving power machinery has been used on sites of Indian villages and on early historic structures, as well as on deeply buried campsites, thereby revealing details of community arrangement that are not ordinarily recoverable by hand operations except at prohibitive cost of time and manpower. The expanding program has provided summertime employment and field training for scores of students, many of whom have gone on to professional careers in archeology.

Missouri Basin Chronology Program

An important phase of the Missouri Basin Project was the initiation in 1958 of a chronology program (*7*). This, too, was a cooperative endeavor in which Project personnel combined efforts with representatives of 30 or more research groups working in the Missouri Basin. Materials suitable for dating by radiocarbon, tree rings, pollen analysis, proportional counting, or other techniques were submitted to appropriate specialists and laboratories, the findings to be made generally available to other workers in the region.

To date, the first two methods seem most promising. About 100 radiocarbon dates have resulted, running back in time to about 8600 B.C. Most samples originated from salvage operations; all, along with a larger number

of dates independently obtained by cooperating agencies but bearing on regional problems of chronology, have significantly enriched our understanding of culture history in the Missouri Basin.

Tree-ring studies have so far produced far fewer dates in the published record, and so their usefulness is difficult to assess. They have been used occasionally and informally at regional conferences, usually with the admonition that wider public dissemination would be premature. It seems likely that tree-ring dating, now being checked and further refined in an outside laboratory, will be helpful in establishing more firmly the archeological chronology for the last three or four centuries, at least. Development of an acceptable master chart, running back to the 14th century or earlier in the Big Bend–lower Oahe reservoir areas, should enable comparison of the dates so derived with others from radiocarbon studies, thus providing opportunity for direct comparison and evaluation of results from both methods. Reported age differences of two centuries or more between the two methods at the early end of the tree-ring record, with tree rings generally giving the later readings, need to be reconciled. Until the two methods are thus reconciled or adjusted, any historical reconstructions based on differing age determinations will remain suspect. Also, as with radiocarbon dates, for which experienced observers insist on more than a single date for any given site or level, it is to be hoped that more than one tree-ring date will be made available for any given site. Dates resting on a single determination—whatever the method—must be considered tentative or suggestive only.

Fig. 5. Superimposed house floors at the Dodd site, destroyed by Oahe dam, show the outline of an 18th-century circular house that was partly removed during excavation of an older (about 11th- or 12th-century?) rectangular house whose entry ramp is in the foreground.

Contributions to Prehistory

Valid appraisal of the salvage program's contributions to our knowledge of human prehistory in the Missouri Basin is not easy. The publications aspect of the program has lagged, so that many of the findings in field or laboratory are reasonably well known to only a handful of individuals directly associated with the operations. The greater support for regional researches, compared with the more modest relief and other projects of the past, perhaps reflects in part the remarkable progress made recently by archeology generally in arousing public interest, although we must not discount the industry and perseverance of the scholars, administrators, legislators, and others who have been responsible over the years for the increased appropriations for the program. The interpretations and regional reconstructions of prehistory that are now offered from time to time, always interesting and sometimes exciting to the professional, owe much to new or improved methods of dating and analysis that were unavailable or still under development in the 1930's and that did not originate from the salvage program.

The contributions have undoubtedly been greatest in the Middle Missouri region—along the mainstem in North and South Dakota. To this section have been allotted the greatest portions of the funds, time, and manpower available since 1956. This emphasis is justified partly by the extraordinary abundance and variety of remains there, but more by the massive destruction of these remains threatened by the construction program. Gavins Point, Fort Randall, Big Bend, Oahe, and Garrison dams have created reservoirs that will stretch for more than 960 kilometers, flooding all but about 240 kilometers of the immediate river valley in the two states. Many hundreds of village and camp sites, burial grounds, and other localities of archeological interest are either going under water or are already lost; and these unfortunately cannot be duplicated on the undammed tributaries or elsewhere. They include nearly all the communities recording ten centuries or more of cultural development culminating in the Arikara, Mandan, and neighboring tribes who, besides representing one of the high points reached in native culture in the United States, played an important role in the early White history of the region.

During the last 20 years, more than 200 of these sites have been tested or extensively excavated. Before the salvage program, less than a dozen had received serious attention from professional archeologists, and none had been thoroughly excavated and fully reported; without salvage archeology, the loss of scientific and historical data would have been incalculable. One could not have given even a broad outline of nearly 1000 years of native cultural development in the area or related it satisfactorily to the broader history of the American Indian. The smaller and usually more widely scattered reservoirs off the mainstem (Fig. 4) are less destructive, since the information lost there can

sometimes be duplicated at sites outside the flooded sections.

