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**Waters, Michael Richard**

THE LATE QUATERNARY GEOLOGY AND ARCHAEOLOGY OF  
WHITEWATER DRAW, SOUTHEASTERN ARIZONA

*The University of Arizona*

PH.D. 1983

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THE LATE QUATERNARY GEOLOGY AND ARCHAEOLOGY  
OF WHITEWATER DRAW, SOUTHEASTERN ARIZONA

by

Michael Richard Waters

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A Dissertation Submitted to the Faculty of the

DEPARTMENT OF GEOSCIENCES

In Partial Fulfillment of the Requirements  
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

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THE UNIVERSITY OF ARIZONA  
GRADUATE COLLEGE

As members of the Final Examination Committee, we certify that we have read  
the dissertation prepared by Michael Richard Waters  
entitled The Late Quaternary Geology and Archaeology of Whitewater  
Draw, Southeastern Arizona

and recommend that it be accepted as fulfilling the dissertation requirement  
for the Degree of Doctor of Philosophy.

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Date

V. R. B.

29 Nov. 83

Date

David M. Hendricks

29 Nov 83

Date

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Date

Date

Final approval and acceptance of this dissertation is contingent upon the  
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Dissertation Director

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SIGNED:

Michael Richard Waters

For Susan,  
whose support and understanding  
were always there

## ACKNOWLEDGMENTS

Thanks are due to a number of people and institutions who contributed to my research in Whitewater Draw. Financial support was received from the Wenner-Gren Foundation for Anthropological Research (Grant-in-Aid No. 4335) and Sigma Xi and the Department of Geosciences, the Department of Anthropology Education Fund for Archaeology, and the Graduate College Program Development Fund, The University of Arizona.

I thank the members of my committee, Drs. V. R. Baker, T. L. Péwé, A. J. Jelinek, and D. M. Hendricks for their comments during the course of this project. I especially thank my advisor, Dr. C. V. Haynes, who provided many helpful comments and suggestions, chemicals and facilities for the pretreatment of radiocarbon samples, made his files and data freely available to me, assisted in obtaining funding from the Wenner-Gren Foundation, and provided funding for two radiocarbon dates. My association with Dr. Haynes has made me a more critical and capable scientist.

Scientists who visited Whitewater Draw and offered useful comments include: Drs. V. R. Baker, Bryant Bannister, O. K. Davis, G. C. Frison, E. W. Haury, J. D. Hayden, C. V. Haynes, A. J. Jelinek, Austin Long, and P. S. Martin, and fellow graduate students, Bruce Huckell, Lisa Huckell, and Thomas Stafford. A number of scientists have lent their expertise to this project. Dr. O. K. Davis collected

pollen samples, which are currently under analysis; Dr. W. H. Birkby is studying the human skeletal remains I recovered; Dr. Everet Lindsay and Kevin Moody, Laboratory assistant, identified the vertebrate remains; and Dr. Austin Long and Timothy Jull, research assistant, dated my radiocarbon samples at reduced cost and gave them priority status. Mike Jacobs and Sharon Urban made the Arizona State Museum collections and files freely available to me and Dr. Keith Anderson of the Western Archeological Center provided space for analysis. Dr. R. G. Vivian, assistant director of the Arizona State Museum, authorized photography of figure 16, and Ellen Horn and Helga Teiwes are responsible for the actual photography. I have also benefited from discussions with Dr. E. W. Haury regarding many aspects of this project.

The people in the Douglas basin were very helpful, which made my field investigations more pleasant. I thank the ranchers who allowed me to examine their property and excavate trenches. Special thanks go to Mr. and Mrs. M. A. Fairchild and Mr. Hugh Pendergrass, who made the stay in Double Adobe very enjoyable.

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## ABSTRACT

A complex late Quaternary alluvial sequence is exposed in Whitewater Draw arroyo, Cochise County, Arizona. The alluvial history is characterized by: (1) sand and gravel deposition in a through-flowing stream between 15,000-8,000 yr B.P. and 6,700-5,500 yr B.P. and (2) cycles of erosion and clay-and-silt deposition in large wet meadows or cienegas between 8,000-6,700 yr B.P. and 5,500 yr B.P.-historic period. Modern arroyo entrenchment began after A.D. 1885 and was largely completed before 1910. The alluvial sequence of the Douglas basin differs in timing, character, and number of degradational and aggradational events, with the exception of the arroyo cutting and filling episode between 6,700 and 5,500 yr B.P., when compared to the alluvial sequence of the adjacent San Pedro Valley and the generalized alluvial chronology for the West.

Megafaunal extinction occurred in the Douglas basin no later than 10,400 yr B.P. as evidenced by the occurrence of articulated camel and mammoth remains in sediments of this age. Mammoth, horse, camel, and dire wolf remains from deposits dating 10,400 to 7,000 yr B.P. are in secondary contexts, redeposited from older units.

Archaeological remains of the Cochise Culture occur in nearly all the Upper Quaternary deposits of Whitewater Draw. Artifacts of the Sulphur Spring phase, the earliest phase of the Cochise Culture, are found at four sites in Whitewater Draw and at the Lehner site, where they overlie the Clovis horizon. Ground-stone artifacts are the most

common element of the Sulphur Spring artifact assemblage and indicate that the Douglas basin was the site of specialized plant gathering and processing. Flaked-stone artifacts are poorly represented and are primarily unifacially retouched flake tools but also include bifacially flaked projectile points. The Sulphur Spring phase dates from 8,000 to 10,000 yr B.P. and probably to 10,500 yr B.P. Evidence suggests that the Sulphur Spring people may have temporally overlapped with relict populations of Pleistocene megafauna during the onset of the Holocene. The Sulphur Spring and western San Dieguito I complex are considered to be temporal equivalents.

The Cazador phase is no longer considered a valid phase of the Cochise Culture. Cazador artifacts at the type site occur in deposits equivalent in age to sediments containing Sulphur Spring remains.

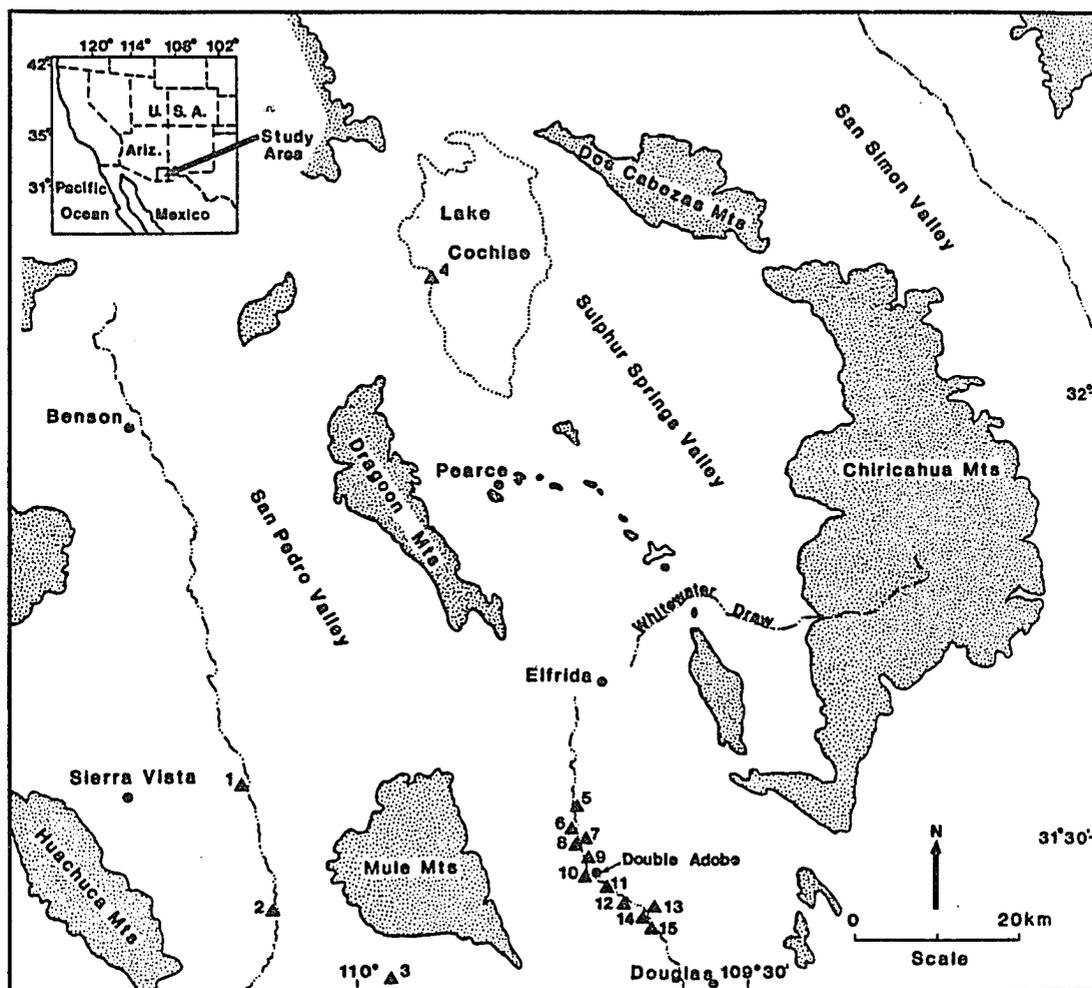
## INTRODUCTION

Whitewater Draw, a deep arroyo in Cochise County, southeastern Arizona, exposes a long sequence of deposits of late Quaternary age, which preserve an archaeological record extending back 10,500 years. Geologist Ernst Antevs and archaeologist Edwin Sayles proposed the first geological and archaeological chronology of Whitewater Draw (Sayles and Antevs, 1941). Since their pioneering interdisciplinary research, many questions have arisen about their findings as both the geological and archaeological data bases have grown, necessitating this reinvestigation of the geology and archaeology of Whitewater Draw.

### Physiographic Setting

Whitewater Draw is located in the southern part of the Sulphur Springs Valley, Arizona (fig. 1). The Sulphur Springs Valley is part of a northeast-trending structural trough within the Basin and Range physiographic province. A surface drainage divide, formed by low volcanic hills near Pearce, separates the Sulphur Springs Valley into two basins: the northern Willcox basin and the southern Douglas basin. The former is a closed basin in which ancient Lake Cochise formed during the late Pleistocene (Meinzer and Kelton, 1913; Schreiber, 1978).

The Douglas basin, encompassing 3,100 km<sup>2</sup>, is that portion of the Whitewater Draw drainage basin north of the international border, even though it extends into Mexico (Coates and Cushman, 1955; White and Childers, 1967). It is characterized by a broad alluvial valley



#### Sites

- |                    |                                       |                                       |
|--------------------|---------------------------------------|---------------------------------------|
| 1. Murray Springs  | 6. Arizona FF:6:9                     | 11. Arizona FF:10:16                  |
| 2. Lehner          | 7. Arizona FF:6:8                     | 12. Arizona FF:10:14                  |
| 3. Naco            | 8. Arizona FF:6:10                    | 13. Terrace cross section, Kings Hyw. |
| 4. Arizona CC:13:3 | 9. Arizona FF:10:4                    | 14. Arizona FF:10:15                  |
| 5. Arizona FF:6:2  | 10. Arizona FF:10:1, Arizona FF:10:13 | 15. Crystal locality                  |

Figure 1. Map of southeastern Arizona showing location of towns, archaeological and geological sites, and physiographic features mentioned in text. -- Sites are indicated by solid triangles and are numbered. Maximum extent of ancient Lake Cochise is shown by a dotted line. Mountain areas are shaded.

about 65 km long and 50 km wide bounded on the east by the Chiricahua, Swisshelm, Pedregosa, and Perilla Mountains and on the west by the Dragoon and Mule Mountains, which rise 900 to 1,200 m above the valley floor. The bedrock lithologies of the surrounding mountains consist of igneous, metamorphic, and sedimentary rocks, ranging in age from Precambrian to Tertiary. The basin axis slopes gently southward at approximately 1.9 m/km from the surface drainage divide (altitude 1,310 m) to the international border (altitude 1,190 m). The climate of the Douglas basin is arid to semiarid, characterized by low precipitation and high evaporation (White and Childers, 1967).

#### Whitewater Draw

Whitewater Draw, named for the outcrops of white caliche along its banks, is an ephemeral stream, which drains the Douglas basin. It is divided into two segments: north and south of Elfrida. Whitewater Draw occupies a continuous channel from its source in the Chiricahua Mountains around the north end of the Swisshelm Mountains to a point northeast of Elfrida where the channel loses its identity. This channel, according to Cooke and Reeves (1976), is similar to those developed at the heads of many arid alluvial fans. There is no evidence that this channel was developed in historic times.

South of Elfrida, Whitewater Draw becomes an arroyo that developed during the nineteenth century. It extends southward from a cienega, approximately 3 km southwest of Elfrida, to its juncture with the Rio Yaqui, which flows south to the Gulf of California. The arroyo

channel meanders and is at an average 30 m wide and 4 m deep, with a width-depth ratio of 10 or less (Cooke and Reeves, 1976).

Few precise data are available on the development of the modern arroyo. What is known is summarized by Meinzer and Kelton (1913) and Cooke and Reeves (1976). Prior to 1885 Whitewater Draw lacked a channel; it was a draw, a shallow subtle depression that was mostly grass covered and expanded out to mudflats and cienegas. Whitewater Draw was transformed into an arroyo beginning in 1885 and entrenchment was largely completed before 1910. The cause of the entrenchment is unclear, but Antevs (1941, 1952, 1983) believed it was the result of overgrazing, vegetation change, and a consequent increase in runoff. Evidence for this is circumstantial. Slight headward erosion of the arroyo into the cienega south of Elfrida, a widening and incising of the channel, and tributary headcutting has occurred in subsequent years. The arroyo channel has downcut since Antevs and Sayles did their field work in 1953; this downcutting resulted in the formation of a bench or terrace within the arroyo.

#### Previous Research

In 1926, Byron Cummings and a group of students recovered a mammoth skull from laminated sediments overlying a rusty sand containing artifacts associated with the remains of bison and horse near Double Adobe, Arizona. These artifacts, unlike the Folsom projectile points discovered that same year with extinct bison, were milling and hand stones with no projectile points.

These finds went relatively unnoticed until 1936 when Sayles and Antevs began an intensive survey of the draw under the auspices of the Gila Pueblo Foundation. This research continued for a number of years and resulted in a 1941 monograph, which outlined the late Quaternary geology of Whitewater Draw and defined the Cochise Culture. On the basis of stratigraphic occurrence, associated fauna, and material culture, three stages of the Cochise Culture were distinguished: from early to late, they are the Sulphur Spring, Chiricahua, and San Pedro. Little further work was conducted until 1953 when Sayles and Antevs returned to Whitewater Draw to collect samples to radiocarbon date the stages of the Cochise Culture. This same year, Sayles defined a fourth stage, the Cazador, which he placed chronologically between the Sulphur Spring and Chiricahua stages. Sayles described this new stage in a 1958 manuscript, which was posthumously published in 1983. In keeping with the terminology proposed by Willey and Phillips (1958), the term "phase" will be used in place of "stage" for the subdivisions of the Cochise Culture. The term "stage" is now used to define general levels of cultural development.

Research in Whitewater Draw has remained dormant since 1953 except for Paul Martin's palynological work in 1959, a 1970 highway salvage operation, and miscellaneous field trips by personnel of The University of Arizona to collect fossils or artifacts.

As the archaeological data base has expanded through the years, especially the recognition of the Clovis Culture and the establishment of a timetable of late Pleistocene extinctions, many questions have arisen concerning the Sulphur Spring and Cazador

phases. Willey and Phillips (1958), Whalen (1971), and Irwin-Williams (1979) have all questioned the validity of the association of extinct fauna with the Sulphur Spring phase. Haury (1960) has defended these associations. Some researchers (Haury, Sayles, and Wasley, 1959; Martin and Plog, 1973; Haury, 1983) have suggested that the Sulphur Spring sites may represent specialized plant processing stations of the Clovis Culture. Whalen (1971) and Irwin-Williams (1979) have questioned the validity of the Cazador phase. Questions have also arisen about the alluvial chronology of Whitewater Draw and timing of late Pleistocene extinctions in the Douglas basin.

#### Purpose

Geological and archaeological investigations of Whitewater Draw had five major objectives: (1) definition of the late Quaternary geologic history of Whitewater Draw, thus providing a stratigraphic framework upon which to reference all other data; (2) comparison of the geologic history of Whitewater Draw with other alluvial sequences outside the Douglas basin to gain insights into regional late Quaternary events; (3) evaluation of the evidence for the timing of late Pleistocene extinctions in Whitewater Draw; (4) determination of the age of the Sulphur Spring phase of the Cochise Culture, the validity of the extinct faunal associations, description of its material culture, and determination of its relationship with other cultures of similar age; and (5) determination of the validity of the Cazador phase of the Cochise Culture.

### Procedure

Field investigations of Whitewater Draw were conducted from September 1982 to May 1983. The arroyo exposures were examined from Douglas to Elfrida for geological and archaeological data and a backhoe was used to expose the older geologic deposits at five archaeological and geological sites. Artifacts, faunal remains, and radiocarbon, sediment, shell, and pollen samples were carefully recorded and collected at selected exposures. Radiocarbon samples were submitted to the University of Arizona Laboratory of Isotope Geochemistry and the Arizona-NSF Regional Accelerator Facility for analysis. Artifacts collected during my field investigations and those in the collections at the Arizona State Museum were studied.

The sites described in this report are assigned Arizona State Museum site designations. Where applicable, a second number follows in parentheses. This number is the Gila Pueblo Foundation designation assigned to the site by Sayles and Antevs and is no longer used. Official site records are on file with the Arizona State Museum, Tucson.

## QUATERNARY GEOLOGY

### Lower Quaternary Stratigraphy

The oldest known valley fill in the Douglas basin is randomly exposed in the arroyo walls of Whitewater Draw and was exposed in all excavated trenches. It is generally a red to greenish-red mottled calcareous clay, probably lacustrine in origin, interbedded with clayey clastic alluvium. The age of the fill is unknown because no fossils have been recovered from it and no other evidence (radiometric or paleomagnetic) bearing on its age is available. This fill may be the equivalent of the St. David Formation in the San Pedro Valley, which dates to the late Tertiary and early Pleistocene. Antevs (1941, 1983) referred to this unit as the "pink clay"; this designation is retained and, in addition, the unit is referred to as unit A.

A paired terrace occurs 5 to 6 m above the modern flood plain of Whitewater Draw. The terrace surface is typically characterized by a smooth desert pavement and development of Haplargids. The terrace deposits are well exposed south of Double Adobe (especially south of Kings Highway) where the arroyo has cut into them. These deposits are a mixture of gravel, sand, silt, clay, and combinations thereof, which rest unconformably on the old valley fill. The recovery of remains of mammoth, horse, sloth, and turtle from these deposits indicates a late Pleistocene age for the terrace sediments. This sequence of deposits is designated unit B.

Typical terrace deposits were exposed in a trench excavated south of Kings Highway (figs. 1 and 2). Overlying the pink clay (unit A) at this site is a coarse alluvial gravel and sand, which, in turn, is overlain by a clayey sand and gravel. A shallow channel is incised into this unit and is filled with sand containing the remains of mammoth, horse, and turtle. Above this are calcareous sandy clays and clayey sands. Four hundred meters downstream from this site, Sayles and Antevs (1941) recovered sloth remains from similar terrace deposits.

One kilometer south of Douglas, Arizona, a tributary arroyo has trenched through terrace deposits. Exposed in the arroyo at a site 2.4 km east of Whitewater Draw, a sandy channel containing mammoth bones is cut directly onto what is probably the pink clay (unit A) (Haynes, personal commun., 1983). The channel is overlain by sandy silts and clays. Sayles and Antevs (1941) also recovered megafaunal remains from gravel and sand in the "barrier area" where the arroyo cuts through the terrace sediments.

#### Upper Quaternary Stratigraphy

No single exposure in Whitewater Draw shows a complete section of the upper Quaternary stratigraphy. Instead, an ordering of geologic events has been achieved by correlation from one radiocarbon-dated site to another, thereby establishing a geologic record for the last 15,000 years. Sixteen major geologic units are defined and labeled C through P, from oldest to youngest. Further internal stratigraphic subdivisions within a geologic unit are indicated by numbers, e.g., 1 oldest, 2 youngest, and facies are designated with lower-case letters. The

- 4 Calcareous sandy clay and clayey sand
- 3 Sand
- 2 Clayey sand and gravel
- 1 Coarse alluvial gravel and sand
- A Pink clay
- Megafaunal remains

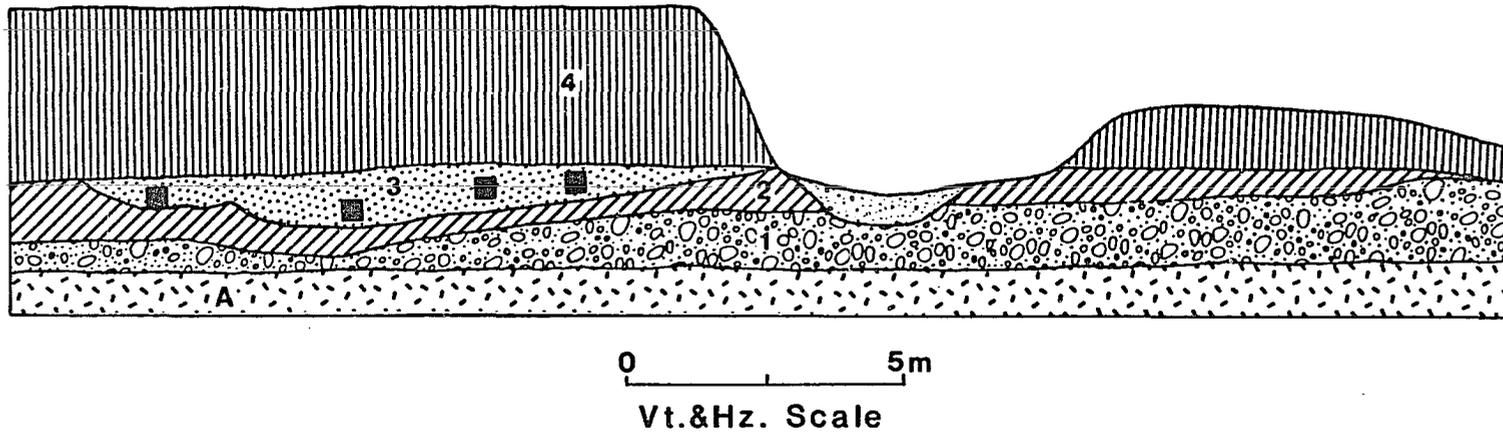


Figure 2. Geologic cross section of terrace deposits south of Kings Highway

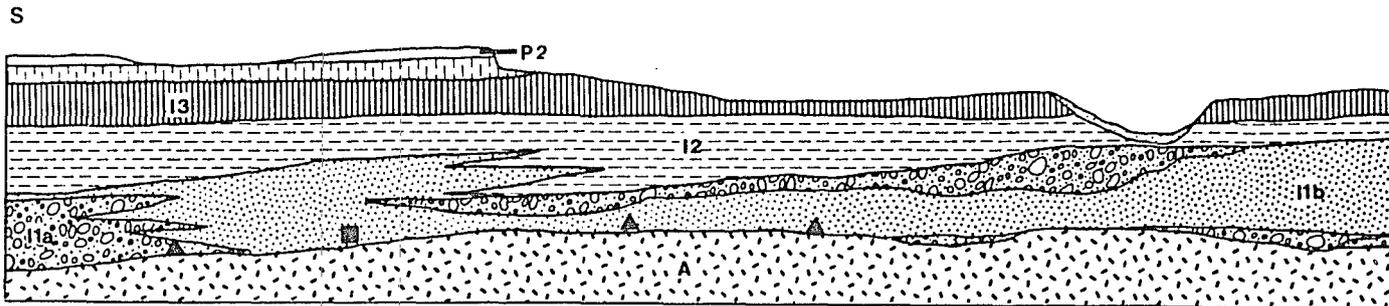
stratigraphy of seven geological and archaeological sites will be discussed and the composite late Quaternary history of Whitewater Draw reviewed.

Site Arizona FF:6:9 (GP Pearce 8:21)

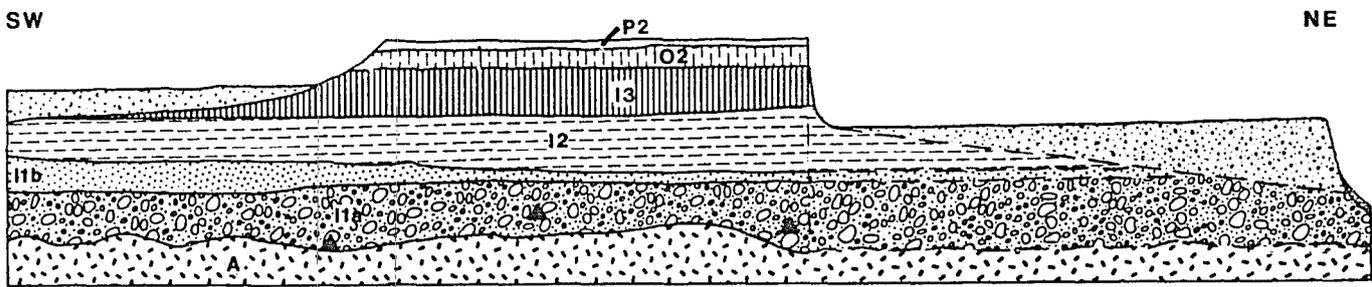
Arizona FF:6:9 is located on the west side of Whitewater Draw approximately 6 km northwest of Double Adobe (fig. 1). It was originally identified by Sayles and Antevs (1941) as a two-component site with Chiricahua or San Pedro phase material overlying Sulphur Spring phase artifacts and was excavated in 1937-38. The upper artifact-bearing stratum was reassigned to the Cazador phase by Sayles (1983a) and Antevs (1983), and artifacts from the lower strata are still considered to be Sulphur Spring (Sayles, 1983c; Antevs, 1983).