Most of the work on the Middle Missouri has been done at the sites of Indian villages. An important link with documentary history has been achieved, however, by the excavation of house foundations, cellars, latrine pits, stockade lines, and other features at several 19th-century trading posts and military forts. The incomplete data preserved in contemporary documents have thus been supplemented by new light on frontier architecture, building methods, and personal, household, military, and trade articles of the period (*8*), as well as on the effects of the White man on the material culture of Indians coming into contact with these frontier establishments.

During the 16th to 18th centuries the Arikara, Mandan, and Hidatsa lived in many villages scattered along the Missouri from Knife River to White River or beyond. Their fixed communities of circular earth-covered lodges, often strongly fortified against the Sioux, were important trade centers and points of contact between the native peoples and the advancing Euramerican frontier. Salvage investigations at key sites have produced an impressive series of artifacts, as well as detailed data on house types, village patterns, and other features. Beyond conventional analyses and interpretations of these new data, the availability of historical and ethnographic documentation for this time level has challenged scholars to explore the possibilities of correlating observable ceramic changes with suggested social changes among the Indians concerned (*9*). Study of White trade goods, and their changes through time, promises intriguing new insights into a field of which far too little is yet known. The extensive collection of skeletal material from more than 800 burials at the Sully, Cheyenne River (39ST1), Leavenworth, and other Arikara sites in Oahe reservoir represent by far the largest tribal sample yet gathered from any Plains Indian group, and their study (partly supported by the National Science Foundation) should provide major contributions to the still-inadequate knowledge of the physical anthropology of the region.

The historic Village tribes were rooted in part in earlier farming cultures broadly known as the Middle Missouri tradition (*10*, p. 140). In sharp contrast with the later settlements, the earlier ones consisted of rectangular pithouses (Fig. 5), probably gable-roofed, often arranged in rows, and only partially covered with earth. Subsistence was by corn-growing and hunting, and in many ways the customs resembled those of historic times except as the latter increasingly reflected the stresses of contact with Whites. Sites attributed to this time level, roughly between the 9th and 16th centuries, have been examined at many places in Oahe, Big Bend, and Fort Randall reservoirs. The steps by which the later cultures developed from the earlier remain to be worked out, but the salvage program has contributed most of what we know, or can ever expect to know, about a phase of cultural development that was only beginning to be suspected in 1940.

Contemporary with the peoples of the Middle Missouri tradition were a series of prehistoric cultures in Nebraska and northern Kansas, which have been assigned by archeologists to the Central Plains tradition (*10*, p. 143; *11*). The people lived in widely scattered villages of earth-covered lodges, subsisted on maize-bean-squash-sunflower agriculture and hunting, and made pottery. In a major salvage project at Medicine Creek reservoir in southwestern Nebraska, the stripping by heavy machinery of large areas of the occupied zone revealed hitherto unknown details regarding arrangement of houses, food-storage pits, refuse dumps, and other features of community life (Fig. 6). The social and political organization of these rural hamlets must have differed greatly from that of the later, larger, and more compact Indian towns of the region. The way of life paralleled that on the Middle Missouri, but many of the artifacts and inferred practices can be distinguished from those of the northern peoples, so that the direction and nature of trade and other contacts can often be deduced.

There is growing evidence from the dust-covered village sites of the Central Plains that widespread droughts, probably resulting in crop failures, may have forced these people out of their western habitat (*12*), some of them perhaps moving northeastward to contribute culturally to development of the later circular-house people on the Middle Missouri. This is but one facet of the much broader problem of primitive human ecology with which Plains archeologists must increasingly

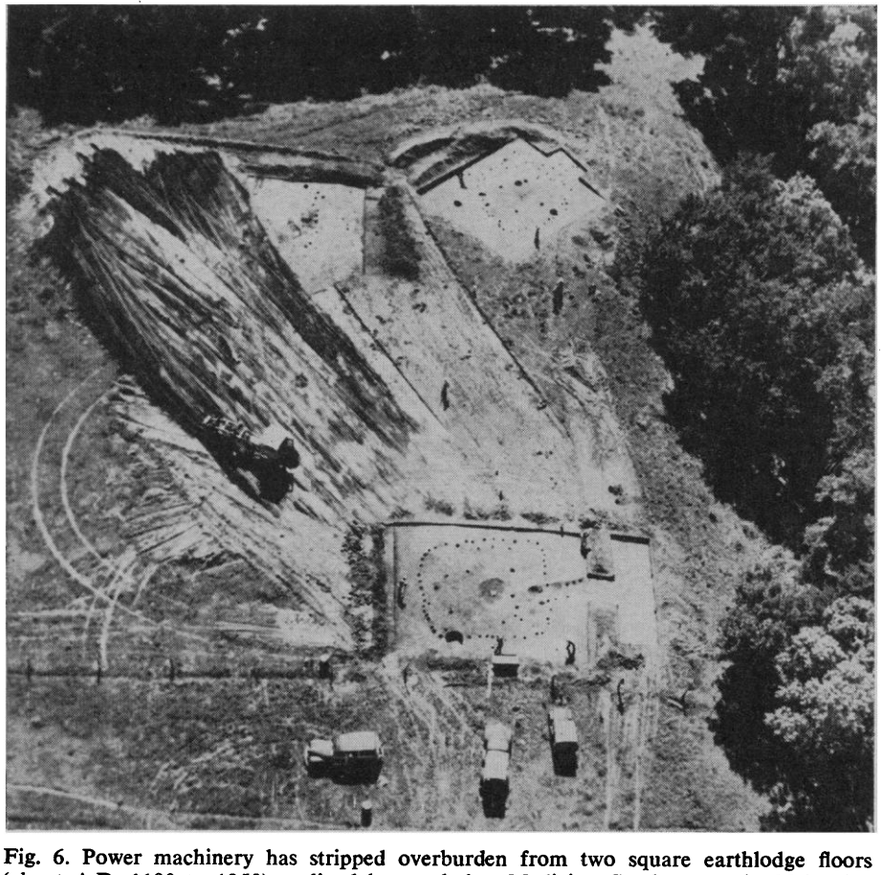

Fig. 6. Power machinery has stripped overburden from two square earthlodge floors (about A.D. 1100 to 1250) outlined by postholes; Medicine Creek reservoir, Nebraska.

deal. The region includes the western and northern limits of native agriculture and is subject to wide variations in temperature, precipitation, and other climatic factors affecting crop production. The archeologic record of land utilization, of the specialization of corn and other domestic food crops, and of shifting population distributions under varying environmental and economic conditions should be materially extended by the widespread salvage operations.

The existence and general cultural characteristics of the prehistoric Central Plains people were well established before 1940, but the distributional data gathered by salvage survey parties at Harlan County, Davis Creek, Glen Elder, and other reservoirs scattered widely throughout the Nebraska-Kansas region have helped greatly to clarify our understanding of the manner in which they adjusted to the peculiarities and uncertainties of their environment.

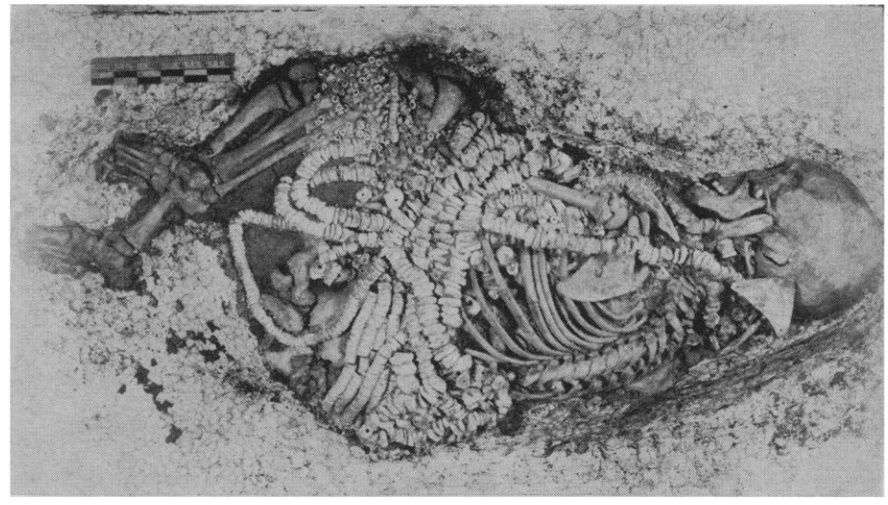

Fig. 7. Burial of a child of the Woodland period (about A.D. 600), with shell disk beads and ornaments; Woodruff ossuary, Phillips County, Kansas.