I reinvestigated this site in January 1983, excavating a 60-m-long trench parallel to the arroyo bank and two trenches perpendicular to the main trench. Fourteen geologic units are defined and described in the appendix, and the stratigraphic relations are shown in figure 3. Correlation of my units with those described by Antevs (1983) are found in the appendix.

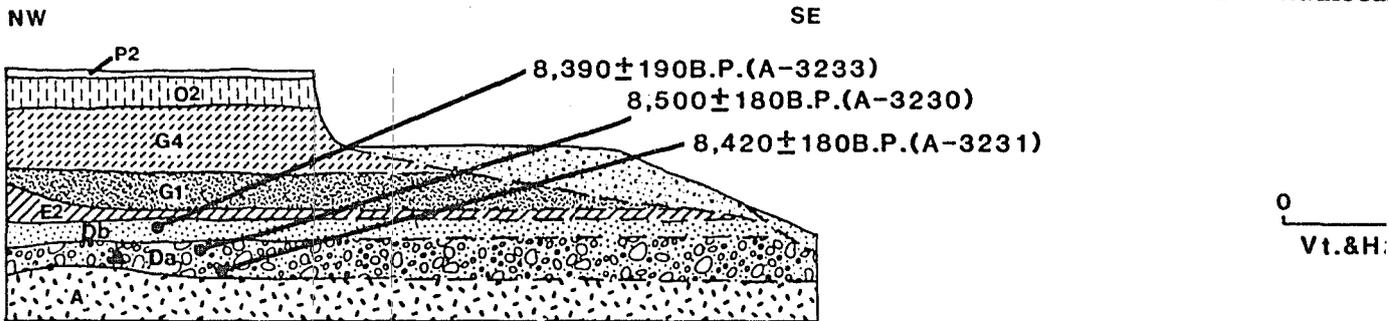
The oldest deposit at the site is a calcareous reddish-brown clay, representing the old valley fill (unit A), which is unconformably overlain by fluvial stream gravel (unit Da) and sand (unit Db). Interbedded thin lenticular silt and clay lenses occur in the sand and represent deposition in charcos (small natural depressions in a streambed where water collects) during periods of reduced flow. Both units contain Sulphur Spring phase artifacts and abundant dispersed charcoal,



a

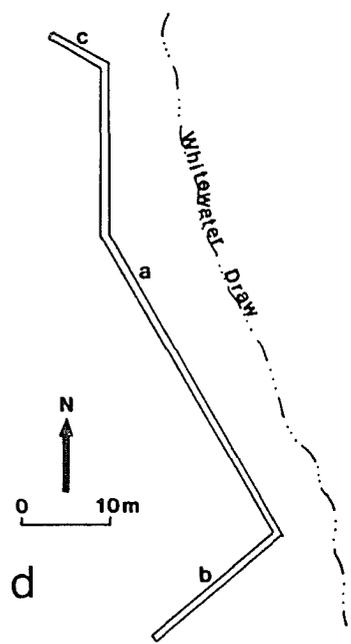
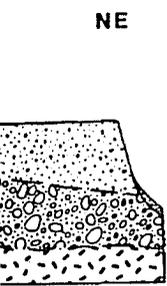
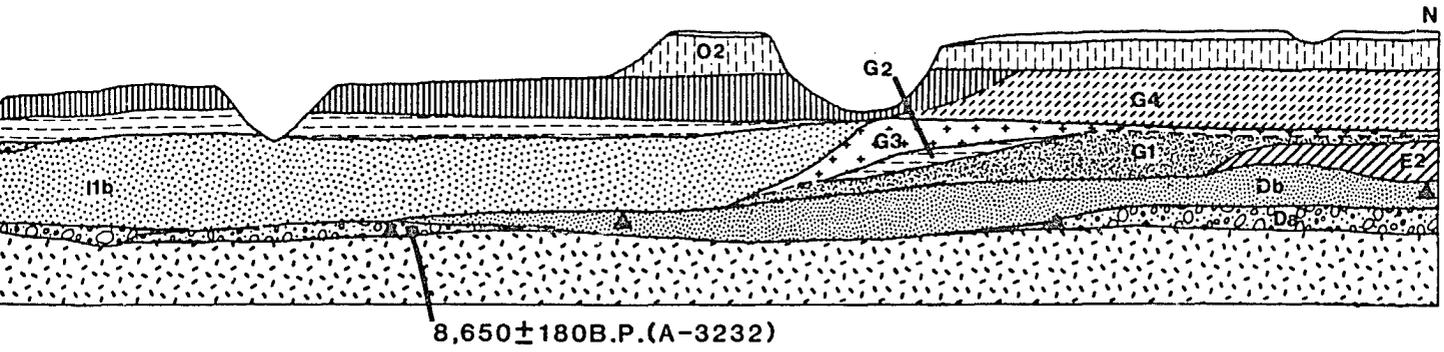


b



c

Figure 3. Geologic cross sections of site Arizona FF:6:9. -- (a) stratigraphic trench; (b) trench layout; (c) stratigraphy of north trench; (d) trench layout.



- ▲ Artifacts
- Radiocarbon-dated samples

0 5m  
Vt.&Hz. Scale

-- (a) stratigraphy of main trench; (b) stratigraphy of south

some of which has been identified as cottonwood (Populus). A freshwater fish vertebra and freshwater pelecypods and gastropods occur in the sand. Two radiocarbon dates on charcoal from the basal gravel (unit Da) are  $8,650 \pm 180$  yr B.P. (A-3232) and  $8,420 \pm 180$  yr B.P. (A-3231), and two charcoal samples from the sand (unit Db) were dated at  $8,500 \pm 180$  yr B.P. (A-3230) and  $8,390 \pm 190$  yr B.P. (A-3233). A sandy clayey silt (unit E2) with coarse prismatic structure overlies the fluvial sand.

A channel cuts through units Db and E2 to within 0.5 m of the pink clay (unit A). The channel is filled with a blue-gray clay (unit G1) with weak prismatic structure, a massive silt (unit G2) and a bluish-gray clay (unit G3), which is transitional into a gleyed cienega soil (unit G4) with strong prismatic structure and abundant  $\text{CaCO}_3$  nodules. Artifacts, attributed to the Cazador phase, were recovered from unit G1 along with freshwater molluscs, 17 species of diatoms, and fine charcoal (Antevs, 1941, 1983; Sayles, 1983a). The diatoms and molluscs indicate that the clay was deposited in slightly alkaline, brackish standing freshwater (Antevs, 1941, 1983).

A prominent channel cuts through the older units to the pink clay (unit A) and is filled with gravel (unit I1a) and cross-bedded sand (unit I1b) deposited in a high-energy fluvial environment. The cross-bedded sand (unit I1b) is conformably overlain by a fining-upward sequence of horizontally laminated, very fine sand, silt, and clay (unit I2), which, in turn, is transitional into a cienega soil (unit I3) with strong blocky structure and abundant  $\text{CaCO}_3$  nodules. Units I1a and I1b contained artifacts, probably reworked from the older gravel (unit

Da) and clay (unit G1), Anodonta shells, and bones of bison, mud turtle (Kinosternon), and Homo sapiens.

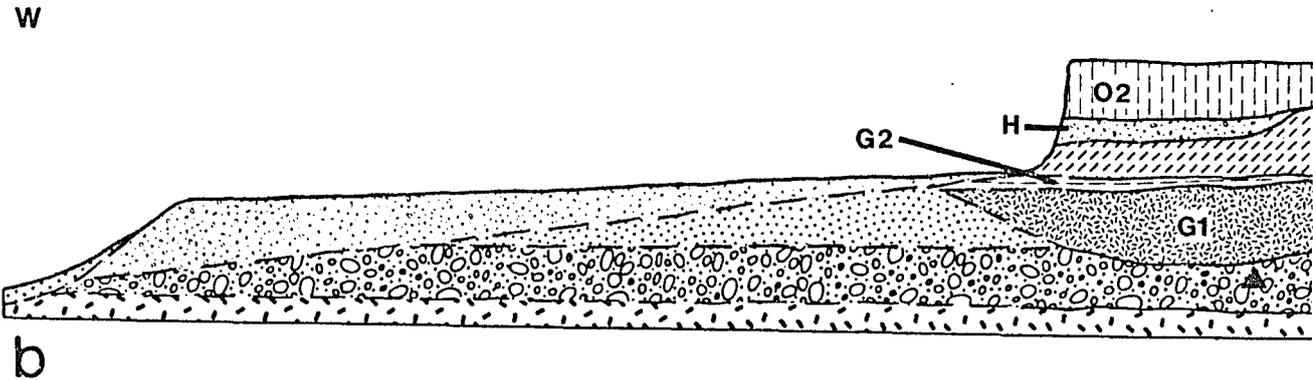
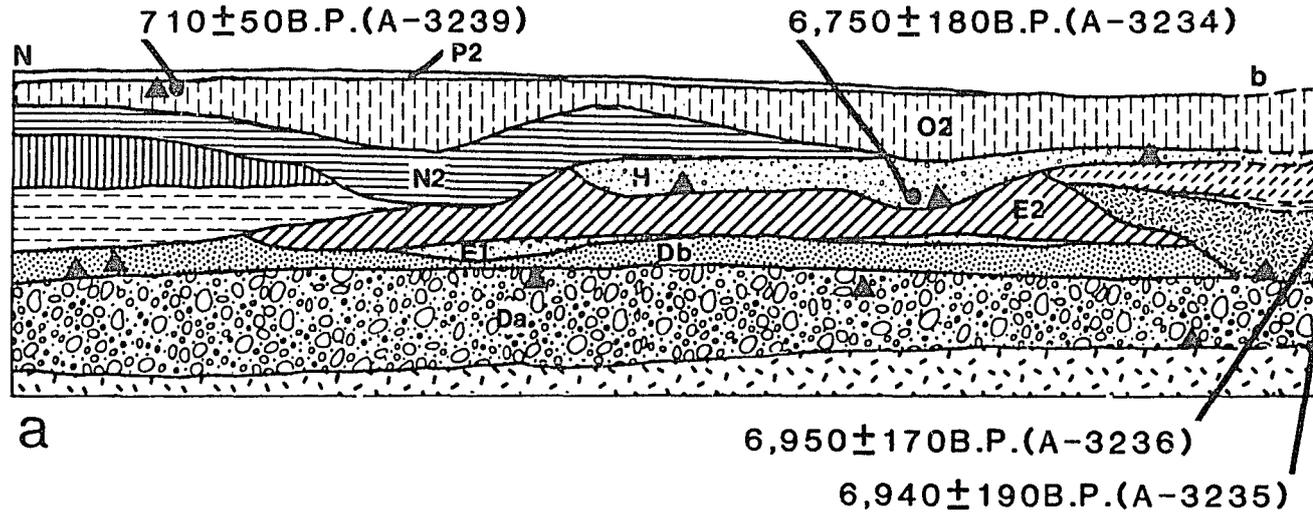
A clay to silty clay (unit O2) with weak soil development overlies units I3 and G4. This deposit, in turn, is overlain by a yellow silt to very fine sand (unit P2), an overbank flood deposit.

A stabilized dune field lies 1.5 km north of this site. Artifacts occur within and under the dunes. Charcoal from a hearth within a dune dated  $350 \pm 50$  yr B.P (SMU-23) (Haynes, personal commun., 1983).

Arizona FF:6:8 (GP Pearce 8:10)

Arizona FF:6:8 is located on the east side of Whitewater Draw, approximately 3.8 km northwest of Double Adobe (fig. 1). It was originally identified as a Sulphur Spring phase site by Sayles and Antevs (1941) with artifacts occurring in five geologic deposits. The upper two artifact-bearing strata were reassigned to the Cazador phase in 1953 by Sayles (1983a) and Antevs (1983) and artifacts from the lower units were still considered to be Sulphur Spring (Sayles, 1983c; Antevs, 1983).

I reinvestigated the site in January 1983, excavating a 45-m-long trench parallel to the arroyo bank and one trench perpendicular to it. Fifteen geologic units are defined and described in the appendix and the stratigraphic relations are shown in figure 4. Correlation of my units with those described by Antevs (1941, 1983) are found in the appendix.

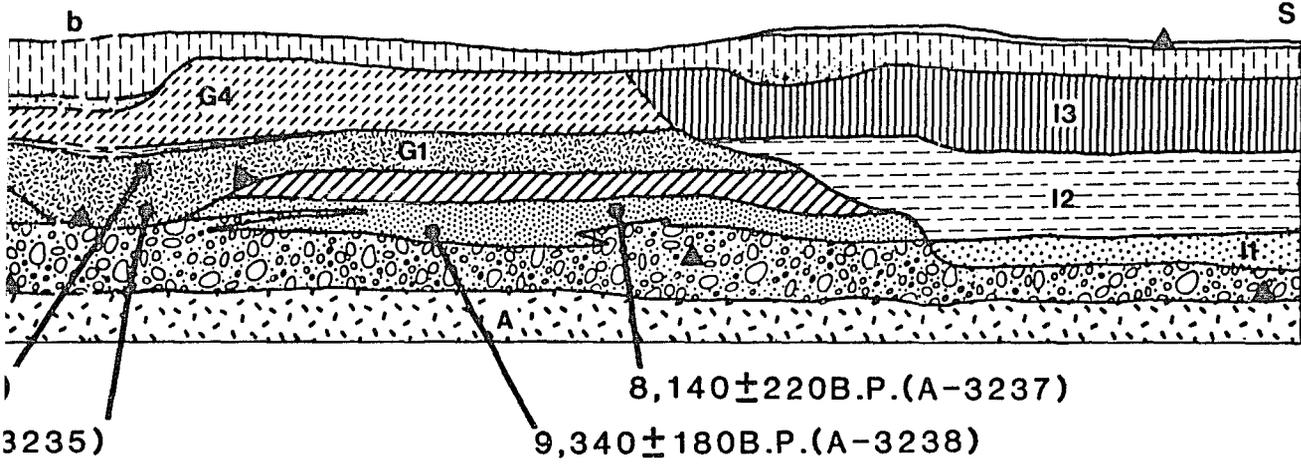


- ▲ Artifacts
- Radiocarbon-dated samples

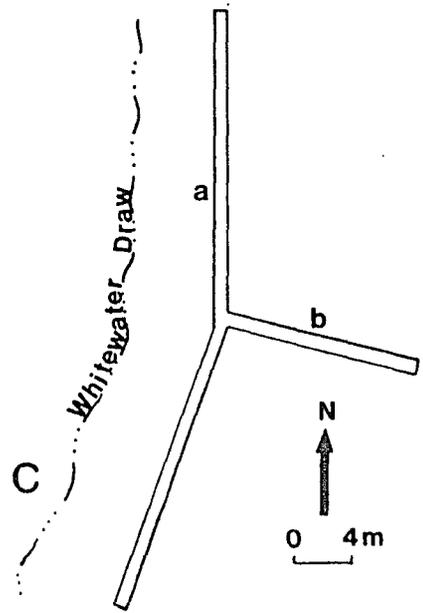
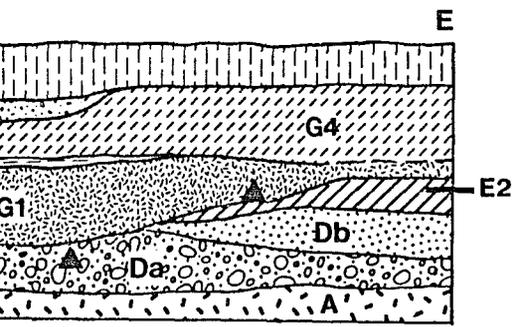
Figure 4. Geologic cross sections of site Arizona FF:6:8. -- (a) stratigraphic trench; (c) trench layout.



14)



3235)



stratigraphy of main trench; (b) stratigraphy of side



Fluvial stream gravel (unit Da) and sand (unit Db) unconformably rest on an eroded surface of calcareous reddish-brown clay (unit A). Thin lenticular discontinuous silt and clay interbeds occur in the sand and represent deposition in charcos. Both units contain Sulphur Spring phase artifacts, and unit Db contains abundant charcoal. A date of  $6,210 \pm 550$  yr B.P (C-511) was derived by the solid radiocarbon method on charcoal collected from the basal portion of the unit Db sand (Antevs, 1983). Two other charcoal samples from the unit Db sand separated by an unconformity date  $9,340 \pm 180$  yr B.P (A-3238) and  $8,140 \pm 220$  yr B.P. (A-3237). The solid radiocarbon date is too young compared to the other more reliable dates from the sand and was rejected.

Shallow channels cut unit Db and are filled with a brown clayey sand (unit E1), containing charcoal and freshwater gastropods and pelecypods. This unit is overlain by a clay to sandy clay with coarse prismatic structure (unit E2), containing freshwater molluscs.

A shallow narrow channel is incised into the older units and is filled with bluish-gray clay (unit G1) with coarse prismatic structure, a massive silt (unit G2), and a gray gleyed cienega soil (unit G4), with strong prismatic structure and abundant  $\text{CaCO}_3$  nodules (fig. 5). Artifacts attributed to the Cazador phase occur along the base of unit G1 in contact with units E2 and Db (Antevs, 1983; Sayles, 1983a). Abundant charcoal, bones of mud turtle (Kinosternon) and fish, and molluscs occur in unit G1.

The turtle and fish bones and molluscs indicate that the clays were deposited in a freshwater pond. A radiocarbon date on charcoal



Figure 5. View of main trench at site Arizona FF:6:8, looking south. -- Pick rests on channel filled with clay unit G1; gravel unit Da below.

at the base of unit G1 is  $6,940 \pm 190$  yr B.P. (A-3235) and another date near the top is  $6,950 \pm 170$  yr B.P. (A-3236). These dates suggest a rapid filling of the channel with clay.

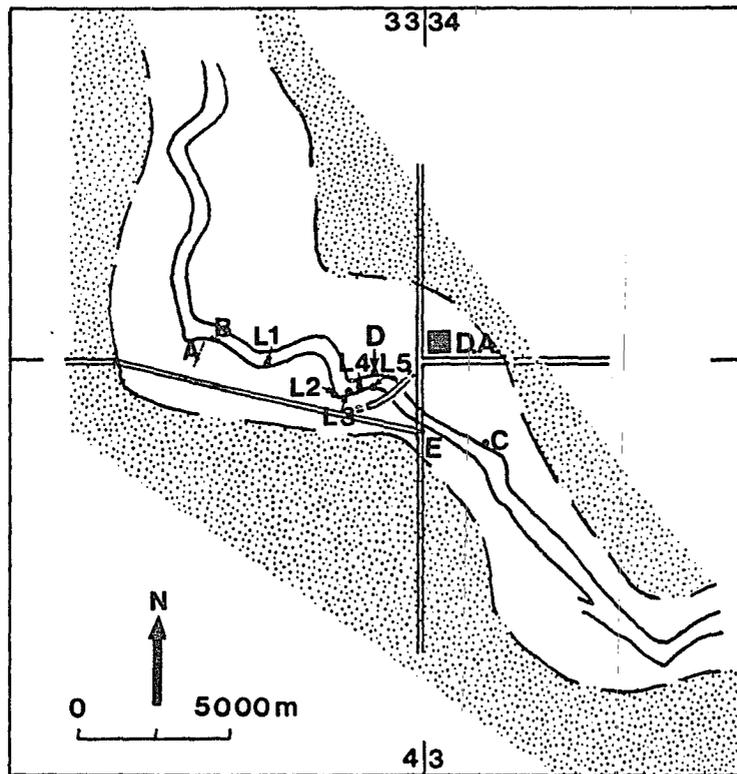
A shallow channel cuts unit G4 and is filled with a clayey sand (unit H). This unit contains freshwater gastropods and pelecypods, charcoal, abundant bones of freshwater fish and mud turtle (Kinosternon), and artifacts attributed by Sayles (1983a) and Antevs (1983) to the Cazador phase. A radiocarbon date on charcoal and humates is  $6,750 \pm 180$  yr B.P. (A-3234).

A prominent channel cuts through the older deposits nearly to the pink clay (unit A) on both the north and south ends of the main trench. The channel is filled with gravel and sand (units I1a and I1b) and a fining-upward sequence of horizontally laminated, very fine sand, silt, and clay (unit I2), which is transitional into a brown cienega soil (unit I3) with strong blocky structure and abundant  $\text{CaCO}_3$  nodules.

This is overlain by a cienega clay (unit N2) with blocky structure, containing shallow channels filled with clayey sand. Overlying the eroded surface of unit N2 is a silty clay with blocky structure (unit O2). A hearth at the top of this unit provided charcoal that dated  $710 \pm 50$  yr B.P. (A-3239). Very fine sand and silt (unit P2), an over-bank flood deposit containing potsherds, overlies unit O2.

Double Adobe Site Area, Arizona FF:10:1  
(GP Sonora F:10:1) and Arizona FF:10:13

The Double Adobe site area (figs. 1, 6, and 7) was first investigated by Cummings in 1926 and later examined in detail by Sayles and Antevs in the late 1930s. This area became the type site of the



- A Location of trench shown in figure 8a
- B Location of trench shown in figure 8e
- C Arizona FF:10:13
- D Location of 1983 test trenches
- E Location of 1970 highway salvage tests
- L1 Arizona FF:10:1, locality 1
- L2 Arizona FF:10:1, locality 2 (Double Adobe II)
- L3 Arizona FF:10:1, locality 3
- L4 Arizona FF:10:1, locality 4
- L5 Arizona FF:10:1, locality 5 (Double Adobe I)
- Shaded area indicates location of terraces
- DA Double Adobe schoolhouse

Figure 6. Map of the Double Adobe site area

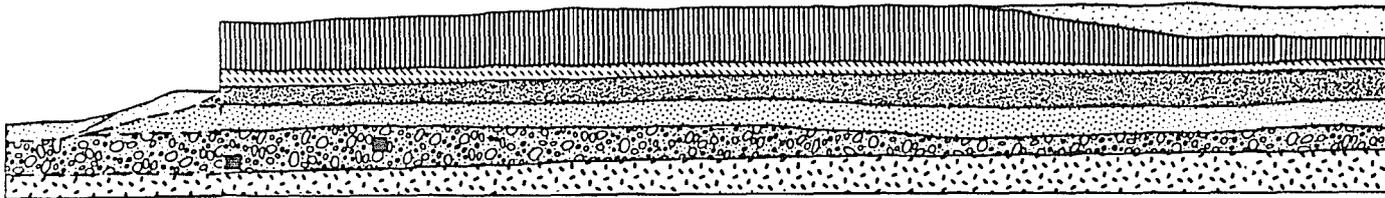


Figure 7. Double Adobe site area, looking west. -- Photograph taken from Arizona FF:10:1, locality 5; localities 4, 3, and 2 are indicated.

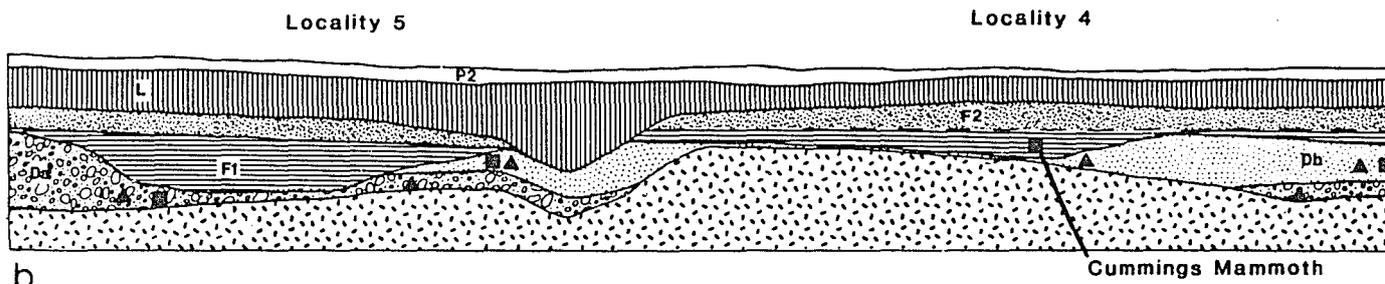
Sulphur Spring and Cazador phases of the Cochise Culture. Further investigations of the area were conducted by Martin in 1959 and Windmiller in 1970. I excavated several test trenches near and two trenches north of the original site area in April 1983. Eighteen stratigraphic units are defined and described in the appendix, and their stratigraphic relations are shown in figure 8. Correlation of my units with those described by Antevs (1941, 1983) are found in the appendix.

The oldest deposit at Arizona FF:10:1, localities 3, 4, and 5 (figs. 6 and 8b), is a calcareous red-brown clay (unit A), which, in turn, is overlain by a calcareous marl (unit C) with interbedded tufa and alluvium containing the remains of horse and mammoth. Unit C was not recognized by Antevs (1941, 1983) or Sayles (1983b) and was included as part of the pink clay (unit A). Stream gravel (unit Da) and sand (unit Db) unconformably cut units A and C. Sulphur Spring artifacts, cottonwood (Populus) and hickory (Carya) charcoal, and the remains of mammoth, camel, horse, dire wolf, bison, pronghorn antelope, and coyote were recovered from the alluvium (units Da and Db) (Sayles, 1941, 1983c; Antevs, 1941, 1983). Haury (1960) reported that he collected articulated leg bones of a camel from these deposits.

The fluvial deposits are cut by a shallow channel and filled with a laminated marl (unit F1) from which the skull, ribs, and leg bone of a mammoth and remains of freshwater molluscs were removed (Cummings, 1927, 1928; Antevs 1941, 1983). This unit is overlain by a massive marl (unit F2), which, in turn, is overlain by a massive to faintly laminated calcareous brownish-gray clay and a clay with strong



a



b

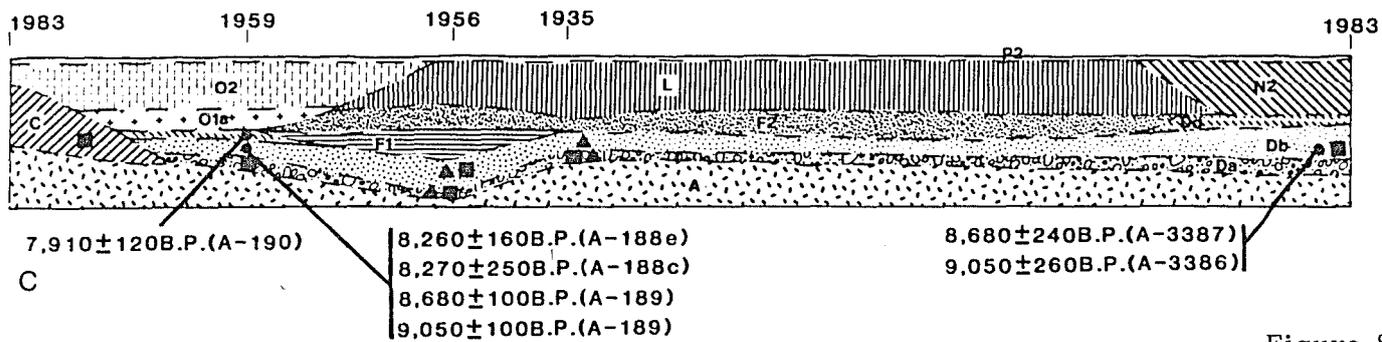
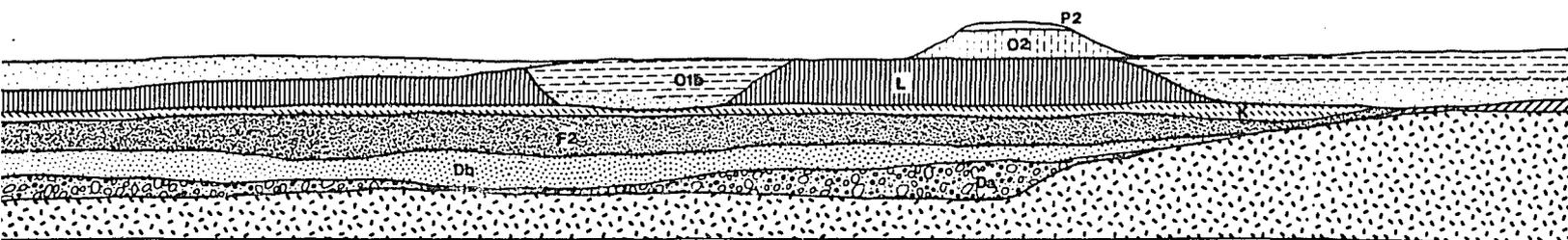
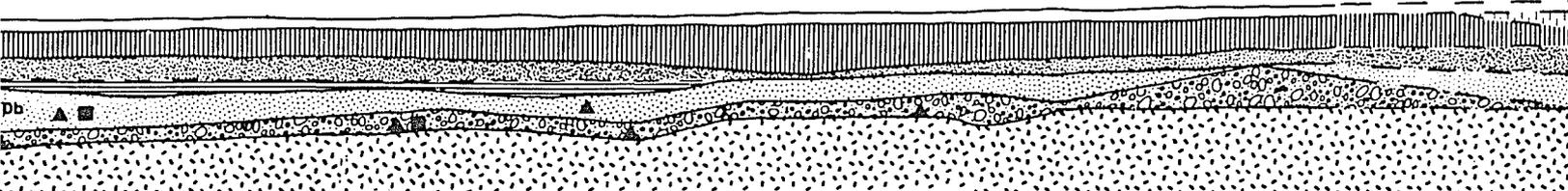


Figure 8  
of Arizona FF:10:1  
Arizona FF:10:1  
stratigraphy of  
Stratigraphy of  
megafauna, and

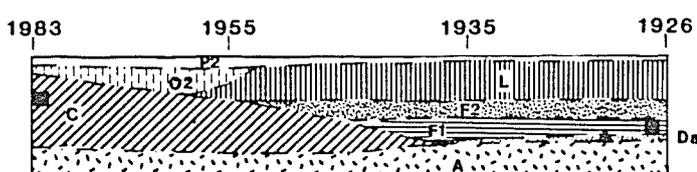




Locality 3



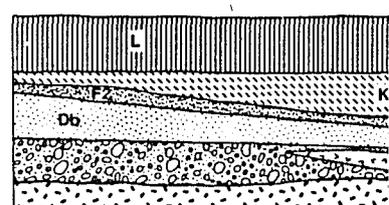
th



d

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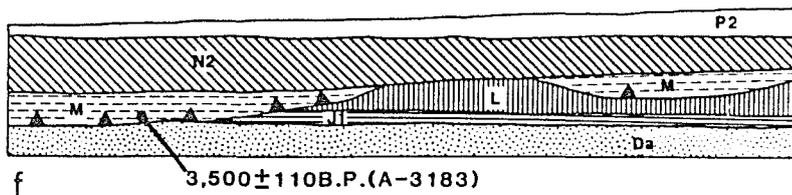
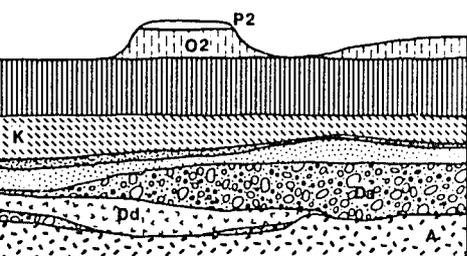
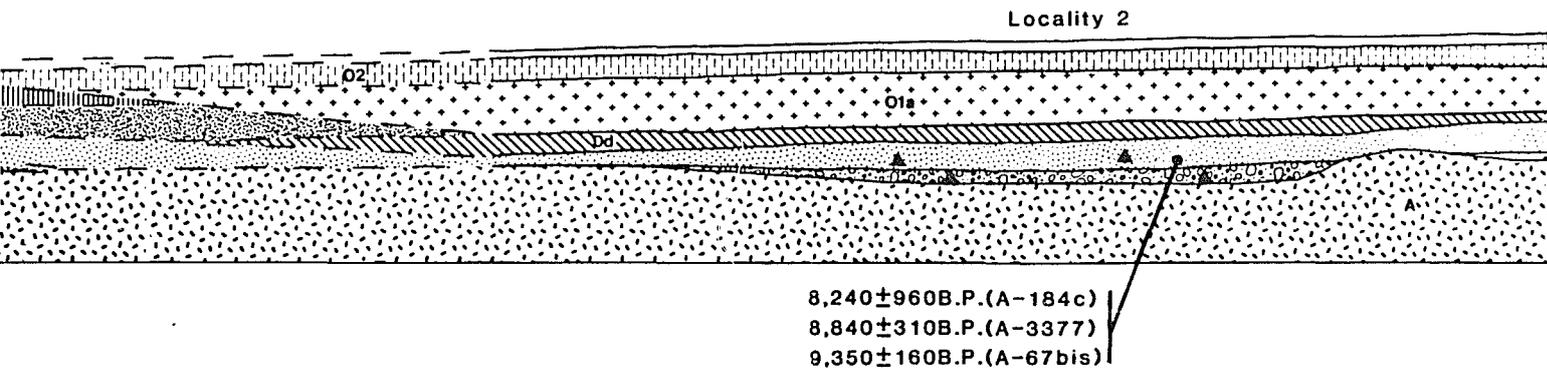
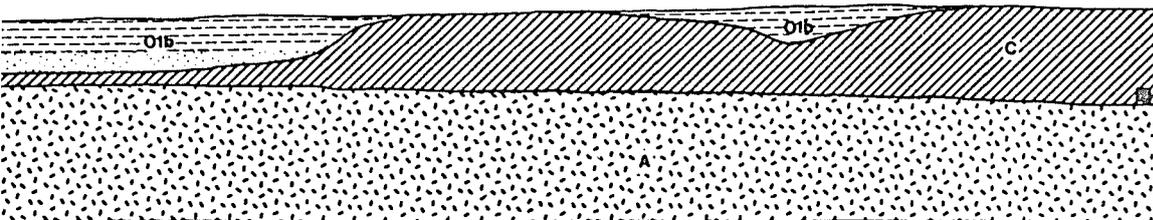
Vt.&Hz. Scale



e

Figure 8. Geologic cross sections of the Double Adobe area. -- (a) Stratigraphy at northernmost trench shown in figure 6. (b) Stratigraphy of Arizona FF:10:1, localities 5, 4, 3, and 2 from an unpublished geologic cross section by Antevs and Sayles (1935). (c) Stratigraphy of Arizona FF:10:1, locality 5, based on stratigraphic information recorded in years indicated; cross section is perpendicular to strike-slip fault. (d) Stratigraphy of Arizona FF:10:1, locality 4, based on stratigraphic information recorded in years indicated; cross section is perpendicular to strike-slip fault. (e) Stratigraphy of northern trench shown as B in figure 6. (f) Stratigraphy of Arizona FF:10:13; solid triangles represent position of radiocarbon-dated samples, and solid dots indicate position of radiocarbon-dated samples.





shown as A in figure 6. (b) Stratigraphy (1937). (c) Interpolated stratigraphy of perpendicular to arroyo. (d) Interpolated section is perpendicular to arroyo. (e) present artifacts, solid squares represent



prismatic structure and abundant  $\text{CaCO}_3$  nodules (unit L). A silt (unit P2) containing potsherds (Antevs, 1941, 1983) overlies this unit.

Martin (1963b) investigated locality 5 in 1959 and designated it the Double Adobe I pollen profile (fig. 6). Through previous erosion and his use of mechanical equipment some of the original deposits described by Antevs (1941) were removed leaving the following sequence of units from oldest to youngest (fig. 8c): pink clay (unit A), gravel (unit Da), sand (unit Db), blue-gray clay (unit Dd), white silt and clay (unit Ola), indurated silt (unit O2), sandy silt (unit P1), and silt (unit P2). Five radiocarbon dates, ranging from  $8,000 \pm 60$  yr B.P. (A-191) to  $8,960 \pm 100$  yr B.P. (A-189) were obtained on charcoal, carbonaceous alluvium, and disseminated charcoal and organic matter collected from the unit Db sand (Martin, 1963b). A sample of carbonaceous alluvium from clay unit Dd, overlying the unit Db sand, dated  $7,910 \pm 200$  yr B.P. (A-190) (Martin, 1963b). A horse tooth was found in the basal gravel (unit Da) by Rogers (1959).

I excavated two test trenches near locality 5 (figs. 6 and 8c), which duplicated the stratigraphy described by Martin (1963b) and dated two charcoal samples from the sand (unit Db). These dates are  $9,050 \pm 260$  yr B.P. (A-3386) and  $8,680 \pm 240$  yr B.P. (A-3387). A tumbled mammoth bone was associated with the latter date.

At Arizona FF:10:1, locality 1 (fig. 6), Antevs (1983) and Sayles (1983c) found Sulphur Spring artifacts and the remains of mammoth, camel, dire wolf, and birds in a stream-deposited gravel (unit Da) and sand (unit Db). Overlying unit Db is a massive marl (unit F2) containing the remains of a camel. This unit is overlain by a

brown cienega clay (unit N2) and a silt (unit P2). Locality 1 has been destroyed by erosion.

Arizona FF:10:1, locality 2, located on the west side of White-water Draw, is the type site of the Cazador phase (fig. 6) (Sayles 1983a; Antevs, 1983). The stratigraphy at this site consists of fluvial gravel (unit Da) and sand (unit Db) resting on an eroded surface of the pink clay (unit A) (fig. 8b). These units are overlain by a massive blue-gray clay (unit Dd), which, in turn, is overlain by a series of massive calcareous sandy silts (unit O1a), a brown silty clay (unit O2), and a yellow silt (unit P2). Cazador artifacts occur in the basal gravel (unit Da) and sand (unit Db) (Sayles, 1983a; Antevs, 1983). Two dates derived by the solid radiocarbon method reported from the alluvium (units Da and Db) are  $7,756 \pm 370$  yr B.P. (C-216) and  $8,200 \pm 260$  yr B.P. (A-67). The carbon residue from the latter sample was reanalyzed using the  $\text{CO}_2$  method and resulted in a date of  $9,350 \pm 160$  yr B.P. (A-67bis) (Damon and Long, 1962). The solid radiocarbon dates appear to be too young when compared to the more reliable gas date and were rejected.

Martin (1963b) reinvestigated locality 2 in 1959 and designated it the Double Adobe II pollen profile (fig. 6). He found that the stratigraphy at the Double Adobe I profile was duplicated here (fig. 8) and obtained radiocarbon dates on charcoal and carbonaceous alluvium from the sand (unit Db):  $8,240 \pm 960$  yr B.P. (A-184c) and  $7,030 \pm 260$  yr B.P. (A-184e), respectively. The latter date is too young compared to other dates from this unit and was rejected. I investigated this site in April 1983, found the stratigraphy as described by Antevs

(1983) correct, and obtained a radiocarbon date on charcoal of  $8,840 \pm 310$  yr B.P. (A-3377) from the unit Db sand.

Several trenches were excavated about 240 m downstream from Arizona FF:10:1 (locality 5) during a highway salvage operation in 1970 (Windmiller, 1970) (fig. 6). Haynes (1971) recorded the stratigraphy exposed in the trenches and obtained four radiocarbon dates. The stratigraphy in the trenches is similar to that found elsewhere in the Double Adobe area. A stream-deposited gravel (unit Da) and sand (unit Db) rests unconformably on an eroded surface of the pink clay (unit A). This, in turn, is overlain by a brown clay (unit E2) with coarse prismatic structure. Cut into this unit is a channel filled with a laminated marl (unit F1), which is overlain by a gleyed cienega soil (unit L) with strong prismatic structure, a brown clay (unit N2), and a yellow flood silt (unit P2).

Sulphur Spring artifacts were found in the unit Db sand, and the remains of a mammoth were recovered from the unit Da gravel. Most of the mammoth bones were unarticulated and scattered across a 60-m<sup>2</sup> area. However, a pair of lumbar vertebrae were found in normal articulated relationship (Huckell, 1972). No association between the mammoth bones and artifacts could be demonstrated. Two radiocarbon dates,  $10,420 \pm 100$  yr B.P. (A-1152) and  $8,920 \pm 1150$  yr B.P. (Tx-1199) were obtained on charcoal from the unit Db gravel near the mammoth bones. Two radiocarbon dates on CaCO<sub>3</sub> laminations from the laminated marl (unit F1) are  $9,730 \pm 100$  yr B.P. (SMU-129) and  $10,980 \pm 90$  yr B.P. (SMU-128). The marl dates were rejected as too old because the laminated marl (unit F1) overlies the unit Db sand, which

dates between about 9,500 and 8,000 yr B.P. The calcium carbonate was probably contaminated by radiometrically inactive carbon.

North of Arizona FF:10:1, I excavated two trenches: one parallel and one perpendicular to the arroyo bank (figs. 6, 8a, and 8e). The oldest exposed deposit was the calcareous pink clay (unit A). This was overlain by a calcareous clay (unit C), probably a marl, containing the bones of horse and mammoth. Inset against units A and C are stream-deposited gravel (unit Da) and sand (unit Db) with interbedded silt and clay lenses. In one trench, a conspicuous channel filled with clay (unit Dd) is underlain and overlain by gravel (unit Da). Within the gravel are freshwater molluscs and mammoth bones. The gravel is overlain by a massive marl (unit F2) with prismatic structure, which, in turn, is overlain by a laminated gray clay, which fills a shallow depression and a massive gray clay with a prominent silt interbed (unit K?). This unit is overlain by a gleyed cienega soil (unit L) with strong prismatic structure and abundant  $\text{CaCO}_3$  nodules. Several small channels are incised into the soil (unit L) and filled with silty sand and silt (unit Olb). These shallow channel fills are overlain by silty clay (unit O2) and overbank flood silts (unit P2).

Arizona FF:10:13 is located 4,000 m downstream from locality 5 (fig. 6). Here a shallow channel is incised into a sequence of older sediments (units Db, J1, and L) and filled with an olive-blue-gray clay (unit M) (fig. 8f). Artifacts, freshwater molluscs, and mud turtle (Kinosternon) and bird bones occur along the contact of the channel with the older units. Charcoal is abundant, and a date of  $3,500 \pm 110$  yr B.P. (A-3183) was obtained on cottonwood (Populus) charcoal from

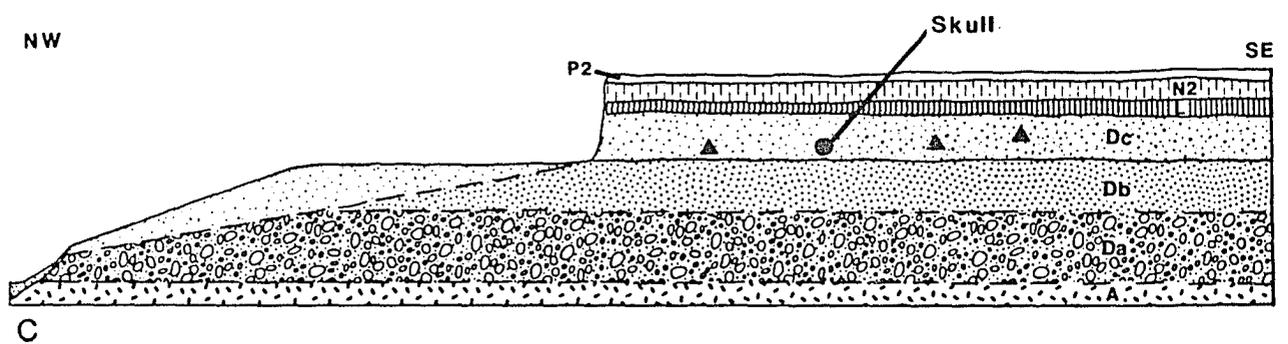
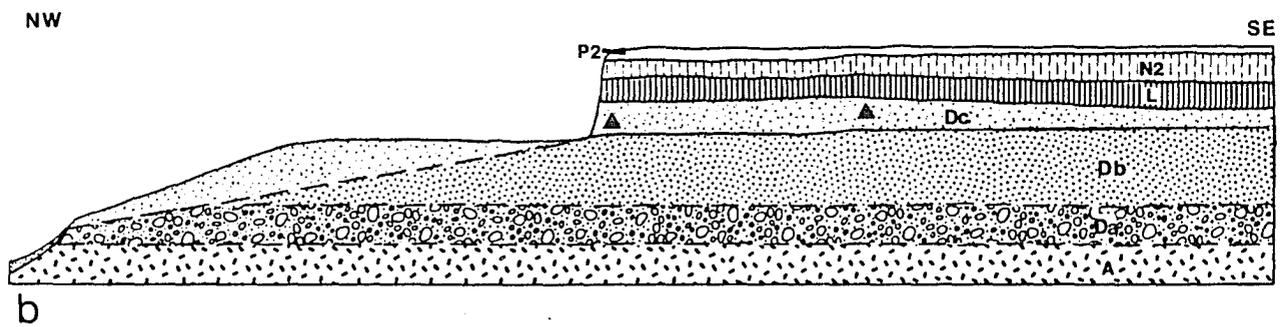
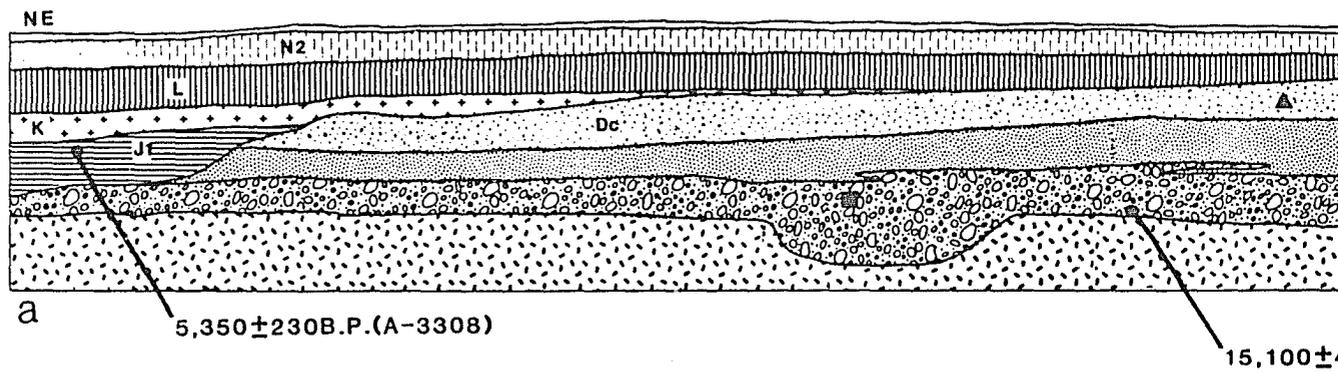
the base of the clay (unit M). This deposit is overlain by a sequence of brown clays (unit N2) and a flood silt (unit P2).

A human skeleton was found in a calcareous silty sand 2 km northwest of Double Adobe. It is not possible to accurately place this unit in the alluvial sequence, and the only statement that can be made with certainty is that it occurred below sediments correlative with Unit N. The silty sand is most similar to unit E1, but this correlation cannot be established with certainty from the available exposures. The skeleton was in a very tightly flexed position in the lower 10 cm of the silty sand. The skull cap was recovered above the rest of the burial in the same silty sand.

Arizona FF:10:14 (GP Sonora F:10:17)

Arizona FF:10:14, a Sulphur Spring site identified by Sayles and Antevs (1941) is located on the west side of Whitewater Draw approximately 2 km southeast of Double Adobe (fig. 1). I reinvestigated this site in February 1983, excavating a 70-m-long trench parallel to the arroyo wall and two trenches perpendicular to it. Two additional trenches were excavated 1,500 m downstream and 3,000 m upstream from the site and are designated the Bull and Tortoise localities, respectively. Twelve stratigraphic units are defined and described in the appendix, and their stratigraphic relations are shown in figure 9. Correlation of my units with those described by Antevs (1941) are found in the appendix.

The oldest unit at the site is a reddish-brown calcareous clay (unit A). On the eroded surface of the clay rests a fluvial stream-



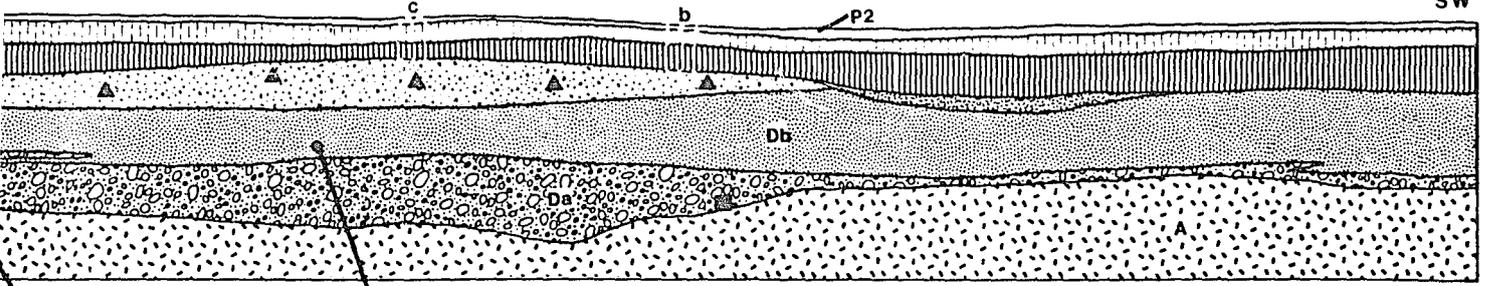
▲ Artifacts

■ Megafauna

● Radiocarbon-dated samples

Figure 9. Geologic cross sections of site Arizona FF:10:14. -- (a) stratigraphic trench layout.