The Woodland and Earlier Cultures

The Middle Missouri and Central Plains traditions were preceded in the Missouri Basin by little-known cultures grouped under the rubric of Woodland. Clearly derived from cultures of the eastern United States, these spread between the beginning of the Christian Era and A.D. 800 over most of the Plains region westward to the Rocky Mountains. Their traces are generally far less conspicuous and yield substantially fewer material objects than do those of the later Village Indians. They apparently represent the remains of simple creek-valley hunters and gatherers who acquired a rudimentary corn agriculture only in the final stages of their occupancy. The principal contribution of the salvage work has been detailed information on their methods of disposing of the dead (*13*). One method is illustrated at the Woodruff ossuary in Harlan County reservoir, northern Kansas, where the bones of many individuals, previously exposed until the softer tissues decayed, were finally gathered and placed with primary flesh burials (Fig. 7) in a common pit, along with large numbers of freshwater-shell beads.

The burial mounds scattered along the Middle Missouri river and in the eastern Dakotas have long puzzled archeologists. Salvage work has shown that the mounds often surmount a log-covered pit containing the disarticulated remains of several or many individuals (Fig. 8). Bison skulls and skeletons are often present, as investigators noted more than 50 years ago. Accompanying artifacts of bone, shell, stone, copper, and occasionally pottery identify the remains with Woodland cultures; associated radiocarbon dates run from about 430 B.C. (too early?) to A.D. 750 or later.

Of the hunters and gatherers preceding potterymaking, sometimes termed Foragers, who preceded the Woodland peoples in the Missouri Basin, there is still only very limited evidence, except in the western sections. Beneath some of the Woodland burial mounds near the Big Bend of the Missouri, human occupation is meagerly indicated by hearths, animal bone, and chipped flints in levels dating from 525 to 2450 B.C. In Wyoming and Montana, and eastward into western Nebraska and South Dakota, many small campsites marked by hearths, distinctive kinds of projectile points, grinding tools, and other items probably reflect heavy reliance by their makers on plant foods and seeds and on the hunting of small animals rather than of bison; some have

Fig. 8. Skulls and bundles of bones in grave pit beneath Woodland mound (about A.D. 720) near former Wheeler bridge, lower Fort Randall reservoir, South Dakota. Traces of log cover are visible on edges of pit.

been dated between about 500 and 3500 B.C. Salvage operations in and around the Black Hills, at Glendo, Keyhole, Boysen, and other westerly reservoirs, and recently in some of the headwaters canyons of the Missouri River have added further information. Always the evidence is scanty; but it is clear that, even at this early period, men had devised techniques for food-gathering that made possible their occupation of many sectors of the Missouri Basin that now seem poorly suited to human habitation.

From between about 3000 and 5000 B.C. there are almost no dated sites in the Plains. By some, this is thought to reflect the Altithermal, a time of increasing warmth and aridity that may have reduced the natural vegetative cover from grassland to desert or semidesert, forcing the larger game animals and the men who had previously depended on them to follow the shifting grasslands to regions enjoying heavier precipitation. There are indications of continuing residence during this interval along the mountain-plains contact zone and at higher elevations to the west, which may have become refuge zones if there was in fact a climatically enforced emigration from the Plains proper.

The period of the early big-game hunters, preceding about 5000 B.C., has received relatively little attention from the salvage operations; it is still unrepresented by sites along the Middle Missouri. At the Long site near Hot Springs, S.D., the River Basin Surveys uncovered the remains of hunters aged 7000 to 9000 years (*14*). Important materials were collected by the cooperating University of Nebraska at the Lime Creek sites (Fig. 9) in Medicine Creek reservoir, southwestern Nebraska, from which hearths, animal-bone refuse, and various hunting tools are radiocarbon dated about 9000 years ago (*15*). Still farther west, in recent investigations at caves in the Yellowtail reservoir on Big Horn River, the lowest levels of occupation have yielded materials aged about 8600 years.

The idea that our knowledge of the prehistoric and historic past in the Missouri Basin has benefited from two decades of federally supported archeological salvage is beyond cavil. It is also true that, measured against the costs of reservoir construction, the salvage program has been relatively inexpensive.

As Frederick Johnson has well stated, publication is the true act of salvage, for it is thus that the information gathered is made generally available. In this respect, the Missouri Basin work has fallen far short of its possibilities and responsibilities. For budgetary and other reasons, most of which might have been anticipated and provided against, the papers produced by or through the River Basin Surveys include disappointingly few major contributions for the Missouri Basin. Significant papers have appeared, but their number is no true measure of the unrealized potential. The site reports and other lesser papers that have appeared vary widely in quality and usefulness.