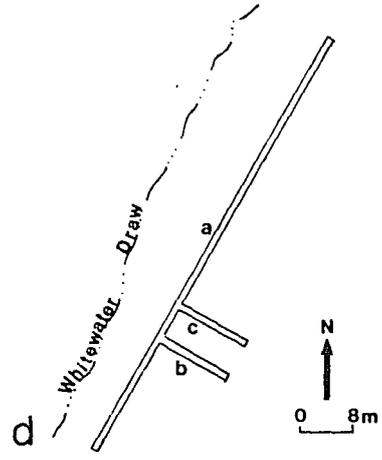
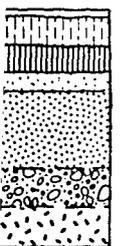




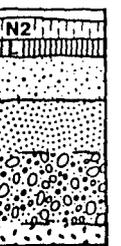
12,850±890B.P.(AA-269)

15,100±400B.P.(AA-233)

SE



SE



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samples

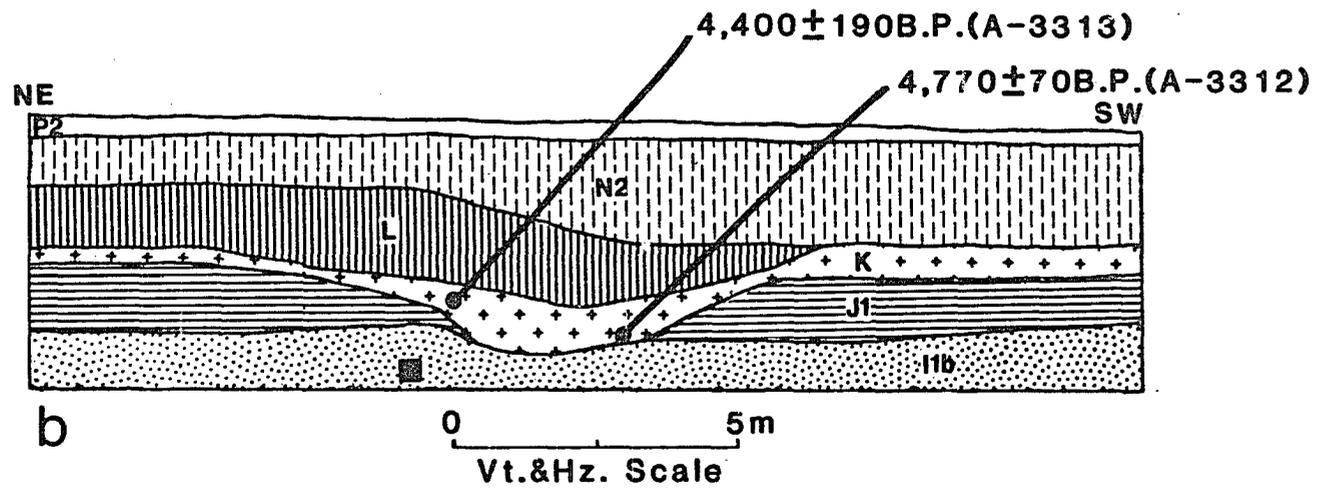
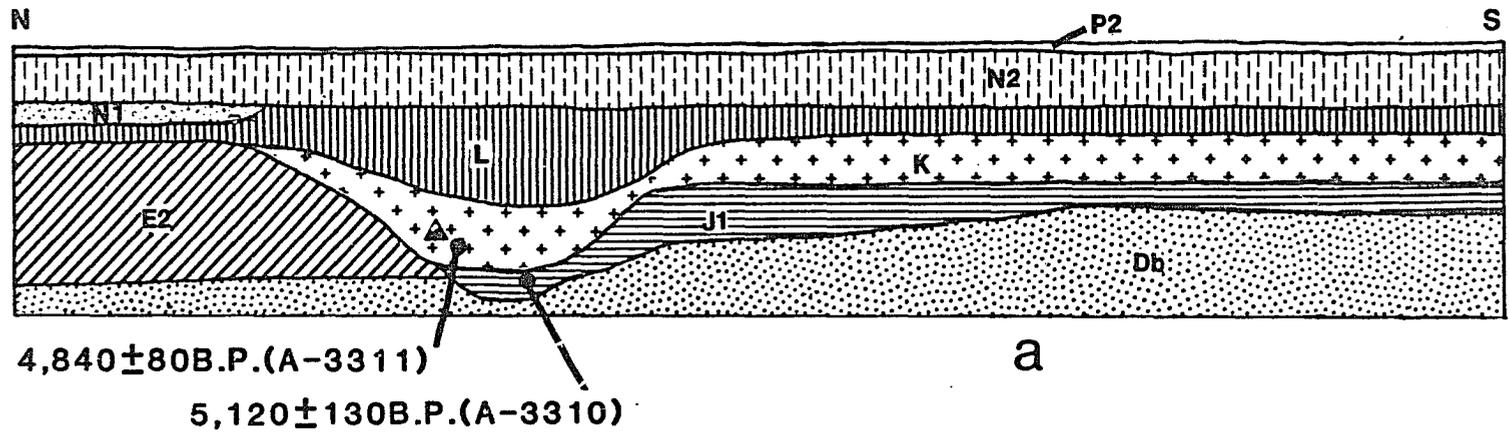
stratigraphy of main trench; (b) and (c) stratigraphy of side trenches; (d)



deposited gravel (unit Da) and sand (unit Db) containing disarticulated mammoth and camel bones and freshwater molluscs. A radiocarbon date of  $15,100 \pm 400$  yr B.P (AA-233) on dispersed charcoal was obtained from the base of unit Da and a charcoal sample from the base of unit Db sand dated  $12,850 \pm 890$  yr B.P. (AA-269). Overlying unit Db is a silty sand (unit Dc) with dispersed pebble gravel, which probably represents deposition in a flood bar. This unit contained Sulphur Spring phase artifacts, human skeletal remains, bison, and very fine dispersed charcoal.

The older deposits are cut by a channel and filled with a laminated brown clay-silt (unit J1), which dated  $5,350 \pm 230$  yr B.P. (A-3308). A channel filled with laminated gray clay (unit K) overlies unit J1 and contains freshwater molluscs and abundant charcoal and carbonized plant remains along laminations, which suggest deposition in a freshwater pond. A shallow channel cuts unit Dc on the north end of the site and is filled with a faintly laminated clay, which is probably the equivalent of unit K. These units are overlain by a gleyed cienega soil (unit L) with strong prismatic structure and abundant  $\text{CaCO}_3$  nodules and freshwater shells, which fills very gentle depressions in the paleotopography. Unit L is overlain by a silty clay and clay (unit N2) with blocky structure, which, in turn, is overlain by a very fine sand and silt (unit P2).

At the Bull and Tortoise localities, the erosional channels filled with units J1, K, and L at Arizona FF:10:14 were exposed (figs. 10 and 11) to obtain data on the size of the channels, the cut-and-fill sequence, and the age of the deposits. The deposits are best exposed



▲ Artifacts      ■ Megafauna      ● Radiocarbon-dated samples

Figure 10. Geologic cross section of (a) Bull locality and (b) Tortoise locality

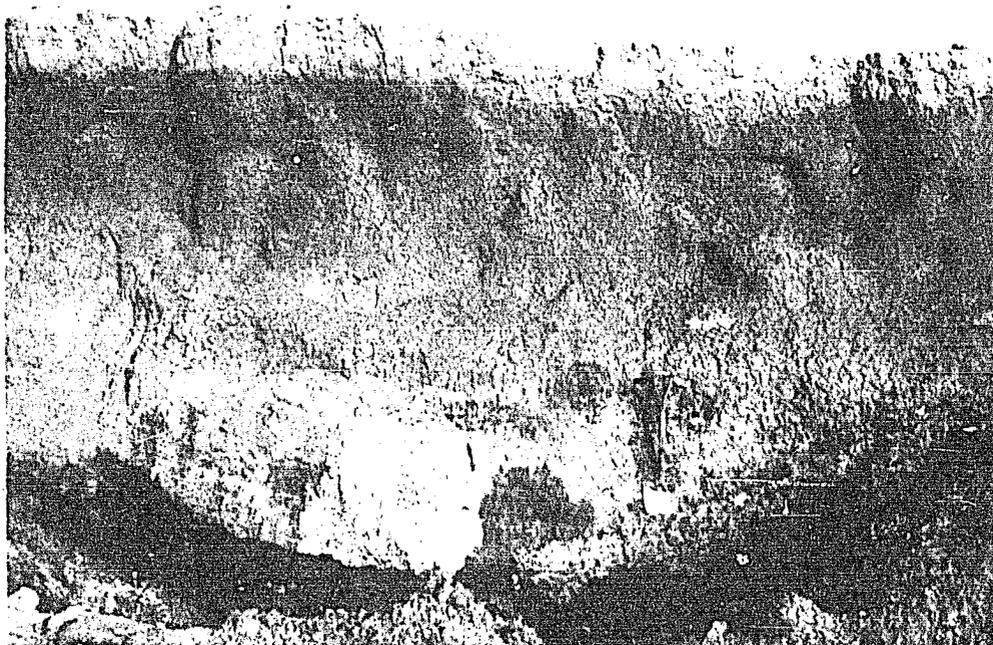


Figure 11. Tortoise locality. Shovel rests on clay unit L filling shallow channel. Dark unit below is clay unit K. Clay-silt unit J1 is shown in the corners below unit K. Units N2 and P2 overlie these units.

at the Bull locality where the oldest channel cuts into sand and gravel (probably unit Db) and a sandy clay with coarse prismatic structure (unit E2). The base of the shallow channel is filled with a thin lense of sand and pebble gravel, which is overlain by a brown laminated clay-silt (unit J1). This deposit is eroded by a channel approximately 3 m deep and a maximum of 7 m wide. This channel is filled with a blue-gray laminated clay (unit K), which is slightly sandy at the base and contains abundant charcoal and remains of mud turtle (Kinosternon) and freshwater molluscs. Unit K is cut by another channel and filled by a massive blue clay with  $\text{CaCO}_3$  nodules, which is transitional into a gleyed soil (unit L) with strong prismatic structure and abundant  $\text{CaCO}_3$  nodules. Freshwater gastropods are abundant in this unit. Unit L is overlain, as at Arizona FF:10:14, by units N1, N2, and P2.

A similar sequence of beds and cut-and-fill relations occur at the Tortoise locality but differ in that the channel is cut into a sand and gravel that is probably unit Ilb. The evidence indicates that all clays were deposited in freshwater ponds. A milling stone fragment was recovered from the gray laminated clay (unit K) at the Bull locality.

Four radiocarbon dates were obtained on charcoal samples collected from these localities. One sample from the basal portion of the brown laminated clay-silt (unit J1) at the Bull locality dated  $5,120 \pm 130$  yr B.P. (A-3310). One sample from the base of the blue-gray laminated clay (unit K) at the Bull locality dated  $4,840 \pm 80$  yr B.P. (A-3311) and two samples from the base and top of the same unit at the

Tortoise locality dated  $4,770 \pm 70$  yr B.P. (A-3312) and  $4,400 \pm 190$  yr B.P. (A-3313), respectively.

#### Arizona FF:10:16

Arizona FF:10:16 is located 2.8 km southeast of Double Adobe on the west side of Whitewater Draw (fig. 1). Exposed in the arroyo wall is a sequence of four geologic units. The stratigraphic relations are shown in figure 12b, and the units are described in the appendix.

The oldest deposit at the site is a gray to grayish-olive clay (unit M), which contains freshwater gastropods and the remains of antelope. This deposit is unconformably overlain by brown clays (units N2a and N2b) with soil structure. Minor erosion surfaces occur in the clay and are marked by small shallow channels filled with clayey sand. A radiocarbon date on dispersed charcoal from the base of unit N2a is  $2,290 \pm 190$  yr B.P. (A-3181). A date of  $1,430 \pm 250$  yr B.P. (A-3182) was obtained on charcoal from a hearth along an erosion surface separating unit N2a from unit N2b. Artifacts occurred along this surface. The clays are overlain by a brown silt to very fine sand (unit P2).

#### Crystal Locality

The Crystal locality is located 8.5 km southeast of Double Adobe on the west side of Whitewater Draw (fig. 1). Exposed in the arroyo wall is a sequence of four geologic deposits. The stratigraphic relations are shown in figure 12a, and the units are described in the appendix.

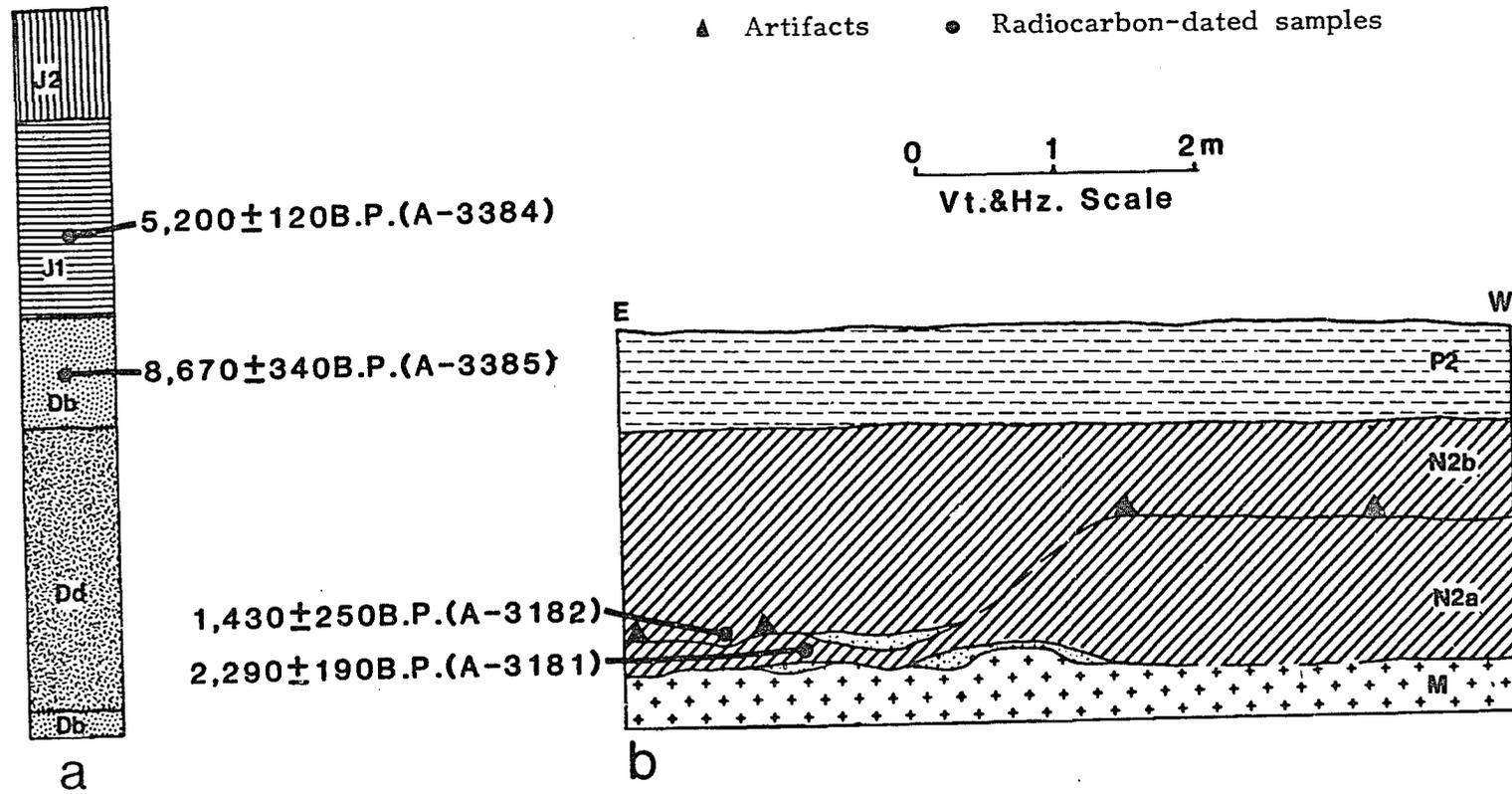


Figure 12. Stratigraphy of Crystal locality (a) and geologic cross section of Arizona FF:10:16 (b)

The oldest deposit exposed at this locality is a bluish-black clayey gleyed soil (unit Dd) with very coarse prismatic structure. This unit is very organic and characterized by large gypsum crystals. Fluvial sand and silt (unit Db) overlie and underlie unit Dd. Dispersed charcoal from the unit Db sand overlying the unit Dd clay dated  $8,670 \pm 340$  yr B.P. (A-3385). This unit is, in turn, overlain by a brown laminated clay-silt (unit J1) of which the upper 70 cm are characterized by soil development (unit J2). Charcoal from the middle of unit J1 dated  $5,200 \pm 120$  yr B.P. (A-3384).

#### Radiocarbon Dating

Forty-eight radiocarbon dates have been obtained from the late Quaternary deposits of Whitewater Draw. The dated materials included charcoal (35 samples), carbonaceous alluvium (8 samples), calcium carbonate (3 samples), and charcoal-humate combinations (2 samples).

Twelve dates are considered to be in error and were rejected. All dates derived by the solid radiocarbon method are considered unreliable. These dates (C-216, C-511, C-515, C-518, and A-67) are either too young or too old when compared with other dates obtained from the same deposits and derived by the more reliable  $\text{CO}_2$  method. The three dates (SMU-128, SMU-129, and A-192a) obtained on calcium carbonate were disregarded because they consistently date older than associated dates on charcoal. This inconsistency probably resulted from the partial precipitation and exchange of dead carbon with the samples during ground-water circulation. Four dates (A-184e, A-191, A-192b,

and A-193) on carbonaceous alluvium were also rejected because they are inconsistent with associated dates on charcoal.

This leaves 36 dates to provide the foundation for the absolute chronology of Whitewater Draw. Twenty-four of the 36 samples were charcoal collected and pretreated by me with hydrochloric acid to remove  $\text{CaCO}_3$  and with sodium hydroxide to remove soluble organic contaminants. These samples were submitted to the University of Arizona Laboratory of Isotope Geochemistry and the Arizona-NSF Regional Accelerator Dating Facility for analysis. Twenty-two samples received a  $\delta^{13}\text{C}$  analysis to correct for carbon isotope fractionation.

Table 1 lists all radiocarbon dates from the late Quaternary sediments of Whitewater Draw. They are grouped according to stratigraphic units and presented in order. Most of these dates have been discussed in the previous section.

#### Late Quaternary Geologic History and Correlations

The alluvial history of Whitewater Draw is complex and characterized by deposition in two divergent energy regimens. The first type is typified by deposition in a high-energy through-flowing stream in which gravel and sand became deposited. Only two periods of erosion and deposition are characterized by this fluvial mode. The oldest (unit D) was characterized by perennial stream flow with an associated high water table. This is evidenced by the presence of thick clay deposits that filled abandoned channels in the highly permeable gravels and the presence of cottonwood and hickory charcoal. Periods of low flow are documented by silt and clay lenses within the sand, which were

Table 1. Radiocarbon dates from Whitewater Draw, southeastern Arizona

Unit	Date <sup>a</sup> (yr B.P.)	Lab. No.	Material Dated	Site	Remarks
Dunes	350±50	SMU-23 <sup>b</sup>	charcoal	--	hearth within dune sediments
O2	710±50	A-3239	charcoal	Arizona FF:6:8	hearth
N2	1,430±250	A-3182	charcoal	Arizona FF:10:16	hearth (N2b)
	1,762±430	C-518 <sup>b</sup>	charcoal	Arizona FF:6:2	solid date rejected
	2,290±190	A-3181	charcoal	Arizona FF:10:16	dispersed (N2a)
	2,860±440	A-194 <sup>b</sup>	carbonaceous alluvium	Arizona FF:6:2	Double Adobe IV, below A-193
	3,860±200	A-193 <sup>b</sup>	carbonaceous alluvium	Arizona FF:6:2	Double Adobe IV, from floor of pit house rejected
M	3,500±110	A-3183	charcoal	Arizona FF:10:13	dispersed
	4,006±270	C-515 <sup>b</sup>	charcoal	Arizona FF:10:4	solid date rejected
	4,960±300	A-192b <sup>b</sup>	carbonaceous alluvium	Arizona FF:10:4	Double Adobe III rejected
	7,560±260	A-192a <sup>b</sup>	inorganic carbonate	Arizona FF:10:4	Double Adboe III rejected
K	4,400±190	A-3313	charcoal	Tortoise locality	dispersed
	4,770±70	A-3312	charcoal	Tortoise locality	dispersed
	4,840±80	A-3311	charcoal	Bull locality	dispersed

Table 1. Radiocarbon dates from Whitewater Draw, southeastern Arizona--Continued

Unit	Date <sup>a</sup> (yr B.P.)	Lab. No.	Material Dated	Site	Remarks	
J1	5,120±130	A-3310	charcoal	Bull locality	dispersed	
	5,200±120	A-3384	charcoal	Crystal locality	dispersed	
	5,350±230	A-3308	charcoal	Arizona FF:10:14	dispersed	
H	6,750±180	A-3234	charcoal and humates	Arizona FF:6:8	Cazador level	
G1	6,940±190	A-3235	charcoal	Arizona FF:6:8	dispersed	
	6,950±170	A-3236	charcoal	Arizona FF:6:8	dispersed	
F1	9,730±100	SMU-129 <sup>b</sup>	calcium carbonate	Arizona FF:10:1	CaCO <sub>3</sub> lamination	rejected
	10,980±90	SMU-128 <sup>b</sup>	calcium carbonate	Arizona FF:10:1	CaCO <sub>3</sub> lamination	rejected
Dd (upper)	7,910±200	A-190 <sup>b</sup>	carbonaceous alluvium	Arizona FF:10:1	Double Adobe I	
Db	6,210±450	C-511 <sup>b</sup>	charcoal	Arizona FF:6:8	solid date	rejected
	7,030±260	A-184e <sup>b</sup>	carbonaceous alluvium	Arizona FF:10:1 (locality 2)	Double Adobe II	rejected
	7,756±370	C-216 <sup>b</sup>	charcoal	Arizona FF:10:1 (locality 2)	Solid date	rejected
	8,000±60	A-191 <sup>b</sup>	carbonaceous alluvium	Arizona FF:10:1 (locality 5)	Double Adobe I	rejected
	8,140±220	A-3237	charcoal	Arizona FF:6:8	Sulphur Spring artifacts	

Table 1. Radiocarbon dates from Whitewater Draw, southeastern Arizona--Continued

Unit	Date <sup>a</sup> (yr B.P.)	Lab. No.	Material Dated	Site	Remarks	
Db (con)	8,200±260	A-67 <sup>b</sup>	charcoal	AZ FF:10:1 (locality 2)	Solid date	rejected
	8,240±960	A-184c <sup>b</sup>	charcoal	Arizona FF:10:1 (locality 2)	Double Adobe II	
	8,260±160	A-188e <sup>b</sup>	carbonaceous alluvium	Arizona FF:10:1 (locality 5)	Double Adobe I	
	8,270±250	A-188c <sup>b</sup>	charcoal	Arizona FF:10:1 (locality 5)	Double Adobe I	
	8,390±190	A-3233	charcoal	Arizona FF:6:9	Sulphur Spring artifacts	
	8,500±180	A-3230	charcoal	Arizona FF:6:9	Sulphur Spring artifacts	
	8,670±340	A-3385	charcoal	Crystal locality	Black clay (Dd) below	
	8,680±100	A-189 <sup>b</sup>	carbonaceous alluvium	Arizona FF:10:1 (locality 5)	Double Adobe I	
	8,680±240	A-3387	charcoal	Arizona FF:10:1 (locality 5)	dispersed	
	8,840±310	A-3377	charcoal	Arizona FF:10:1 (locality 2)	Cazador type site	
	8,960±100	A-189 <sup>b</sup>	charcoal	Arizona FF:10:1 (locality 5)	Double Adobe I	
	9,050±260	A-3386	charcoal	Arizona FF:10:1 (locality 5)	tumbled mammoth bone	
	9,120±270	A-2235	charcoal	Arizona FF:10:1	downstream from locality 5	

Table 1. Radiocarbon dates from Whitewater Draw, southeastern Arizona--Continued

Unit	Date <sup>a</sup> (yr B.P.)	Lab. No.	Material Dated	Site	Remarks
Db (con)	9,340±180	A-3238	charcoal	Arizona FF:6:8	Sulphur Spring artifacts in this unit and below in the Da gravel
	9,350±160	A-67bis <sup>b</sup>	charcoal	AZ FF:10:1 (locality 2)	CO <sub>2</sub> rerun of A-67
	12,850±890	AA-269 <sup>b</sup>	charcoal	Arizona FF:10:14	underlies Sulphur Spring artifacts
Da	8,420±180	A-3231	charcoal	Arizona FF:6:9	upper gravel-Sulphur Spring artifacts
	8,650±180	A-3232	charcoal	Arizona FF:6:9	upper gravel-Sulphur Spring artifacts
	8,920±1150	Tx-1199	charcoal	Arizona FF:10:1	lower gravel, downstream from locality 5, associated with articulated mammoth--Sulphur Spring artifacts?
	10,420±100	A-1152	charcoal and humates	Arizona FF:10:1	lower gravel, downstream from locality 5, associated with articulated mammoth--Sulphur Spring artifacts?
	15,100±400	AA-233 <sup>b</sup>	charcoal	Arizona FF:10:14	camel and mammoth bones

a. Unless otherwise noted, dates  $\delta^{13}\text{C}$  corrected.

b. Dates not  $\delta^{13}\text{C}$  corrected.

deposited in charcos or small ponds in the channel. The youngest channel fill (unit I) is characterized by more ephemeral stream flow and flooding, and its relationship to a water table is unclear.

The second type of depositional mode is characterized by low-energy flow between a series of discontinuous ponds in which clay and silt became deposited in narrow shallow channels with low gradients. This regimen is the most common in the Whitewater Draw alluvial sequence, and two explanations are advanced to account for the formation of these deposits.

Antevs (1941, 1952, 1983) suggested that sedimentation occurred in discontinuous ponds formed behind beaver dams across a through-flowing stream. This suggestion is based on the fact that there were probably no natural obstructions along the course of the stream, that this would have been ideal beaver habitat, and that beaver were trapped historically from the San Pedro River. This, however, remains an unsupported hypothesis because no beaver skeletal remains have been found in the sediments of Whitewater Draw.

Alternatively, these sediments could have formed in thalweg plunge pools or highly vegetated shallow channels in a cienega. A cienega is a heavily vegetated marsh formed in a shallow depression. Modern cienegas, for example, the San Simon Cienega, extend over 8 km in length and 1 km in width (Wasley, 1983; Antevs, 1983). Water is supplied to the cienega by springs and seeps and travels sluggishly through shallow vegetated channels. Only fine-grained sediments are deposited in a cienega because plants on the cienega margins filter the sediment derived from the adjacent slopes and remove the coarse

fractions. Therefore, the following sequence of deposition in a cienega would be expected:

1. Massive to laminated fine-grained sediment filling a channel with little or no marginal deposition.
2. Deposition of fine-grained sediments over the channel and in the marginal areas as the cienega expands over a broader area because the water is no longer confined to a channel.
3. Soil development under saturated stable conditions obliterating laminations except in the basal portion of the channel.

This depositional sequence is represented in the alluvial succession of Whitewater Draw. Laminated to massive clays and silts, commonly with carbonized plant remains along laminations, occur in a channel. These are overlain by massive, more laterally extensive clay and silty clay deposits with soil structure. This suggests that the laminated sediments are the pool-channel facies and that the overlying massive clay and soil are the broad wet meadow facies of a cienega.

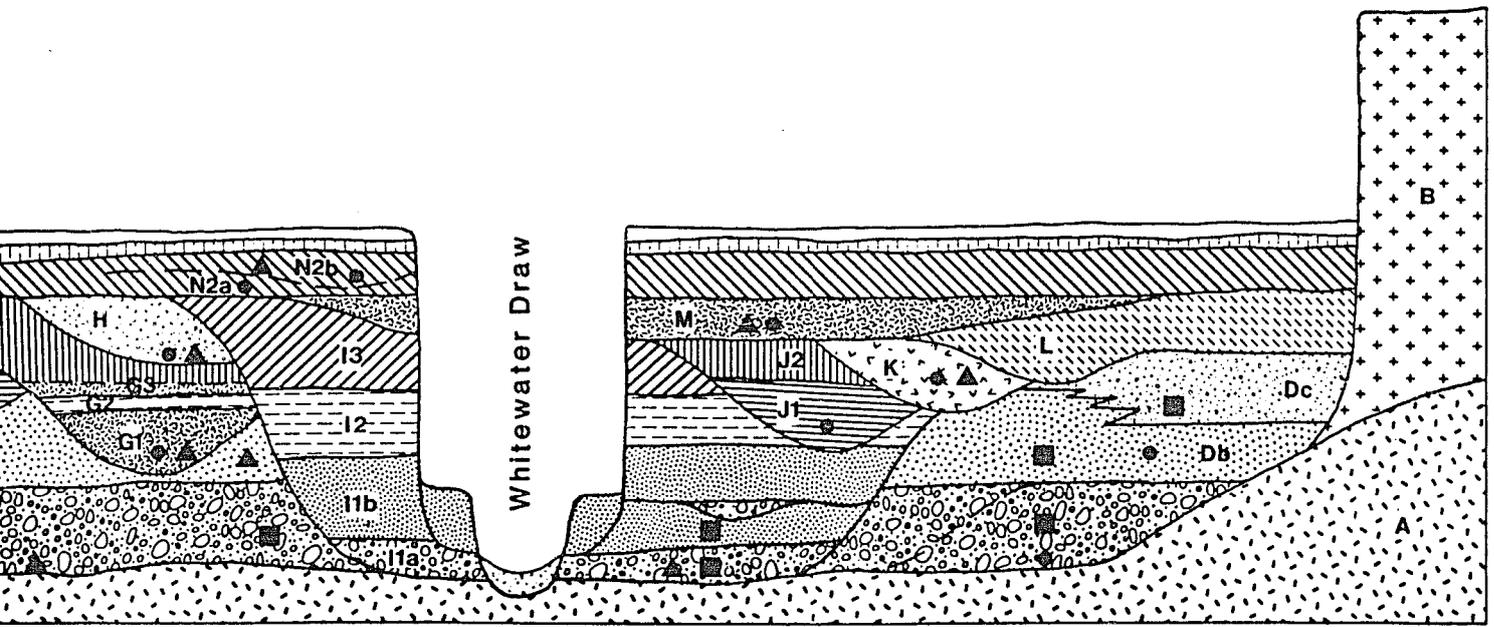
The extent of these former cienegas is poorly known because of the lack of exposure and the numerous periods of erosion during which older deposits could have been destroyed. However, the former extent of the Holocene cienegas can be estimated from the distribution of the distinctive clay-silt deposits of unit J. These deposits are found intermittently along an 11-km stretch of the arroyo and have provided similar dates at either end. These deposits indicate that at least this former cienega and probably other Holocene cienegas were larger or at least as large as modern cienegas.

Based on the data previously presented, the late Quaternary geologic history of Whitewater Draw is outlined. Figure 13 is a generalized geologic cross section of Whitewater Draw showing the stratigraphic relationships of the alluvial units. Figure 14 shows the geologic units arranged according to stratigraphic succession and the associated radiocarbon dates.

A perennial bedload stream flowed south along the axis of the Douglas basin between 15,000 and 8,000 yr B.P and left gravel and sand deposits (units Da, Db, and Dc). This stream occupied a channel that was incised into the old basin fill (unit A) and inset against Pleistocene terrace sediments (unit B). This channel probably shifted position across a broad flood plain that was no more than 0.65 km wide. This is evidenced by the presence of numerous cuts and fills within gravel unit Da and sand unit Db as shown in figure 13. The oldest gravel and sand was deposited between approximately 15,000 and 12,000 yr B.P., with later periods of gravel and sand deposition occurring between 10,500 and 8,000 yr B.P. Older gravel and sand deposits were continually reworked, and probably only a few undisturbed older sections are left. Unit Da gravels are indistinguishable from one another, and the overlying unit Db sands differ slightly. Pre-12,000-yr-B.P. sands show no evidence of charco deposition, whereas the post-12,000-yr-B.P. sands do. The discharge of the river was probably maintained by the more mesic conditions of the terminal Pleistocene and early Holocene (Van Devender and Spaulding, 1979) and possibly by spring discharge. After 8,000 yr B.P., clay (unit E2) deposition and soil formation occurred in a cienega.

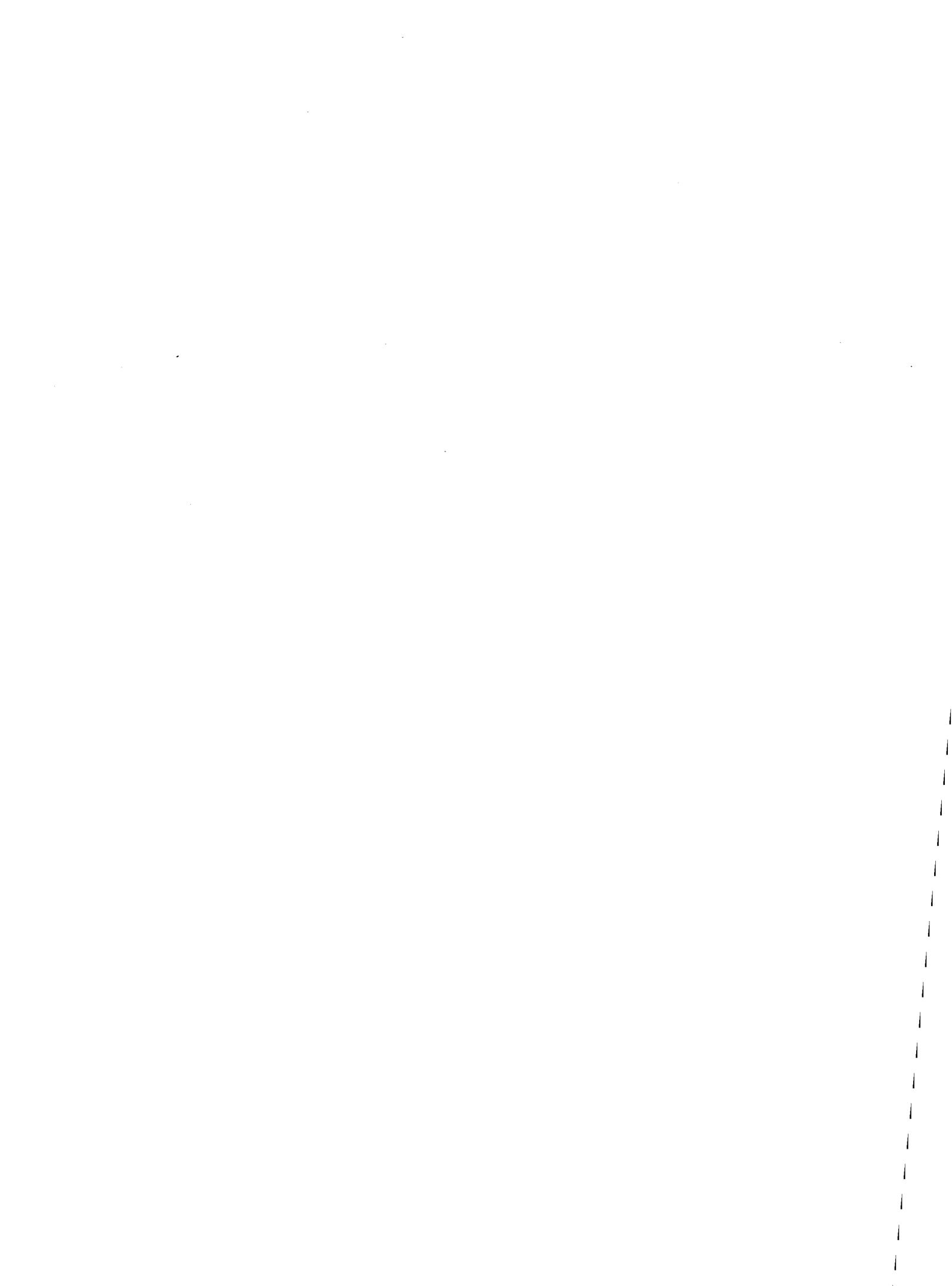






0 5m  
Vt. Scale

cross section of Whitewater Draw, southeastern Arizona







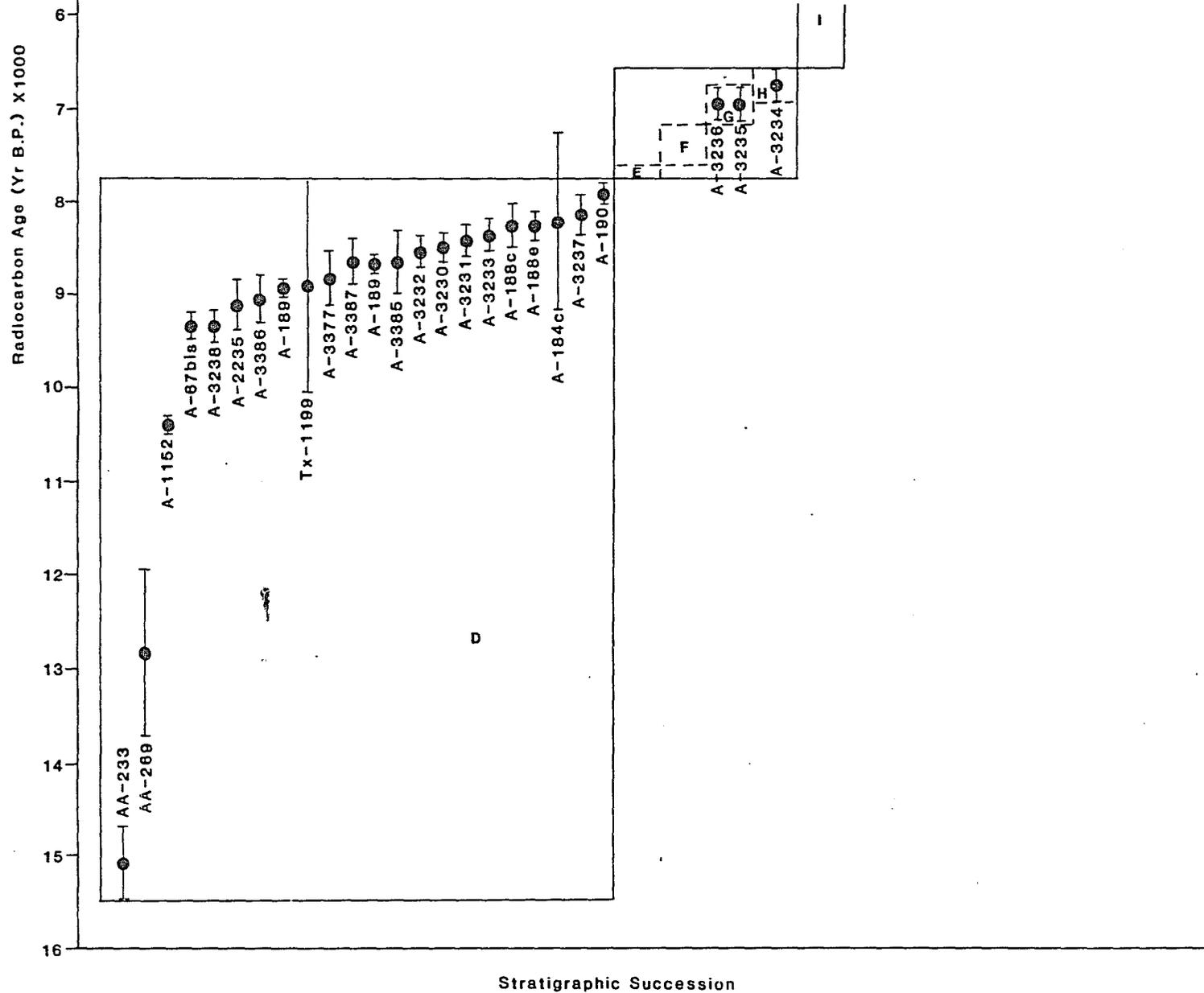


Figure 14. Radiocarbon age range of geologic units, Whitewater Draw, southeastern Arizona, -- Geologic units are indicated by capital letters. Solid lines group units deposited under similar conditions. Radiocarbon mean is indicated by a solid dot, and a one-sigma standard deviation is indicated by the bar. Radiocarbon dates are identified with number of laboratory performing age dating.



A shallow channel was incised into the unit E2 clay after 8,000 yr B.P. and filled with a laminated marl (unit F1) and massive marl (unit F2) before 7,000 yr B.P. Degradation and aggradation again occurred between 7,000 and 6,800 yr B.P., when a narrow channel was incised into the unit Db sand and unit Da gravel and filled with the unit G1 clay and unit G2 silt. Deposition took place in slightly alkaline, brackish, standing water in a series of discontinuous pools along a sluggish stream flowing through a cienega. Aggradation was completed with the deposition of clay (units G3 and G4) and soil formation.

A shallow channel cut into the cienega clay at 6,750 yr B.P. and was filled with a clayey sand (unit H). This must have been a low-gradient through-flowing stream as indicated by the abundant fish remains.

Sometime after 6,750 yr B.P. and before 5,500 yr B.P., a large channel was deeply incised into the older deposits to the old valley fill. It was filled with a gravel (unit I1a) and cross-bedded sand (unit I1b), which were probably deposited during large floods. The gravel and sand were overlain by a fining-upward sequence of horizontally laminated very fine sand and silt (unit I2), which, in turn, were overlain by a cienega soil (unit I3).

Degradation and aggradation between 5,500 and 3,500 yr B.P. is exclusively limited to cienega deposition. Four distinct periods of shallow channel incision, filling, and soil formation occurred, producing deposits J, K, L, and M. From 3,500 to 750 yr B.P., Whitewater Draw was characterized by continued cienega clay and silty clay deposition (units N and O). However, distinct channels are absent, and only

small, discontinuous, very shallow channels are associated with these clay deposits, representing numerous unrelated hiatuses. The period after 750 yr B.P. is characterized by the cutting and filling of small draws (unit P1) and the deposition of a large sheet of flood silt (unit P2). Dune activity took place in Whitewater Draw at least by 350 yr B.P., but little other data concerning the dunes is available. The modern arroyo formed between A.D. 1885 and 1910, and an inset terrace within the channel has formed since 1953.

The alluvial sequence of Whitewater Draw can be compared on a specific level with the alluvial chronology of the Murray Springs (Haynes, 1981) and Lehner sites (Haynes, 1982a) in the adjacent San Pedro Valley, Arizona, and at a general level with Haynes's (1968) alluvial chronology of the West. At both levels, the correlation is poor with one exception. The exception is the correlation of a middle Holocene arroyo-cutting event in the Douglas basin with one in the San Pedro Valley.

In the Douglas basin an arroyo was cut to a depth of 4.35 m after 6,750 yr B.P. and filled with clastic alluvium (units I1a, I1b, and I2) and a cienega clay (unit I3) before 5,500 yr B.P. A similar cutting and filling event occurred at the Murray Springs site where an arroyo was cut to a depth of 4.5 m between 7,000 and 6,500 yr B.P. and filled with clastic alluvium and a cienega clay (the Weik alluvium) between 6,000 and 4,000 yr B.P. (Haynes, 1981). A similar event took place at the Lehner site and is evidenced by the deposition of unit G1 at this site (Haynes, 1982a). The Douglas basin and San Pedro Valley were affected similarly at this time; both had arroyos cut to similar

depth and became filled with a similar type of alluvium at approximately the same time. This event is noted by Haynes (1968) on a regional scale in the West and correlates with Unit C2 of his generalized alluvial chronology. This large-scale regional cutting and filling event indicates that valleys in the West were affected uniformly by a regional climatic change.

The alluvial history of the Douglas basin differs from that in the San Pedro Valley and other valleys in the West in timing, character, and number of degradational and aggradational events. The reasons for these differences are unclear but perhaps indicate that local geomorphic controls in the Douglas basin produced a different response to external climatic perturbations compared to the other valleys in the West. Alternatively, Whitewater Draw might not have been responding to changes in external variables (if, indeed, they were changing) but instead was responding to changes in intrinsic geomorphic variables peculiar to the Douglas basin.

#### Pleistocene Extinctions in Whitewater Draw

The remains of six genera of extinct Pleistocene megafauna, mammoth, horse, camel, dire wolf, sloth, and bison, have been recovered from the upper Quaternary deposits of Whitewater Draw (Antevs, 1941, 1983, Haury, 1960). They have been found in six separate geologic units dating from the late Pleistocene to approximately 7,000 yr B.P. These include the terrace deposits (unit B), white clay (unit C), gravel (unit Da), sand (unit Db), laminated marl (unit F1), and massive marl (unit F2) (table 2).

Table 2. Geological occurrence of megafaunal remains from Whitewater Draw

Unit	Megafauna Occurrence <sup>a</sup>					
	Sloth	Mammoth	Camel	Horse	Dire Wolf	Bison
Post-I	-	-	-	-	-	-
Ila and Ilb	-	-	-	-	-	+
F2	-	-	+	-	-	-
F1	-	+	-	-	-	-
Dc	-	-	-	-	-	+
Db	-	+	+	+	-	+
Da	-	+	+	+	+	+
C	-	+	-	+	-	-
B	+	+	-	+	-	-

a. + = present; - = absent.

The early Holocene occurrences of megafauna in Whitewater Draw conflict with the accepted date for late Pleistocene extinctions in North America. Traditionally, the maximum accepted date for megafaunal extinctions has been placed at 11,000 yr B.P. (Martin, 1967). A reevaluation of the radiocarbon evidence, however, suggests that these extinctions could have taken place as late as 10,000 yr B.P., but not beyond (Kurtén and Anderson, 1980; Meltzer and Mead, 1983). Whalen (1971) has advanced two explanations to account for the early Holocene occurrence of extinct fauna in Whitewater Draw. He suggested that the evidence could be interpreted to suggest that either relict megafaunal populations survived in selected congenial environments beyond the terminal date ascribed for the extinctions or the fossil remains are older than the deposits in which they occur and have been redeposited from older alluvial units. Two criteria were used to evaluate these hypotheses: radiocarbon dates associated with bone, with reference to the ascribed date for extinctions, and the articular nature of the bones.

Disarticulated mammoth, sloth, and horse bones occur in shallow channel sediments within the terrace deposits (unit B) (fig. 2). Mammoth and horse bones have also been found scattered in the white clay (unit C) (fig. 8a). The terrace deposits and the white clays are undated, but the oldest radiocarbon date from the younger gravel (unit Da), which is inset against these units, places a minimum age of 15,100  $\pm$  400 yr B.P. (AA-233) on them. These units surely date to the late Pleistocene and thus should be expected to contain the bones of extinct fauna.

Mammoth, horse, camel, dire wolf, and bison bones have been recovered from the unit Da gravel and unit Db sand in the Double Adobe site area (Arizona FF:10:1) (fig. 8) and at Arizona FF:10:14 (fig. 9) (Antevs, 1941, 1983). The mammoth and camel bones found in the gravel at the latter site pose no problem because they are associated with a date of  $15,100 \pm 400$  yr B.P. (AA-233). Most fossils from the unit Da gravel and unit Db sand have been collected from the Double Adobe area. Most of the bones are isolated finds, but two finds of articulated remains have been reported: (1) Haury (1960) recovered articulated leg bones of a camel in the sand from which Sulphur Spring artifacts had previously been recovered and (2) Windmiller (1970) uncovered the remains of a single mammoth in gravel (unit Da) 240 m downstream from locality 5 at Arizona FF:10:1. At the latter locality, two lumbar vertebrae were found in normally articulated position and the humeri and ulnae were very close to one another with the remainder of the bones scattered in the gravel (Huckell, 1973). Radiocarbon dates on charcoal from the gravel near the mammoth are  $10,420 \pm 100$  yr B.P. (A-1152) and  $8,920 \pm 1150$  yr B.P. (Tx-1199). The latter date, with a large standard deviation, was obtained on a small sample and is of questionable accuracy. The date for the other sample may be slightly younger than its true age because the soluble humates were not removed. By extension, the articulated camel bones found upstream may date to 10,400 yr B.P. or be older. Because the bones are articulated and in one case associated with a radiocarbon date of 10,400 yr B.P. (before the maximum date of 10,000 yr B.P.), they are considered to be primary association within the gravel.

The bones recovered from the sand (unit Db) in radiocarbon-dated contexts between 9,400 and 8,000 yr B.P. are probably reworked from older sediments. They are not articulated, there are abundant older sediments from which they could have been dislodged, and they occur in a radiocarbon-dated context well beyond the maximum acceptable date of extinctions in North America.

The skull of a mammoth was recovered by Cummings in 1926 in the laminated marl (unit F1) at Arizona FF:10:1 (fig. 8b). Mammoth vertebrae and ribs were later recovered from this same deposit (Antevs, 1983). Saunders (1970) examined the teeth from the mammoth and based on dental morphology suggested that the Cumming's mammoth represented a highly advanced form of Mammuthus (Parelephos) columbi. No reliable radiocarbon dates exist from this unit, but two dates on calcium carbonate are  $10,980 \pm 90$  yr B.P. (SMU-128) and  $9,730 \pm 100$  yr B.P. (SMU-129). Radiocarbon dates from the top of the underlying sand (unit Db) and from clays (unit G1) in an overlying channel bracket the laminated marl (unit F1) between 7,000 and 8,000 yr B.P. The mammoth remains from the laminated marl were probably redeposited because they are not articulated (except for the upper tusk fragments, which were still attached to the skull), and there is no precedence for megafauna of this age anywhere in North America. The mammoth skull may have been originally deposited in the white clay (unit C) or sand (unit Db), and a shallow channel could have cut down to and through the clay or sand, uncovered the skull, and allowed it to become "cleaned-up," because it was too heavy to transport in the low-energy environment, and then rapidly reburied by the laminated marl

(unit F1), thus giving the illusion that it was in primary association within the laminated marl. This argument is strengthened by the presence of mammoth bones in the sand (unit Db) and the white clay (unit C). Mammoth bones have been found by both C. V. Haynes (1983, personal commun.) and me in unit C, 15 m directly behind the site where the Cummings mammoth was discovered (fig. 8d).

Antevs (1983) reported a camel bone from the massive marl (unit F2) at Arizona FF:10:1, locality 1. This bone would also date roughly between 7,000 and 8,000 yr B.P. and was probably in secondary context. It was probably dislodged from one of the older units and became redeposited in the massive marl (unit F2).