More serious, perhaps, is the fact that the last 15 years have seen inadequate effort to produce biennial or annual summary reports on the progress of the work and relating its accomplishments to the broader picture of regional archeology (*16*). There have been annual administrative reports, usually of high caliber and often constituting the only source, for anyone not directly and constantly connected with the work, of information on its progress; they are essentially substantive in nature (*17*) and do not adequately integrate the findings and interpretations in a broader framework. Probably much of the doubt sometimes expressed by outsiders in the profession, regarding the quality of the work, could have been forestalled by the regular or frequent publication of scholarly resumés prepared by the persons most intimately connected with the planning and execution of the operations. Such publication would also have helped narrow the information gap when it became obvious that, for one reason or another, the professional field workers were falling behind in their obligation to produce publishable reports on their researches.

Federal salvage programs have not been restricted to the Missouri River basin, though this area has seen much the largest regional effort. Its scope and urgency posed administrative problems (*18*) on a scale that few practicing archeologists had faced previously. I am not prepared to say how its accomplishments and contributions compare with those in other regions

Fig. 9. Archeologists (bottom right) uncover a 9000-year-old hunters' campsite under 13 meters of silt and wind-blown soil in Medicine Creek reservoir, Nebraska.

(*19*). Professional opinions doubtless vary regarding the judgment used in selecting sites for extended investigation, and on other points. In general, the work has been carried on with a sense of scientific problem, though one wonders whether the possibilities of a full interdisciplinary approach were properly considered. As nonfederal participation increased and more cooperating agencies joined in the concentrated attack on the Middle Missouri, other investigators have found it possible to resume their researches elsewhere in the basin and not necessarily at sites directly or immediately threatened by the federal water-control program. This result has provided a healthy balance—not all our archeologic problems can be solved in the reservoir areas, though the work there may well suggest where researches are needed outside. Moreover, expanding agricultural and other activities are probably as destructive of sites in the long run (though not as spectacular) as is flooding.

In retrospect, the archeologic salvage program in the Missouri River Basin must be reckoned a major advance toward our understanding of human prehistory and its development in the region through some thousands of years. Any shortcomings in planning or performance are perhaps the price we must pay to learn that a tight administrative rein must be combined with a scholarly approach to scientific problems; that high standards of planning, staffing, field work, and reporting must be maintained at all times; that addition of any major field-research program to an existing agency's regular operations must be balanced by expansion in publications, with appropriate funding and expert supervision; and that proper public relations and free exchange of information and ideas must include the public and professional colleagues no less than immediate associates. When the vast quantities of raw data, artifacts, and records accumulated in the Missouri Basin salvage work have been critically studied and reported according to the highest possible standards of scholarship, American archeology will benefit from a store of new and important information much of which, but for the salvage effort, would have been lost forever.

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Regulation of the Lac Operon

Recent studies on the regulation of lactose metabolism in *Escherichia coli* support the operon model.

Jonathan R. Beckwith

The mechanism of regulation of gene expression is today one of the most actively studied problems in molecular biology, in good part as a result of the pioneering work of Jacob and Monod on the control of the genes involved in lactose metabolism in the bacterium *Escherichia coli*. Since 1961, when Jacob and Monod first proposed the operon model for gene regulation (*1*), a number of alternative suggestions have been published for the ways in which genes are controlled (*2–5*), some of them radically different from the Jacob-Monod model.

The lactose (*lac*) system is still the best-studied example of gene regulation. In the years since 1961, there has been a considerable amount of new information, both genetic and biochemical, on the *lac* operon. On the basis of the most recent information, which will be discussed in this article, it appears that the original formulation of the operon, in most of its aspects, is still the simplest model fitting all the known facts about the *lac* system (*6*).

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Lactose Metabolism in Escherichia coli

The initial steps in the metabolism of lactose by *E. coli* involve two protein components: (i) a membrane-bound protein [M-protein (*7*) or permease (*8*)] which is probably responsible for both the transport of lactose into the bacterial cell and for its concentration therein; and (ii) the enzyme β-galactosidase which catalyzes the hydrolysis of lactose within the cell to glucose and galactose. The structure of these two proteins is determined by two chromosomal genes, *y* for the permease and *z* for β-galactosidase. In wild-type strains of *E. coli* grown on almost any carbon source but lactose, the activities of these genes are repressed, their products being found in only very small amounts. However, growth on lactose as sole carbon source, or addition to the growth medium of various compounds structurally related to lactose, results in the induction of gene expression, with an increase in