In summary, remains of extinct fauna found in the terrace deposits (unit B), the white clay (unit C), and the older gravel and sand (units Da and Db) dating 10,400 yr B.P. or older are considered to be in primary contexts. Remains of extinct fauna found in the younger sediments, units Db, F1, and F2, are considered to be in secondary contexts. Thus, megafaunal extinction in Whitewater Draw probably occurred no later than 10,400 yr B.P.

#### Palynology in Whitewater Draw

The only palynological studies of Whitewater Draw have been conducted by Martin (1963b). He collected pollen from four sites: Arizona FF:10:1, locality 5, designated Double Adobe I, and locality 2, designated Double Adobe II; Arizona FF:10:4, a Chiricahua phase site, designated Double Adobe III; and Arizona FF:6:2, a San Pedro phase site, designated Double Adobe IV (fig. 1). Data from the Whitewater

Draw pollen profiles were used to redefine the Altithermal as warm and mesic (Martin, 1963a, 1963b) rather than warm and xeric (Antevs, 1941, 1948, 1955b, 1962). My geological investigations show that there is a problem with the data used to formulate Martin's redefinition of the Altithermal.

The deposits sampled by Martin (1963a, 1963b) for pollen at the Double Adobe I profile are, from bottom to top: pink clay (my unit A; Martin's pink clay), gravel (unit Da; sand, silt, gravel), sand (unit Db; rusty sand, silt, charcoal), clay (unit Dd; gray clay and charcoal), silty sand (unit O11; white silt, clay), silty clay (unit O2; indurated silt), and sandy silt and silt (units P1 and P2; sandy silt, channel fill and yellow loose silt) (fig. 8c). This stratigraphy is essentially duplicated at the Double Adobe II pollen profile (Martin, 1963a, 1963b). Based on correlations with my alluvial chronology of Whitewater Draw, the lower upper Quaternary units (Da, Db, and Dd) range from 10,400 to approximately 8,000 yr B.P. A major unconformity, as noted by Haynes (1968), separates unit Dd and the overlying units O11, O12, P1, and P2. The upper three units were deposited sometime between 1,500 yr B.P. and the historic period based on correlation with my alluvial sequence.

The stratigraphy at the Double Adobe III and IV pollen profiles postdates 3,500 yr B.P. The deposits at Double Adobe III are similar to those at site Arizona FF:10:13 and are, from bottom to top: clay (my unit A; Martin's pink clay), sand and clay (?), clay (unit M; blue clay), clay and silty clay (unit N2 or unit O2; silt, silty clay), and sandy silt (unit P2; sandy silt). The upper stratigraphy containing

the San Pedro phase pithouse at the Double Adobe IV profile probably dates to less than 2,800 yr B.P., correlating with my units N2 and O2. The radiocarbon date obtained by Martin (1963b) from the pithouse fill,  $3,860 \pm 200$  yr B.P. (A-193) was here considered too old and the date of  $2,860 \pm 440$  yr B.P. (A-194) from below the pithouse was accepted. The former date is not in accord with other dates from these units, whereas the latter date is. It is possible that charcoal from an older unit was introduced into the pithouse.

In summary, the pollen profiles reported by Martin (1963b) from Whitewater Draw cover a range of sediments dating from approximately 10,500 to 8,000 yr B.P. and from 3,500 yr B.P. to the historic period. Therefore, the Altithermal (7,500-4,500 yr B.P.) is not represented in the pollen profiles as originally thought by Martin (1963a, 1963b). He used the palynological data from Whitewater Draw and Murray Springs to infer that the Altithermal was warm and mesic. This interpretation is greatly undermined by the proper placement of the pollen profiles in the Whitewater Draw alluvial sequence.

## ARCHAEOLOGY OF WHITEWATER DRAW

Archaeological remains of the Cochise Culture are found in nearly all the upper Quaternary deposits of Whitewater Draw. This discussion, however, focuses primarily on the Sulphur Spring and Cazador phases, the earliest phases of the Cochise Culture.

### The Sulphur Spring Phase

The Sulphur Spring phase was defined by Sayles (1941, 1983c) as the earliest phase of the Cochise Culture. As originally defined, this artifact assemblage was characterized by milling stones, hand-stones, percussion-flaked knives, scrapers, and choppers, and by the absence of bifacially flaked knives and projectile points. These artifacts were considered to be in primary association with mammoth, horse, camel, dire wolf, and bison remains. Sulphur Spring artifacts were recovered from six sites along Whitewater Draw and one site on the shoreline of pluvial Lake Cochise. Antevs (1941, 1983) considered this phase to date from 12,500 to 11,000 yr B.P., based on a geologic estimate. The following discussion redefines the Sulphur Spring phase in terms of site identification, material culture, chronological placement, and association with extinct fauna.

#### Sites

Four Sulphur Spring phase sites occur in Whitewater Draw: Arizona FF:6:9 (GP Pearce 8:21); Arizona FF:6:8 (GP Pearce 8:10); Arizona FF:10:1 (GP Sonora F:10:1 (Double Adobe site), localities 1, 2,

3, 4, and 5); and Arizona FF:10:14 (GP Sonora F:10:17) (fig. 1). This is a revision of the original Sulphur Spring site inventory (Sayles, 1941, 1983c), which included sites Arizona FF:6:10 (GP Pearce 8:17), Arizona FF:10:15 (GP Sonora F:10:40), and Arizona CC:13:3 (GP Arizona L:13:10) and did not include locality 2 at Double Adobe (fig. 1). Sulphur Spring phase artifacts have also been found at the Lehner site in the San Pedro Valley, Arizona (Haynes, 1982a).

At Arizona FF:6:9, Arizona FF:6:8, and Arizona FF:10:1 (localities 1-5), Sulphur Spring artifacts occur in a channel gravel, unit Da, and in the overlying sand, unit Db (figs. 3, 4, and 8). These artifacts occur in secondary contexts. The presence of abundant charcoal and the concentration of unabraded artifacts and hearthstones in the deposits suggest that this material did not move far from its source and was probably eroded from campsites that were adjacent to the stream.

At Arizona FF:10:14, Sulphur Spring artifacts occur in unit Dc, a cross-bedded silty sand with dispersed gravel, probably representing a flood bar (fig. 9). Here, artifacts have only been very slightly disturbed because a partially articulated human burial and numerous secondary flakes were recovered from the deposit. The Sulphur Spring campsite was on the flood bar and is the least disturbed of all Sulphur Spring phase sites.

Arizona FF:10:15 and Arizona FF:6:10, minor sites that produced only six artifacts, were not examined. I have reservations about assigning them to the Sulphur Spring phase based on Antevs (1941) brief stratigraphic descriptions because of the problem of stratigraphic

repetition within the Whitewater Draw alluvial sequence. Two possibilities exist for the placement of these artifacts; they occur either in units Da and Db or in units I1a and I1b. If they occur in the former beds, they would be Sulphur Spring age; however, if they occur in the latter deposits, they would be later. These sites must remain problematical until they can be further investigated.

The greatest revision of the original site inventory is the inclusion of locality 2 at Double Adobe with the Sulphur Spring phase. Locality 2 was originally defined (Sayles, 1983a) as the type site of the Cazador phase, a phase intermediate between the Sulphur Spring and Chiricahua phases. My investigations have invalidated the Cazador phase and have shown the deposits at locality 2 to be the same age as the other localities at Arizona FF:10:1 (see Cazador section for details).

The correlation of Arizona CC:13:3, a site on the shoreline of pluvial Lake Cochise in the Willcox basin, with those in Whitewater Draw is tenuous. These artifacts do not occur in beach gravels as reported by Sayles (1983c) and Haury, Antevs, and Lance (1953) but instead occur in colluvium overlying well-cemented beach sediments of ancient pluvial Lake Cochise. Because the age of the colluvium is unknown, the correlation of this site with the Sulphur Spring sites in Whitewater Draw is open to question.

#### Material Culture

The material culture of the Sulphur Spring phase is very poorly represented. The artifact assemblage consists of 139 ground-stone and 55 flaked-stone artifacts. This material comes from sites Arizona

FF:6:8, Arizona FF:6:9, Arizona FF:10:1 (localities 1, 2, 3, 4, and 5), and Arizona FF:10:14. All the artifacts I collected and only some of the artifacts collected by Sayles and Antevs (1941) were used for this discussion.

Four hundred forty-eight artifacts collected from six sites were used to formulate the original definition of the Sulphur Spring material culture (Sayles, 1941). I have reservations about the stratigraphic position of artifacts collected from some of these sites.

At Arizona FF:10:15 and Arizona FF:6:10, the artifact-bearing strata cannot be shown to be the equivalent of the Sulphur Spring artifact-bearing gravel (unit Da) and sand (unit Db) elsewhere (see previous section). These sites yielded only six artifacts, making only a minor contribution to the total assemblage (Sayles, 1941). These artifacts were not used here.

A major revision is the assignment of artifacts from Arizona FF:10:1, locality 2, to the Sulphur Spring phase and their use in this analysis. This was done because the artifact-bearing strata (units Da and Db) at locality 2 were shown to be the same age as the other Sulphur Spring localities at Arizona FF:10:1 and elsewhere. However, only those artifacts collected during the October 1953 excavations (particularly three projectile points) were examined. I have reservations about the stratigraphic position of artifacts, especially 9 of the 12 projectile points, which include side-notched and serrated forms, found in May 1953. According to Sayles's (1953) notes, these artifacts were not excavated but collected from the modern streambed gravel adjacent to the arroyo bank and inferred to have come from the artifact-bearing

gravel (unit Da) and sand (unit Db). All the flaked-stone tools and only a handful of the ground-stone artifacts remain in the Arizona State Museum collections.

Site Arizona FF:6:8 was first described as a pure Sulphur Spring locality with artifacts occurring in five geologic units (Sayles and Antevs, 1941). These were combined by Sayles in his 1941 artifact analysis. My investigations have shown that the upper two artifact-bearing strata (units G1 and H) from which most of the artifacts originated are not Sulphur Spring in age. Unfortunately, the collections no longer exist and it is impossible to determine which artifacts came from the upper and lower units; thus, Sayles's (1941) artifact tabulations for this site could not be used.

There is no confusion concerning the stratigraphic position of artifacts collected by Sayles and Antevs (1941) from Arizona FF:6:9, Arizona FF:10:14, and Arizona FF:10:1 (localities, 1, 3, 4, and 5). All the existing artifacts were examined and Sayles's 1941 tabulations were used in this analysis.

The following analysis is descriptive because the total collection of 194 artifacts is inadequate for a statistical study. I have retained Sayles's 1941 ground-stone artifact categories and tabulations (with only slight modification) because the collections no longer exist, preventing a reanalysis. The total number of ground-stone versus flaked-stone tools is biased because of the nature of the available collections. In site contexts, ground-stone artifacts far outnumber flaked-stone tools at all sites except Arizona FF:10:14 and Arizona FF:10:1, locality 2.

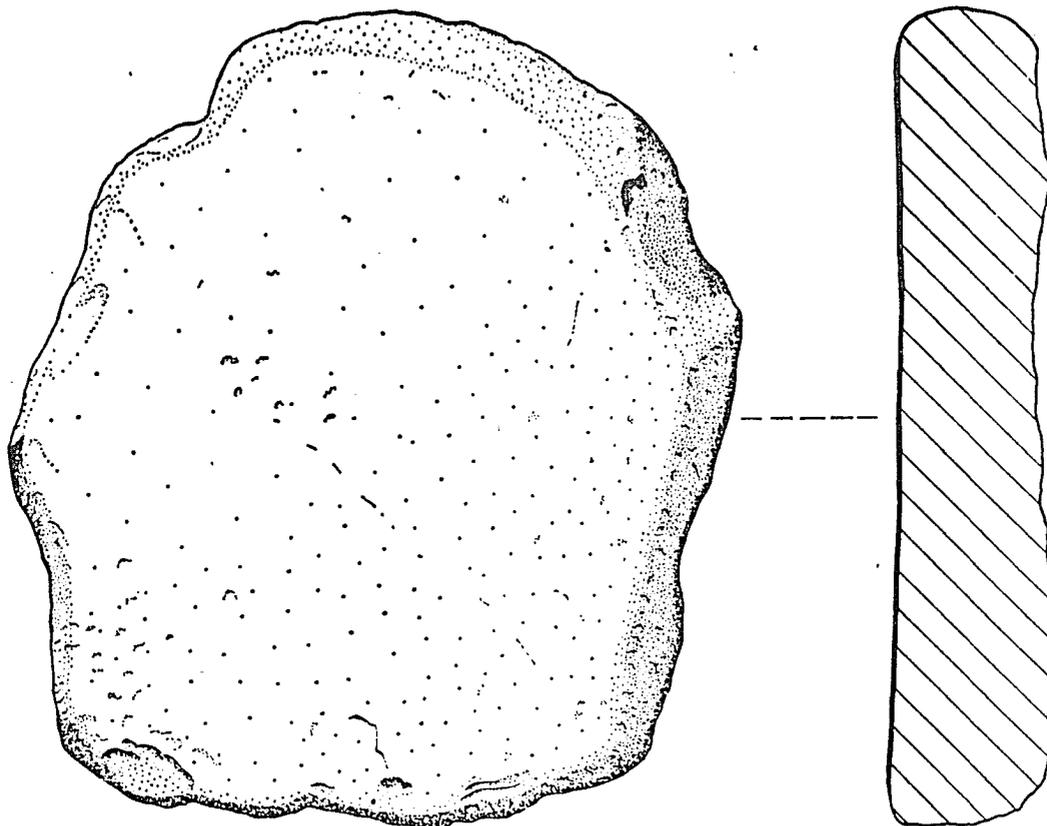
Ground-stone Artifacts. Ground-stone artifacts are the most common element of the Sulphur Spring assemblage (Sayles, 1941, 1983c). These artifacts are milling stones and handstones (fig. 15, table 3).

Milling stones made from tabular pieces of sandstone or quartzite are unshaped and modified only through use (fig. 15a). The grinding surfaces are flat to slightly concave and occasionally show evidence of pecking. Milling stones have commonly been used on both sides. They range from large (ca. 35 cm across) to small (ca. 10 cm across), possibly suggesting different functions: perhaps food and pigment grinding. Complete specimens are rare; most are fragmentary and show evidence of firecracking.

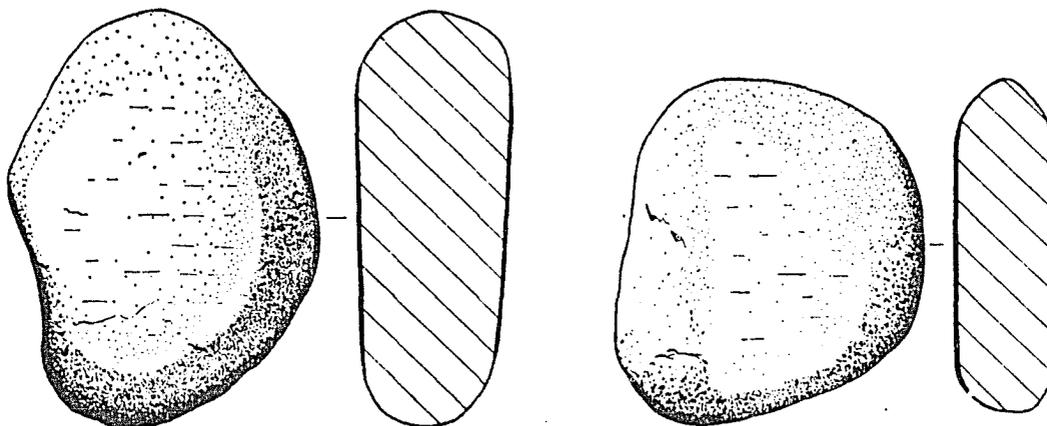
Unifacial and bifacial handstones are common (Sayles, 1941, 1983c) (figs. 15b and 15 c). They are generally made from sandstone

Table 3. Ground-stone artifact distribution at Sulphur Spring sites

Site	Handstones				Milling Stones	Totals
	Asymmetric Biface	Asymmetric Uniface	Symmetric Biface	Frag- ments		
Arizona FF:6:9	3	6	1	1	14	25
Arizona FF:10:1	2	20	2	0	38	62
Arizona FF:10:14	2	2	4	5	17	30
Arizona FF:6:8	<u>5</u>	<u>1</u>	<u>2</u>	<u>1</u>	<u>13</u>	<u>22</u>
Totals	12	29	9	7	82	139



a. Unshaped milling stone



b. Unshaped asymmetrical  
bifacial handstone

c. Unshaped asymmetrical  
unifacial handstone

Figure 15. Sulphur Spring ground-stone artifacts. -- By permission, E. B. Sayles, "Sulphur Spring Stage," in The Cochise Cultural Sequence in Southeastern Arizona, Anthropological Paper No. 42, Tucson: The University of Arizona Press, Copyright 1983.

or quartzite cobbles and are unmodified except through wear. A few specimens have been shaped by pecking the entire periphery of the stone. The short axis of the grinding surfaces are either flat or slightly convex and are occasionally modified by pecking. The edges of many handstones are battered. Many specimens are fire cracked.

Flaked-stone Artifacts. Flaked-stone artifacts are predominantly unifacial; bifacial flaking is rare. Basalt, rhyolite, chalcedony, chert, siliceous mudstone, quartzite, and obsidian were used to make tools (fig. 16; table 4).

The most common tools are unifacial percussion-flaked side-scrapers, end-scrapers, and side-and-end-scrapers made on primary flakes of all sizes (figs. 16e-16j, 16l). The worked edges are commonly straight to convex, but several have concave edges (fig. 16m) and graver tips. Reverse flaking, a method of preparing opposite faces on opposite edges of a flake, is noted in the collection (Sayles, 1983c). Two unifacially retouched cortical or teshoa flake scrapers were found.

Domed or plano-convex scraper-cores are common (figs. 16n-16p). These tools have either a prepared or more commonly a natural flat platform from which flakes were driven. The flaked edges are steep, ranging from 80 to 85 degrees.

Cobble core-choppers are usually unifacially flaked along one edge of the cobble, leaving cortex at the other (fig. 16k). Only a few bifacial specimens were found.

Three biface (projectile point) fragments were found at Arizona FF:10:1 (locality 2) by Sayles (1983), and I found one fragment at



Figure 16. Sulphur Spring flaked-stone artifacts. -- (a)-(d) bifaces (projectile points); (e)-(j) side and end flake scrapers. Photograph by Helga Teiwes, Arizona State Museum, Tucson.

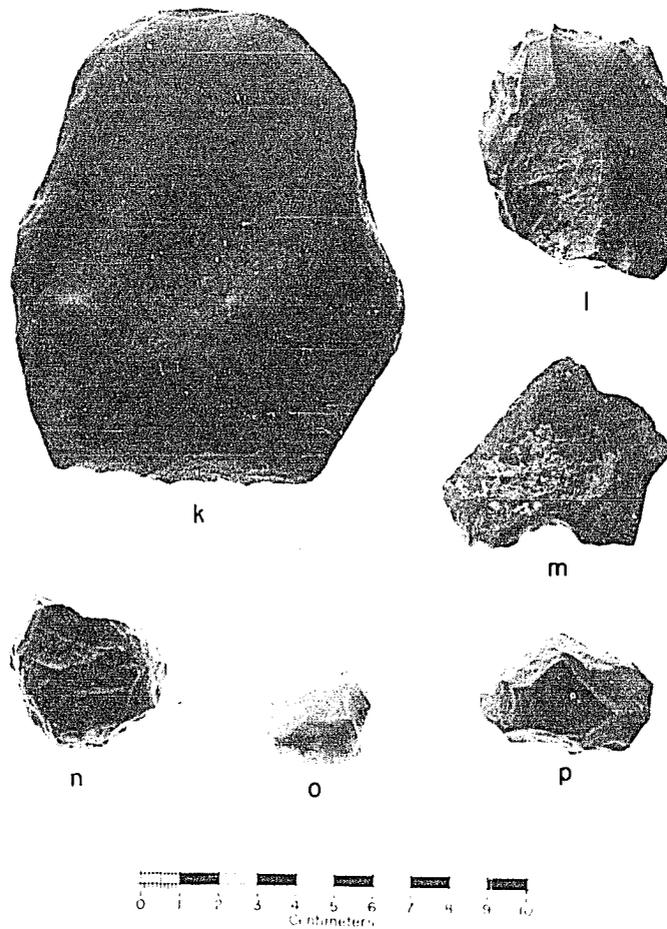


Figure 16. Sulphur Spring flaked-stone artifacts--Continued.  
 -- (k) cobble core-chopper; (l) side scraper; (m) concave flake  
 scraper; (n)-(p) domed or plano-convex scraper-cores. Figure 16o is  
 shown in cross section. Photograph by Helga Teiwes, Arizona State  
 Museum, Tucson.

Table 4. Flaked-stone artifact distribution at Sulphur Spring sites

Site	Flaked-stone Artifacts						Totals
	Unifacial Scraper	Plano- convex Scraper	Chopper	Bifacial Knife	Point	Hammerstone	
Arizona FF:6:9	0	0	0	0	0	0	0
Arizona FF:10:1	8	8	9	3	3	7	38
Arizona FF:10:14	11	3	2	1	0	0	17
Arizona FF:6:8	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
Totals	19	11	11	4	3	7	55

Arizona FF:10:14 (fig. 16b). The three projectile points (figs. 16a, 16c, and 16d) from Arizona FF:10:1 were originally assigned to the Cazador phase by Sayles (1983a) and are here reassigned to the Sulphur Spring phase. Two are rounded base fragments made of chert (figs. 16a and 16b), another is the midsection of a chalcedony biface (fig. 16c), and the fourth is the tip of an obsidian projectile point (fig. 16d). Three bifacially retouched flake knives have been recovered.

Hammerstones are made from either a waterworn cobble or an exhausted core-chopper. Unmodified debitage has been found at most sites.

Shell and Bone. A fragment of a marine gastropod (Olivella) was recovered from unit Db sand containing Sulphur Spring artifacts at Arizona FF:10:1 (Antevs, 1941). This shell was obviously transported to this site by man and may have been part of a shell ornament.

A possible bone tool made from a mammoth leg bone is reported from Arizona FF:10:1, locality 1 (Sayles, 1983b). It is spirally fractured and extremely waterworn. Spirally fractured bone is not the exclusive work of man, and the artifactual nature of the bone is doubtful.

#### Burials

A Sulphur Spring phase burial was discovered in unit Dc at Arizona FF:10:14 (fig. 9). Sayles and Antevs (1941) had also recovered human skeletal remains of another individual from this deposit. Unfortunately, the burial was exposed by a backhoe, which removed most of the bones and left only the upper skull and a portion of the

mandible in situ (fig. 17). Based on the nature of the bones encased in the hard sediment and the location from which the bones came, the conclusion was made that the skeleton had been partially articulated and was either in a tightly flexed position or was a bundle burial. The orientation of the face was northwest, based on the in situ position of the upper skull fragment. The remains are those of an adult. The teeth are worn smooth and exhibit a sinodont dental pattern (Turner, 1983). No grave offerings were found with this burial, but numerous artifacts were found in the same unit. Some post-depositional rodent disturbance of the bones was noted. Radiocarbon dates at the site bracket the age of the skeleton between  $5,350 \pm 230$  yr B.P. (A-3308) and  $12,850 \pm 890$  yr B.P. (AA-269). Radiocarbon dates from other Sulphur Spring phase sites place the age of the remains between 8,000 and 10,000 yr B.P. and possibly as early as 10,500 yr B.P.

#### Dating

Antevs (1983) placed a final estimate on the age of the Sulphur Spring phase of more than 12,500 to 11,000 yr B.P., based on geologic-climatic dating. Geologic-climatic dating was a method used by Antevs (1955a, 1955b) to date archaeological sites in the arid and semiarid West. It consists of attributing a deposit with archaeological remains to a particular dated climatic period. A relative regional climatic history for the West was deduced from a variety of data and roughly dated by correlation to the North American and Finno-Swedish varve chronologies. The climatic episodes defined by Antevs (1941, 1948, 1955a, 1962, 1983) were, from oldest to youngest: subhumid Provo Pluvial

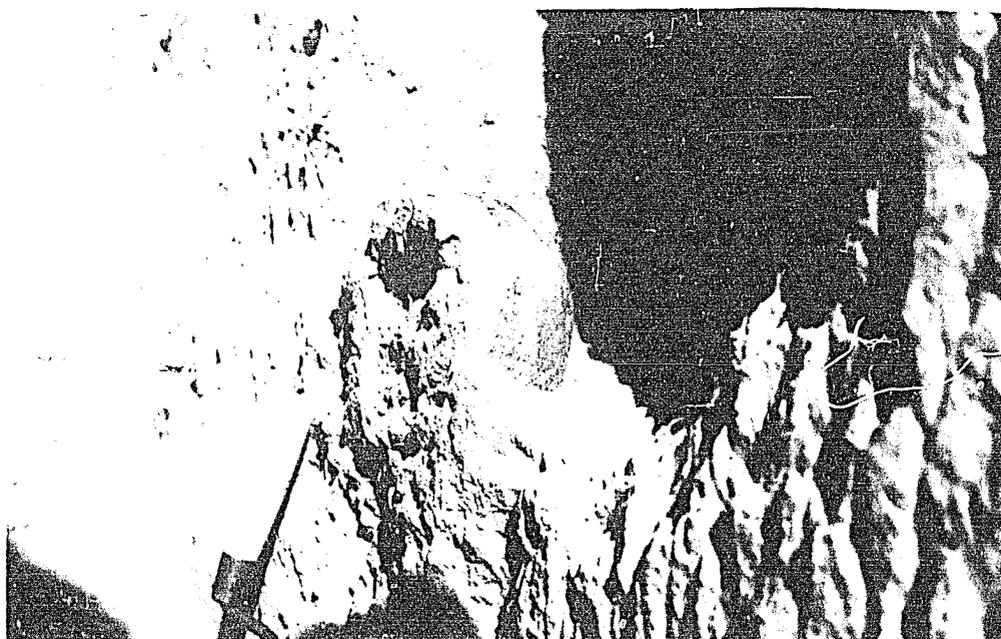


Figure 17. Human skull and mandible fragment in situ. --  
Sulphur Spring phase burial, Arizona FF:10:14, unit Dc.

(>14,000-10,000 yr B.P.), semiarid Anathermal (10,000-7,500 yr B.P.), arid Altithermal (7,500-4,000 yr B.P.), and semiarid Medithermal (4,000 yr B.P.-present). Fundamental to the geologic-climatic dating method is the dependence of geological processes and thus the physical characteristics of a deposit on vegetation and specific climatic regimes (especially temperature and moisture). For example, Antevs (1955b) considered distinctly laminated deposits indicative of subhumid Pluvial age sediments. He also believed that calcium carbonate accumulation occurred during the arid Altithermal. The parent deposits in which the caliche accumulated and the beds below the caliche-bearing strata were interpreted to be pre-Altithermal, and the deposits in channels cut into them post-Altithermal. Supplementary data were provided by vertebrate fossils and macrofloral evidence; extinct fauna indicated Pluvial sediments and modern fauna post-Pluvial sediments. Thus, by examining the deposits for diagnostic characteristics and assigning the deposits to a specific climatic phase it was possible to date an archaeological site.

Antevs (1941, 1955b) used the following logic to date the Sulphur Spring phase at the Double Adobe site (Arizona FF:10:1). In stream-deposited gravel (unit Da) and sand (unit Db), Sulphur Spring artifacts, remains of mammoth, horse, camel, dire wolf, and bison, and hickory charcoal are found. These deposits are overlain by a distinctly laminated marl (unit F1) containing mammoth bones, which Antevs (1941, 1983) believed lay in primary context. Overlying this unit was a massive marl (unit F2). These pond sediments are heavily impregnated

with soft calcium carbonate and interlaminated with hard flat  $\text{CaCO}_3$  concretions.

From these observations Antevs (1941, 1955b) considered the gravel, sand, and marl deposits to indicate permanent water and a sub-humid pluvial climate. The heavy calcium carbonate accumulation in the pond deposits were interpreted to be Altithermal; therefore the pond deposits themselves were pre-Altithermal or Pluvial. The occurrence of hickory charcoal and remains of extinct fauna, especially mammoth, in the sand and gravel also suggested a moist pluvial climate. Antevs concluded that the artifacts of the Sulphur Spring phase belonged to the Provo Pluvial and dated in excess of 10,000 yr B.P.

Antevs (1983) proposed a more precise dating of the Sulphur Spring phase in 1983 by reference to the mammoth remains in the laminated pond sediments, the assumed moisture requirements of mammoth, and a late Provo Pluvial drought, the Datil, which occurred between 12,500 and 10,500 yr B.P. Antevs (1983) assumed that mammoth required a dense luxurious vegetation to survive and concluded that a climate more moist than now must have prevailed in the area. Consequently, he concluded that mammoth became extinct in the Southwest during either the first late Pluvial or a post-Pluvial drought. Antevs (1983) favored the former date and believed that the mammoth became extinct by about 11,500 yr B.P. during the Datil Drought. He concluded that the Sulphur Spring artifacts, occurring in a moist-climate bed beneath mammoth remains, were derived from the Double Adobe I Subpluvial (before the Datil Drought) of the late Provo Pluvial and

therefore dated in excess of 12,500 yr B.P. Similar logic was employed to date other sites to the Sulphur Spring phase.

Sayles and Antevs returned to Whitewater Draw in 1951 after the introduction of the radiocarbon dating method to collect samples to date the phases of the Cochise Culture, especially the Sulphur Spring phase. In the Double Adobe area they discovered charcoal and artifacts in a gravel and sand similar to the Sulphur Spring phase sediments at other localities at Double Adobe, but they considered this material to be Cazador not Sulphur Spring. Therefore all the early radiocarbon dates derived by the solid radiocarbon method from locality 2 material were attributed to the Cazador and not to the Sulphur Spring phase. Because my research has shown that the sediments at locality 2 are Sulphur Spring in age and that the Cazador is not a valid phase, the dates did apply to the Sulphur Spring phase. These dates are  $7,756 \pm 370$  B.P. (C-216) and  $8,200 \pm 260$  yr B.P (A-67). A single date of  $6,210 \pm 450$  yr B.P. (C-511) was obtained from the Sulphur Spring-bearing sand at Arizona FF:6:8. Antevs (1983) considered this date incorrect and disregarded it in favor of his geologic estimate.

No more radiocarbon dates were obtained until Martin's (1963b) palynological work at the Double Adobe I pollen profile. He obtained six dates, ranging from 8,960 to 8,000 yr B.P (table 1) on charcoal and carbonaceous sediments from deposits he believed were correlative with the Sulphur Spring phase sediments at locality 5. Sayles (1965, 1983b) and Antevs (1983) disagreed with this geologic assessment and reassigned the section to the Cazador phase by correlation to locality 2. Rogers (1959) visited the Double Adobe I profile late in 1959 and found

a horse tooth in the gravels. His find would tend to support Martin's correlation. Nevertheless, these dates apply to the Sulphur Spring phase because, as stated previously, locality 2 is now considered to be Sulphur Spring. Martin (1963b) also obtained two dates directly from locality 2, which are  $8,240 \pm 960$  yr B.P. (A-184c) and  $7,030 \pm 260$  yr B.P. (A-184e).

In the early 1960s, the solid carbon residue of sample A-67 from locality 2 was found and redated by the  $\text{CO}_2$  radiocarbon method and gave an age of  $9,350 \pm 160$  yr B.P. (A-67bis) (Damon and Long, 1962). During a highway salvage operation near Double Adobe in 1970, Haynes (1971) obtained two dates,  $10,420 \pm 100$  yr B.P. (A-1152) and  $8,920 \pm 1150$  yr B.P. (Tx-1199) on charcoal from unit Da gravel in association with mammoth bones. Although no artifacts were found at that time, artifacts had previously been found in similar gravels 240 m upstream.

Much speculation has surrounded the dating of the Sulphur Spring phase because of the unreliability of solid radiocarbon dates, the poor quality of the early  $\text{CO}_2$  dates (pretreatment, material dated), and confusion over the correlation of the Cazador and Sulphur Spring phases. Nine dates from deposits containing Sulphur Spring phase remains at four sites (table 5) and additional dates from the units Da and Db alluvium (table 1) provide dating control.

The unit Da gravel and unit Db sand containing Sulphur Spring artifacts at Arizona FF:6:9 date between approximately 8,390 yr B.P. and 8,650 yr B.P. based on four radiocarbon analyses (fig. 3, table 5). The Sulphur Spring artifact-bearing unit Db sand at Arizona

Table 5. Radiocarbon dates associated with Sulphur Spring artifacts

Site	Unit	Laboratory Number	Date (yr B.P.)
Arizona FF:6:9	Db	A-3233	8,390±190
		A-3230	8,500±180
	Da	A-3231	8,420±180
		A-3232	8,650±180
Arizona FF:6:8	Db	A-3237	8,140±220
		A-3238	9,340±180
	Da		no dates
Arizona FF:10:1	Db <sup>a</sup>	A-3377	8,840±310
	Da <sup>b</sup>		no dates
Arizona FF:10:14	Dc		no dates
Lehner site, Arizona		SMU-197	9,860±80
		SMU-204	9,900±80

a. Ten additional radiocarbon dates range from 8,000 yr B.P. to 9,340 yr B.P. for unit Db at Arizona FF:10:1 but are not directly associated with artifacts (see table 1).

b. Two radiocarbon dates on charcoal of 10,420±100 yr B.P. (A-1152) and 8,920±1150 yr B.P. (Tx-1199) were obtained from unit Da 240 m downstream from Arizona FF:10:1 but were not directly associated with artifacts (see table 1).

FF:6:8 dates between about 8,140 yr B.P. and 9,340 yr B.P. on the basis of two radiocarbon analyses (fig. 4, table 5). The artifact-bearing unit Da gravel is undated, but is older than 9,340 yr B.P. At Arizona FF:10:1 a date of  $8,840 \pm 310$  yr B.P. (A-3377) is associated with artifacts in the unit Db sand (fig. 8, table 5). Ten additional radiocarbon dates from the unit Db sand range from approximately 8,000 to 9,350 yr B.P. (table 1). Artifacts have also been recovered from the underlying gravel (unit Da) that is older than 9,350 yr B.P. Only two dates have been obtained from the gravel:  $10,420 \pm 100$  yr B.P. (A-1152) and  $8,920 \pm 1150$  yr B.P. (Tx-1199); these were associated with mammoth remains but no artifacts. These two dates may be applicable to the artifact-bearing gravel (unit Da) at Double Adobe and Arizona FF:6:8. However, this must remain speculative because these dates are not associated with Sulphur Spring artifacts. No dates were obtained from the Sulphur Spring deposit (unit Dc) at Arizona FF:10:14. Two radiocarbon dates on charcoal,  $9,860 \pm 80$  yr B.P. (SMU-197) and  $9,900 \pm 80$  yr B.P. (SMU-204), are associated with Cochise Culture artifacts at the Lehner site, Arizona (Haynes, 1982a). These artifacts directly overlie the Clovis horizon dated at  $10,890 \pm 40$  yr B.P. (average of 15 dates, Haynes, 1983, personal commun.).

Therefore, radiocarbon dates from strata containing Sulphur Spring artifacts at three sites in Whitewater Draw and from the Lehner site place the Sulphur Spring phase between approximately 8,000 and 10,000 yr B.P. At two sites in Whitewater Draw, artifacts occur in gravel (unit Db) of unknown age below deposits dated at 9,400 yr B.P. If the dates from the unit Da gravel at Double Adobe can be applied to

the Sulphur Spring phase, which I believe they can, it would indicate that this phase extends back to 10,500 yr B.P. Although the evidence for a beginning date of 10,500 yr B.P. for the Sulphur Spring phase is compelling, additional data are needed to ascertain its true maximum age.

#### Extinct Faunal Associations

No extinct faunal remains were found in Sulphur Spring artifact-bearing deposits at Arizona FF:6:8 or at Arizona FF:6:9. Bison was found in the Sulphur Spring artifact-bearing unit Dc sand at Arizona FF:10:14, and mammoth and camel bones were found in deposits below unit Dc, but these bones were not associated with artifacts. The only associations between extinct fauna and Sulphur Spring artifacts occurs at Arizona FF:10:1, where mostly unarticulated mammoth, horse, camel, dire wolf, and bison remains have been recovered from unit Da gravel and unit Db sand with artifacts of the Sulphur Spring phase (Sayles and Antevs, 1941).

As mentioned earlier, the remains of mammoth and camel are considered to be in primary association in the unit Da gravel dating 10,400 yr B.P. because these bones are in articulated relationship and the associated date falls before the maximum accepted date of 10,000 yr B.P. for extinctions in North America. However, the megafaunal remains in unit Db sand dating between 8,000 and 9,400 yr B.P. are considered to be redeposited from older sediments and therefore not in primary association with the Sulphur Spring artifacts.

It is possible that Sulphur Spring people did temporally overlap with relict populations of Pleistocene megafauna during the terminal Pleistocene. The oldest direct dates associated with the Sulphur Spring artifacts are about 10,000 yr B.P., but this phase could date as early as 10,500 yr B.P. Sulphur Spring artifacts and articulated megafaunal remains have not been found in direct association. Instead the mammoth dated at 10,400 yr B.P. was found in gravel 240 m downstream from the Arizona FF:10:1 localities where artifacts occur in similar gravel deposits below those with dates of 9,400 yr B.P. The articulated camel remains reported by Haury (1960) at Arizona FF:10:1 were recovered from deposits that had previously yielded Sulphur Spring phase artifacts, but no artifacts were found with the camel remains. Although the evidence for an overlap is compelling, the question remains unresolved because no direct association of articulated megafaunal remains and Sulphur Spring artifacts have been found. It is possible, although, in my opinion, unlikely, that the megafaunal remains occur in gravels dating 10,400 yr B.P., whereas the Sulphur Spring artifacts occur in directly superimposed post-10,400 yr B.P. gravels.

#### Discussion of the Sulphur Spring Phase

The presence of two divergent tool assemblages, one emphasizing hunting (Clovis) and the other plant gathering (Cochise), of seemingly similar antiquity in southeastern Arizona has led to much speculation. Some researchers (Haury, Antevs, and Lance, 1957; Martin and Plog, 1973; Haury, 1983) have suggested that the Sulphur Spring

material could represent specialized plant-gathering stations of the Clovis Culture. However, failure to find diagnostic artifacts of the two cultures mixed on a site, their superposition at the Lehner site (Haynes, 1982a), and the chronological placement of the Sulphur Spring phase show that they are not temporally equivalent and invalidate this hypothesis.

The Sulphur Spring phase of the Cochise Culture, dated between 8,000 and 10,000 yr B.P. and probably as early as 10,500 yr B.P., is the oldest recognized archaic manifestation in southeastern Arizona. It is encompassed under the "Desert Culture" concept (Jennings, 1964, 1978) at the adaptational level and will be shown to be one of two early archaic traditions in southern Arizona as suggested by Haury (1950) and Rogers (1958).

The Sulphur Spring artifact assemblage is dominated by ground-stone artifacts, as are all later assemblages at Cochise Culture sites in Whitewater Draw. These artifacts indicate that the Douglas basin was the site of specialized plant gathering and processing. Other Sulphur Spring artifacts indicate that limited hunting and other activities took place, but that plant processing was the primary concern. These sites probably represent part of a wider pattern of seasonal resource exploitation followed by a single people who traveled widely.

Ventana Cave in Pima County, south-central Arizona, is the only dated site in the Southwest of similar antiquity and to which comparisons with the Sulphur Spring phase artifacts can be made. Here, the Ventana Complex defined by 90 artifacts, including projectile

points (2), knives (11), scrapers (63), gravers (3), choppers (3), planes (6), a hammerstone, and a handstone, were recovered from the volcanic debris layer in association with remains of horse and four other extinct species and a radiocarbon date of  $11,300 \pm 1200$  yr B.P. (A-203) on dispersed charcoal (Haury, 1950; Haury and Hayden, 1975). This assemblage was first interpreted as a blending of the western San Dieguito I Complex and the Folsom Culture. This interpretation was based on Haury's (1950, p.531) conclusion that the typology of the San Dieguito I tools from Ventana Cave were "not only similar, but identical" to those in the West and that the Folsom influence was evidenced by a basalt projectile point. Haury and Hayden (1975, p. v) have since decided that the point is a "local imitation of a Clovis point." The basalt concave-base projectile point from Ventana Cave is similar in outline to Folsom-Clovis lanceolate points but is unfluted and made on a flake, not by the Clovis bifacial reduction technique. The other Ventana Complex artifacts do not resemble non-projectile point Clovis artifacts, and the handstone seems especially out of place in a Clovis assemblage. Rogers (1958, 1966) and Hayden (1975) agree that the San Dieguito I Complex is strongly represented in the Ventana Complex.

Rogers (1958, 1966), Hayden (1975), and Irwin-Williams (1979) also found strong similarities between the Ventana Complex and the Sulphur Spring phase, which include flaked-stone tool types and technology, the handstone, stone projectile points, and the probable association with extinct faunal remains. Differences in age and the relative percentage of flaked- versus ground-stone tools are the only stumbling blocks to equating the Sulphur Spring phase and the Ventana Complex.

The date from the volcanic debris layer at Ventana Cave has wide margins of error and could fall anywhere between 12,500 and 10,100 yr B.P., thus overlapping the early part of the Sulphur Spring phase. The differences between the Ventana Complex and Sulphur Spring assemblages may be attributed to varying regional food resources due to environmental changes from southeastern to southwestern Arizona (McGuire, 1981; Haury, 1950, 1983). The physiography of southern Arizona produces an east-west environmental gradient resulting in greater aridity moving westward. Even though the early Holocene climate was different from today's the east-west gradient would still have made the west more arid than the east. Thus a single contemporary adaptation would not be expected in both southwestern and southeastern Arizona and probably led to less emphasis on food processing by grinding in the west. The lack of emphasis on food grinding in the west is also shown by a qualitative east-west decline in ground-stone artifacts in later Chiricahua-Amargosa II and San Pedro-Amargosa III sites from east to west.

The correlations between the Ventana Complex, the Sulphur Spring phase, and the San Dieguito I Complex seem reasonable. Most Ventana Complex and Sulphur Spring artifacts seem to fit Rogers (1958, 1966) trait list for San Dieguito I, with the exception of the presence of ground-stone tools and stone projectile points in the Sulphur Spring. As mentioned above, the absence of ground stone in the western San Dieguito I sites may be due to less emphasis on grinding due to the more arid environment of the west. The absence of projectile points in San Dieguito I sites in the west may be the result of preservation.

Perhaps perishable materials were more commonly used to make points and are thus not preserved on surface San Dieguito I sites. Nonstone projectile points are known from Clovis sites ancestral to the San Dieguito I sites (Haynes, 1982b), early stone projectile points are rare at both Ventana Cave and Whitewater Draw, and the steep-angled form of many of the San Dieguito I, Ventana, and Sulphur Spring tools suggest a woodworking tool kit.

Thus, the Sulphur Spring phase and the San Dieguito I Complex are brought into chronological agreement through the linking site of Ventana Cave as suggested by Haury (1950) and Rogers (1958). As figure 18 indicates, there were two early archaic traditions in southern Arizona during the terminal Pleistocene: the western San Dieguito I Complex (southern California, western Arizona, and southern Nevada) and the eastern Sulphur Spring (southeastern Arizona and western New Mexico).

The origin of these early archaic traditions is unknown. A pre-Clovis ancestry is possible, but at present not supportable, because unequivocal evidence for the existence of man in North America prior to 11,500 yr B.P. does not exist (Haynes, 1967; Waters, n.d.). There is also little evidence for the derivation of early archaic peoples from a Paleo-Indian base.

Although there are vast differences between the archaic and Paleo-Indian material cultures, the rudiments of the archaic ground-stone technology are present in the Paleo-Indian assemblage. This is evidenced in the Clovis assemblage by grinding on flaked-stone artifacts and bone tools and the presence of a grinding-hammerstone in

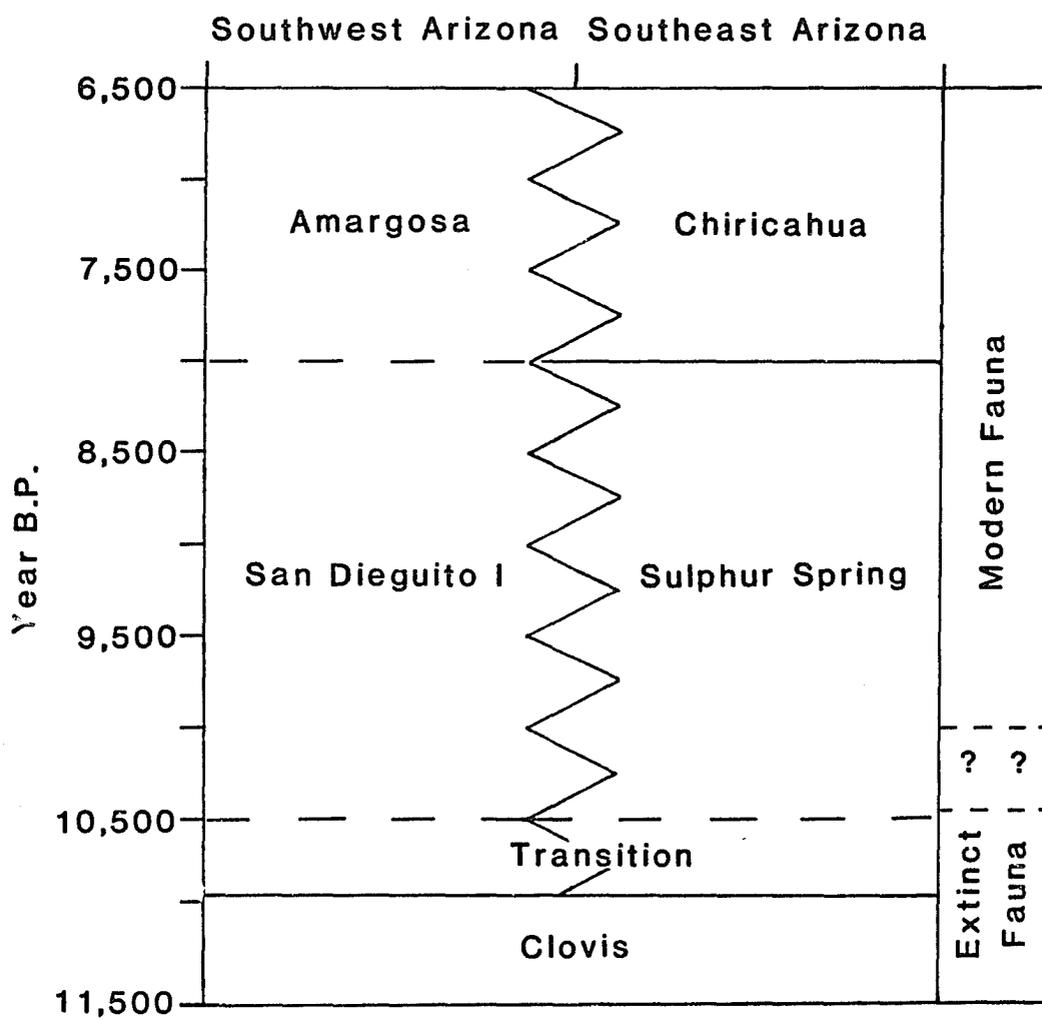


Figure 18. Correlation of early archaic cultures in southern Arizona

the Clovis horizon at Blackwater Draw, New Mexico (Hester, 1972). Grinding technology is well established in the later Folsom assemblage, which is obviously derived from Clovis. Wilmsen and Roberts (1978) reported 27 Folsom ground-stone artifacts, 10 of which were used for pigment grinding, from the Lindenmeier site, Colorado. The Paleo-Indians occupying the West during the onset of the Holocene would not be expected to retain big-game hunting equipment as the later Folsom people did in the Plains, but would reorganize their tool kit to exploit the changing environment in the West. Thus, development of early archaic western traditions from a Paleo-Indian base is not unrealistic, although there are no data to support this speculation.

The shift in emphasis from hunting to collecting probably began before the complete extinction of megafauna during the onset of the Holocene (Haury, 1983). The timing of this transition is imprecisely known and probably took place at different times in different areas. An archaic lifestyle is well established in the Great Basin at Danger Cave by  $10,270 \pm 650$  yr B.P. (M-202) (Jennings, 1957), in southwestern Arizona by  $11,300 \pm 1200$  yr B.P. (A-203) at Ventana Cave (Haury and Hayden, 1975), in southeastern Arizona by 10,000 yr B.P. and probably as early as 10,500 yr B.P. as evidenced by the Sulphur Spring phase sites, and in Oaxaca, Mexico, by  $10,700 \pm 350$  yr B.P. (M-2099) (Flannery, Marcus, and Kowalewski, 1981; Schoenwetter, 1974). Thus, the transition to an archaic lifestyle occurred during the terminal Pleistocene in the western United and Mexico.

### Cazador Phase

The Cazador phase was defined by Sayles (1983a) as a phase transitional between the Sulphur Spring and Chiricahua phases of the Cochise Culture. As originally defined, it was characterized by milling stones, handstones, flaked-stone tools comparable to those of the Sulphur Spring phase, and the first appearance of pressure-flaked projectile points. These artifacts are associated only with modern fauna. Antevs (1983) considered this phase to date from 11,000 to 8,000 yr B.P., based on a geologic estimate that placed the artifacts in late Provo Pluvial (Double Adobe II Subpluvial) deposits formed after the Datil Drought. Cazador artifacts were recognized at three sites: Arizona FF:10:1, locality 2; Arizona FF:6:9; and Arizona FF:6:8. The following discussion considers the validity of the Cazador phase as a phase of the Cochise Culture.

At the type site, Arizona FF:10:1, locality 2, Cazador artifacts occur in a gravel and sand. Two radiocarbon dates on charcoal,  $8,240 \pm 960$  yr B.P. (A-184c) (Martin, 1963b) and  $8,840 \pm 310$  yr B.P. (A-3377), and one date on carbonaceous alluvium,  $7,030 \pm 260$  yr B.P. (A-184e) (Martin, 1963b), were obtained from the sand. The date for sample A-184e was rejected because it is much younger than the other two dates on charcoal from the same deposit and the material dated has questionable reliability. The remaining two dates place the Cazador artifacts in deposits equivalent to the unit Da gravel and unit Db sand of the alluvial sequence. At sites Arizona FF:10:1, localities 1, 3, 4, and 5, Arizona FF:6:8, and Arizona FF:6:9, units Da and Db contain Sulphur Spring artifacts that date between 9,400 yr B.P. and 8,000 yr

B.P. and possibly as early as 10,400 yr B.P. (see dating section). Therefore, the artifact-bearing gravel and sand at the Cazador type site were misidentified and should be correlated with units Da and Db, making the Cazador artifacts at locality 2, Sulphur Spring.

At site Arizona FF:6:8, Cazador artifacts were recovered by Sayles and Antevs from a blue-gray clay (unit G1) and a clayey sand (unit H). Charcoal samples collected from unit G1 dated  $6,940 \pm 190$  yr B.P. (A-3235) and  $6,950 \pm 170$  yr B.P. (A-3236). A radiocarbon date on charcoal and humates from unit H is  $6,750 \pm 180$  yr B.P. (A-3234). Therefore, Cazador artifacts from this locality date about 2,000 years later than those at the type site (Arizona FF:10:1, locality 2). These artifacts could by definition be assigned to the Chiricahua phase as first suggested by Sayles and Antevs (1941).

At Arizona FF:6:9, Cazador artifacts were also collected from a blue-gray clay (unit G1) (Sayles, 1983a; Antevs, 1983). No radiocarbon dates were obtained from unit G1 at this site, but this deposit is correlative with unit G1 at Arizona FF:6:8. Therefore, these artifacts are about 7,000 years old. Again, a Chiricahua phase assignment would be in order.

Thus, the Cazador artifacts are shown to have come from Sulphur Spring and early Chiricahua phase contexts. As a result, the Cazador phase can no longer be considered a valid phase of the Cochise Culture.

### Pre-Sulphur Spring Phase Artifacts

No Clovis sites and only one Clovis point have been found in the Sulphur Springs Valley despite its close proximity to the San Pedro Valley where the presence of the Clovis Culture is established at the Lehner, Murray Springs, Escapule, and Naco sites (fig. 1). The point was recovered in a dune area covering the northeastern portion of ancient Lake Cochise in the Willcox basin (Di Peso, 1953). No Clovis artifacts are known from the Douglas basin (Huckell, 1982), but the potential for such finds remains high because Clovis-age deposits occur in Whitewater Draw.

Three fluted obsidian projectile points from Whitewater Draw were reported by Myers (1976). All are isolated surface finds, considered by Myers to be typologically similar to Folsom points and manufactured by a regional manifestation of that culture. In my opinion these points are crudely made replications of recent manufacture. They are very thick and poorly fluted (sometimes only on one side) and are very "fresh" in appearance.

### Miscellaneous Aspects of the Archaeology of Whitewater Draw

Artifacts are found in almost all of the upper Quaternary deposits of Whitewater Draw. Most are hand and milling stones of little diagnostic value, making Cochise Culture phase identifications impossible. Projectile points are needed to make a proper phase identification, and these are rarely found in situ. Only three projectile points, excluding the Sulphur Spring phase specimens, have been found in the alluvial sediments.

The oldest point was found by Sayles and Antevs (1941) in unit G1 at Arizona FF:6:9. It is a serrated leaf-shape form with a contracting base. Two radiocarbon dates from correlative deposits at Arizona FF:6:8 are  $6,940 \pm 190$  yr B.P. (A-3235) and  $6,950 \pm 170$  yr B.P. (A-3236). Two short concave base side-notched "Chiricahua" points were found by Sayles and Antevs (1941) at Arizona FF:10:4 in deposits that are correlative to unit M at site Arizona FF:10:13. A radiocarbon date from unit M at Arizona FF:10:13 of  $3,500 \pm 110$  yr B.P. (A-3183) can be applied to these points.

By far the most common artifacts in Whitewater Draw regardless of age are hand and milling stones. The preponderance of ground-stone artifacts in the Douglas basin indicates that it was the site of intensive specialized plant gathering and processing from the very earliest archaic (10,500 yr B.P.) to the ceramic period (ca. A.D. 1). Thus the artifacts from the Douglas basin show one manifestation of a wider pattern of food procurement followed by the archaic people of southern Arizona.

## CONCLUSIONS

Nineteenth-century arroyo cutting in the Douglas basin, Arizona, created Whitewater Draw and exposed in its walls a complex alluvial sequence dating in excess of 15,000 yr B.P. The alluvial history is characterized by deposition in a through-flowing perennial stream from 15,000 to 8,000 yr B.P., followed by cycles of erosion and deposition in cienegas from 8,000 to 6,700 yr B.P., arroyo cutting and filling between 6,700 and 5,500 yr B.P., and numerous cycles of erosion and cienega deposition from 5,500 yr B.P. to the historic period. For the most part, the alluvial sequence of the Douglas basin differs in timing, character, and number of degradational and aggradational events, with the exception of a middle Holocene arroyo cutting-and-filling episode, when compared to the alluvial sequences for the adjacent San Pedro Valley and the generalized chronology for the West.

Remains of six genera of Pleistocene megafauna, mammoth, horse, camel, dire wolf, sloth, and bison were recovered from six upper Quaternary deposits in Whitewater Draw dating from late Pleistocene to 7,000 yr B.P. Megafaunal extinction probably occurred in the Douglas basin around 10,400 yr B.P. as evidence by the occurrence of articulated camel and mammoth remains in sediments of this age. Mammoth, horse, camel, and dire wolf remains from deposits dating 10,400 to 7,000 yr B.P. are in secondary contexts, redeposited from older sediments.

Archaeological remains of the Cochise Culture are found in nearly all the upper Quaternary deposits of Whitewater Draw. Artifacts of the earliest phase, the Sulphur Spring, are found at four sites in Whitewater Draw and at the Lehner site, where it overlies the Clovis horizon. The Sulphur Spring artifact assemblage is characterized by milling stones, handstones, unifacial flake tools, and a few bifacially flaked knives and projectile points.

The preponderance of milling stones and handstones at Sulphur Spring sites indicates that the Douglas basin was the site of intensive plant processing, and other artifacts suggest only limited hunting and other activities took place. These sites probably represent part of a wider pattern of seasonal food procurement practiced by a single people. Radiocarbon dating places the Sulphur Spring phase between 8,000 and 10,000 yr B.P. and probably as early as 10,500 yr B.P. Evidence suggests that the Sulphur Spring people may have temporally overlapped with relict populations of Pleistocene megafauna during the onset of the Holocene. The Sulphur Spring phase is considered to be the temporal equivalent of the western San Dieguito I complex.

The Cazador phase is no longer considered to be a valid phase of the Cochise Culture. At the type site, artifacts occurred in a gravel and sand that yielded dates equivalent in age to sediments containing Sulphur Spring material. Cazador artifacts also occurred in deposits at two sites dating 6,750 yr B.P. and 6,950 yr B.P. These artifacts could by definition be assigned to the Chiricahua phase.

APPENDIX

DESCRIPTIONS OF GEOLOGIC UNITS

Arizona FF:6:9 (GP Pearce 8:21)

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
P2	Silt and very fine sand, dull-brown (7.5 YR 5/3)d, dark-brown (7.5 YR 3/3)w; faint lamination, platy structure; soft; visible reaction; equivalent to unit K of Antevs (1983, p. 38).	25
O2	Silty clay, dull-brown (7.5 YR 5/3)d to grayish-brown (7.5 YR 4/2)d, brown (7.5 YR 4/3)w; medium subangular to crumb structure; hard; visible reaction; equivalent to unit j (upper) of Antevs (1983, p. 38).	95
I3	Clay, dull-brown (7.5 YR 6/3)d, dull-brown (7.5 YR 4/4)w; strong, fine angular to subangular blocky structure; hard; audible reaction, abundant <2-cm hard CaCO <sub>3</sub> nodules, especially along ped surfaces; equivalent to unit j (lower south half) of Antevs (1983, p. 38).	110
I2	Sand, silt, and clay, dull-brown (7.5 YR 6/3)d, brown (7.5 YR 4/4)w, fine, horizontally laminated to bedded very fine sand, silt, and clay; soft to slightly hard; visible reaction; limonite staining; overall fining upward sequence; equivalent to unit i of Antevs (1983, p. 38).	140
I1b	Sand, light-gray (10 YR 8/1-8/2)d, moderately sorted, subangular to angular, medium to fine arkosic sand; soft; no reaction; prominent planar cross-bedding, minor silt and pebble-gravel interbeds; no equivalent unit.	180

Arizona FF:6:9 (GP Pearce 8:21)--Continued

<u>Unit</u>	<u>Description</u>	Maximum Thickness (cm)
I1a	Gravel, light-gray (10 YR 8/1-8/2)d, well-rounded to subrounded, small pebble to coarse cobble gravel, clay balls; loose; no reaction; coarse sand interbeds; limonite and manganese staining; no equivalent unit.	160
G4	Clay, dull-brown (7.5 YR 5/3)d, brown (7.5 YR 4/3)w; strong, fine to medium prismatic to medium angular blocky structure; hard; audible reaction, abundant hard CaCO <sub>3</sub> nodules; equivalent to units g and j (lower north half) of Antevs (1983, p. 38).	135
G3	Clay, dull-brown (7.5 YR 5/4)d, dark-brown (7.5 YR 3/4)w, mottled; upper part medium to coarse angular blocky structure, base massive; hard; visible reaction, sparse CaCO <sub>3</sub> nodules; transitional into unit G4; equivalent to units h and f (upper) of Antevs (1983, p. 38).	100
G2	Silt, dull-brown (7.5 YR 6/3)d, brown (7.5 YR 4/4)w; massive, vuggy; soft; visible reaction; equivalent to unit f (lower) of Antevs (1983, p. 38).	40
G1	Clay, grayish-yellow-brown (10 YR 5/2)d, brownish-black (10 YR 2/3)w; weak, coarse prismatic structure, mottled; hard; audible reaction, sparse hard <1-cm CaCO <sub>3</sub> nodules, especially along ped surfaces; shells; equivalent to unit e of Antevs (1983, p. 38).	105
E2	Sandy clayey silt, dull-yellow-orange (10 YR 6/3)d, dull-yellowish-brown (10 YR 5/3)w; coarse prismatic structure; hard; persistent reaction; equivalent to unit d of Antevs (1983, p. 38).	90

Arizona FF:6:9 (GP Pearce 8:21)--Continued

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
Db	Sand, light-gray (10 YR 7/1)d, grayish-yellow-brown (10 YR 5/2)w; moderately to poorly sorted, subangular to angular, coarse to fine arkosic sand; soft; no reaction; discontinuous, undulatory, <5-cm-thick clay and silt interbeds, brownish-gray (10 YR 5/1)d, brownish-gray (10 YR 4/1)w to grayish-yellow-brown (10 YR 4/2)w, occasional fine pebble-gravel lense; limonite staining; equivalent to unit c of Antevs (1983, p. 38).	110
Da	Gravel, light-gray (10 YR 7/1)d, grayish-yellow-brown (10 YR 5/2)w, well-rounded to subrounded, small pebble to small boulder gravel, average small cobble; loose; no reaction; medium to coarse sand interbeds; limonite and manganese staining; equivalent to unit b of Antevs (1983, p. 38).	60
A	Clay, dull-orange (2.5 YR 6/3)d, dull-reddish-brown (2.5 YR 5/3)w; very hard; visible reaction, abundant CaCO <sub>3</sub> nodules; equivalent to unit a of Antevs (1983, p. 38).	150+

Arizona FF:6:8 (GP Pearce 8:10)

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
P2	Silt and very fine sand, grayish-brown (7.5 YR 5/2)d, dark-brown (7.5 YR 3/3)w; faint lamination, platy structure; soft; visible reaction; equivalent to unit j of Antevs (1941, p. 49; 1983, p. 39).	20
O2	Silty clay, grayish-brown (7.5 YR 4/2)d, grayish-brown (7.5 YR 4/2)w; medium angular to subangular, blocky to crumb structure; hard; visible reaction; interbedded silty sand, channel sand and gravel at base; equivalent to unit i of Antevs (1941, p. 49; 1983, p. 39).	120
N2(?)	Clay, dull-brown (7.5 YR 5/3)d, brown (7.5 YR 4/3)w; medium angular to subangular blocky to crumb structure; hard; visible reaction, <1-cm CaCO <sub>3</sub> nodules; shallow clayey sand channels with reworked CaCO <sub>3</sub> nodules; equivalent to unit h of Antevs (1941, p. 48; 1983, p. 39).	125
I3	Clay, dull-brown (7.5 YR 6/3)d, brown (7.5 YR 4/4)w; strong, fine angular to subangular blocky structure; hard; audible reaction, abundant <2-cm hard CaCO <sub>3</sub> nodules, especially along ped surfaces; some dispersed very fine sand, interbedded clayey sand; equivalent to unit h of Antevs (1941, p. 49; 1983, p. 39).	130
I2	Sand, silt, and clay, dull-brown (7.5 YR 5/4-6/3)d, dark-brown (7.5 YR 3/4)w to brown (7.5 YR 4/4)w; fine horizontally laminated to bedded very fine sand, silt, and clay; soft to slightly hard; visible to persistent reaction; salts; upper 50 cm alternating clay-silt laminations with hard <1-cm irregular CaCO <sub>3</sub> nodules; limonite staining; overall fining-upward sequence; equivalent to unit g of Antevs (1941, p. 49; 1983, p. 39).	150

Arizona FF:6:8 (GP Pearce 8:10)--Continued

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
I1a and I1b	Sand and gravel, light-gray (10 YR 8/1-8/2)d; sub-angular to angular, very fine to coarse arkosic sand and well-rounded pebble gravel with clay balls; loose; no reaction; interbedded <1-cm-thick clay and silt lenses; limonite and manganese staining; equivalent to unit g of Antevs (1941, p. 49; 1983, p. 39).	75
H	Clayey sand, dull-brown (7.5 YR 5/3)d, brown (7.5 YR 4/3)w; subangular to angular, coarse to medium arkosic sand with clay matrix; slightly hard; visible reaction; shells; equivalent to unit f of Antevs (1941, p. 49; 1983, p. 39).	95
G4	Clay, dull-brown (7.5 YR 6/3)d, brown (7.5 YR 4/4)w; strong, fine to medium prismatic structure; hard; audible reaction, abundant <2-cm CaCO <sub>3</sub> nodules, especially along ped surfaces; minor clayey sand interbeds, base (G3?) massive to coarse prismatic; equivalent to unit e of Antevs (1941, p. 49; 1983, p. 39).	150
G2	Silt, dull-brown (7.5 YR 6/3)d, brown (7.5 YR 4/3)w; massive, vuggy; soft; visible reaction; equivalent to unit e of Antevs (1941, p. 49; 1983, p. 39).	20
G1	Clay, grayish-yellow-brown (10 YR 5/2)d, brownish-black (10 YR 3/2)w, mottled; coarse to medium prismatic structure; hard; audible reaction; few 4-8-cm-thick medium to coarse sand and small pebble gravel lenses in lower 30 cm, upper half scattered <2-cm CaCO <sub>3</sub> nodules, especially along ped surfaces; base massive; shells; equivalent to unit e of Antevs (1941, p. 49; 1983, p. 39).	125
E2	Clay to sandy clay, dull-brown (7.5 YR 6/3)d, brown (7.5 YR 4/3)w; coarse prismatic to medium angular blocky structure, vuggy; hard; visible reaction, scattered hard 0.25-cm CaCO <sub>3</sub> nodules; shells; equivalent to unit d of Antevs (1941, p. 49; 1983, p. 39).	125

Arizona FF:6:8 (GP Pearce 8:10)--Continued

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
E1	Clayey sand, dull-brown (7.5 YR 5/3)d, brown (7.5 YR 4/3)w; angular to subangular medium sand with clay matrix; hard; persistent reaction; shells; equivalent to unit d of Antevs (1941, p. 49; 1983, p. 39).	35
Db	Sand, light-gray (10 YR 7/1)d, grayish-yellow brown (10 YR 5/2)w; moderate to well-sorted, subangular to angular, coarse to fine arkosic sand; soft; no reaction; discontinuous undulatory <5-cm-thick laminated sandy clay, clay, and silt interbeds, brownish-gray (10 YR 5/1)d, brownish-gray (10 YR 4/1)w to grayish-yellow-brown (10 YR 4/2)w, occasional fine-pebble gravel lense and thick clay; limonite staining; equivalent to units c and b of Antevs (1941, p. 49; 1983, p. 39).	80
Da	Gravel, light gray (10 YR 7/1)d, grayish-yellow-brown (10 YR 5/2)w; well-rounded to subrounded, small pebble to small boulder gravel, average small cobble; loose; no reaction; occasional thin, medium to coarse sand interbed; limonite and manganese staining; equivalent to unit a of Antevs (1941, p. 49; 1983, p. 39).	175
A	Clay, dull-orange (2.5 YR 6/3)d, dull-reddish-brown (2.5 YR 5/3)w; very hard; visible reaction, CaCO <sub>3</sub> nodules; no equivalent unit.	50+

Arizona FF:10:1 (GP Sonora F:10:1) and Arizona FF:10:13

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
P2	Silt, dull-orange (7.5 YR 7/3)d, dark-brown (7.5 YR 3/4)w; platy structure; soft; visible reaction; equivalent to unit f of Antevs (1941, pp. 46-47; 1983, p. 37).	20
P1	Sandy silt, dull-orange (7.5 YR 7/3)d, dark-brown (7.5 YR 3/4)w; soft; visible reaction; no equivalent unit.	200
O2	Silty clay, grayish-brown (5 YR 5/2)d, grayish-brown (5 YR 4/2)w; fine subangular blocky to crumb structure; soft; audible reaction; equivalent to unit e of Antevs (1983, p. 37).	80
O1b	Clay-silt, light-gray (7.5 YR 8/1)d, light-brownish-gray (7.5 YR 7/2)w; alternating clay-silt laminations, coarse to medium, subangular to angular blocky structure; soft; visible to persistent reaction; lower portion arkosic sand with abundant reworked CaCO <sub>3</sub> nodules; no equivalent unit.	155
O1a	Sandy silt, grayish-yellow-brown (10 YR 6/2)d, dark-brown (10 YR 3/4)w; hard; strong reaction, abundant reworked CaCO <sub>3</sub> nodules; equivalent to units d <sup>1</sup> -d <sup>3</sup> of Antevs (1983, p. 37).	160
N2	Clay, grayish-brown (5 YR 5/2)d, grayish-brown (5 YR 4/2)w; medium subangular blocky structure; hard; audible reaction, sparse to no CaCO <sub>3</sub> nodules; no equivalent unit.	140
M	Clay, gray (7.5 Y 5/1)d to grayish-olive (7.5 Y 5/2)d, gray (7.5 Y 4/1)w to grayish-olive (7.5 Y 4/2)w; massive; hard; audible reaction; shells; no equivalent unit.	80

Arizona FF:10:1 (GP Sonora F:10:1) and Arizona FF:10:13--Continued

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
L	Clay to silty clay, grayish-brown (7.5 YR 6/2)d, dark-brown (7.5 YR 3/3)w; strong, fine to medium prismatic structure; very hard; visible to audible reaction, abundant hard <1-1.5-cm irregular CaCO <sub>3</sub> nodules, especially along ped surfaces; shells; possibly equivalent to units d and e of Antevs (1941, pp. 46-47).	170
K(?)	Clay, yellowish-gray (2.5 Y 5/1)d, yellowish-gray (2.5 Y 4/1)w, mottled; medium prismatic structure to massive; hard; visible reaction, small soft CaCO <sub>3</sub> nodules; shells; 2 cm silt interbed near base, dull-orange (5 YR 7/3)d, dull-reddish brown (5 YR 4/4)w, vuggy, soft; audible reaction. Lower 70 cm in channel, clay, gray (5 Y 4/1)d, gray (5 Y 5/1)w; fine laminated to massive; hard; audible reaction; fissile; flat seams of charcoal and decayed flora along laminations; limonite staining; no equivalent unit.	160
J1	Clay-silt, grayish-brown (5 YR 6/2)d to dull-brown (7.5 YR 6/3)d, dull-reddish brown (5 YR 4/3)w; fine horizontal clay-silt laminations, fissile; slightly hard; visible reaction; no equivalent unit.	50
F2	Marl, light-gray (10 YR 8/1)d, light-gray (10 YR 8/2)w; clayey, coarse prismatic structure to massive, vuggy; very hard; persistent reaction; equivalent to unit c <sup>2</sup> of Antevs (1941, pp. 46-47).	125
F1	Marl, dull-yellow-orange (10 YR 7/2)d, brownish-black (10 YR 3/2)w; laminated clay, silt, and CaCO <sub>3</sub> , coarse prismatic structure, interbedded with hard flat CaCO <sub>3</sub> nodules; persistent reaction; equivalent to unit c <sup>1</sup> of Antevs (1941, pp. 46-47).	100

Arizona FF:10:1 (GP Sonora F:10:1) and Arizona FF:10:13--Continued

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
Dd	Clay, yellow-gray (2.5 Y 5/1)d, yellowish-gray (2.5 Y 4/1)w to dark-olive-brown (2.5 Y 3/2)w; massive, laminated at base, silt interbeds; hard; audible reaction; equivalent to unit c of Antevs (1983, p. 37).	65
Db	Sand, light-brownish-gray (7.5 YR 7.2)d to dark-grayish-yellow (2.5 Y 5/2)d, dull-brown (7.5 YR 5/3)w to dark-grayish-yellow (2.5 Y 5/2)w; very fine to very coarse arkosic sand with 30-cm-thick silt and clay interbeds; soft to loose; audible to no reaction; limonite staining; equivalent to unit b <sup>2</sup> of Antevs (1941, pp. 46-47; 1983, p. 37).	95
Dd	Clay, light-gray (10 YR 8/1)d to gray (5 Y 5/1)d, grayish-yellow-brown (10 YR 6/2)w to gray (5 Y 4/1)w; massive to laminated; hard; audible reaction; limonite staining; no equivalent unit.	100
Da	Gravel and sand, grayish-brown (7.5 YR 6/2)d to grayish-yellow-brown (10 YR 5/2)d, brown (7.5 YR 4/3)w to grayish-yellow-brown (10 YR 4/2)w); well-rounded, small pebble to small cobble gravel, average large pebble, interbeds of poorly to moderately sorted, subrounded to angular, medium to very coarse arkosic sand, clay balls, <10-cm-thick silty clay and clay interbeds; loose; audible to no reaction; limonite and manganese staining; equivalent to unit b <sup>1</sup> of Antevs (1941, pp. 46-47; 1983, p. 37).	155
C	Sandy clay, light-gray (10 YR 8/1)d to dull-orange (2.5 YR 6/3)d, dull-yellow-orange (10 YR 7/2)w to dull-reddish-brown (2.5 YR 5/4)w; medium prismatic to angular blocky structure to massive; very hard; persistent reaction, hard irregular CaCO <sub>3</sub> nodules; locally 50-cm-thick porous tufa beds; no equivalent unit.	260

Arizona FF:10:1 (GP Sonora F:10:1) and Arizona FF:10:13--Continued

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
A	Clay, reddish-brown (10 R 5/3)d, reddish-brown (10 R 4/3)w, mottled light-gray (7.5 Y 8/2)d, grayish-olive (7.5 Y 6/2)w; very hard; visible reaction, <4-cm CaCO <sub>3</sub> nodules; equivalent to unit a of Antevs (1941, pp. 46-47; 1983, p. 37).	100+

Arizona FF:10:14 (GP Sonora F:10:17) and  
Tortoise and Bull Localities

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
P2	Silt to very fine sand, dull-brown (7.5 YR 5/3)d, brown (7.5 YR 4/3)w; faint lamination, platy structure; soft; visible reaction; equivalent to unit i of Antevs (1941, p. 51).	40
N2	Silty clay to clay, dull-brown (7.5 YR 5/3)d to brown (7.5 YR 4/3)d, dark-brown (7.5 YR 3/3)w; fine to medium subangular blocky to crumb structure; hard; visible reaction; equivalent to unit h of Antevs (1941, p. 51).	200
N1	Silty sand, dull-brown (7.5 YR 5/3)d, dark-brown (7.5 YR 3/3)w; slightly hard; audible reaction; no equivalent unit.	20
L	Clay, gray (10 Y 5/1)d, gray (10 Y 5/1-4/1)w, with dull-reddish brown (5 YR 4/4)d, dark-reddish brown (5 YR 3/4)w mottles; strong medium prismatic to medium subangular to angular blocky structure, banded; hard; visible reaction, abundant <2-cm hard to soft CaCO <sub>3</sub> nodules, especially along ped surfaces, nodules form bands; in places lower quarter massive; shells; equivalent to unit g of Antevs (1941, p. 51).	180
K	Clay, gray (5 Y 4/1)d to gray (7.5 Y 6/1)d, gray (5 Y 6/1-5/1)w to gray (7.5 Y 5/1)w; very finely laminated to massive, fissile; hard; audible reaction; flat charcoal and decayed flora along laminations; limonite staining; base sandy clay; shells; equivalent to unit f of Antevs (1941, p. 51).	120

Arizona FF:10:14 (GP Sonora F:10:17) and  
Tortoise and Bull Localities--Continued

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
J1	Clay-silt, grayish-brown (5 YR 6/2)d to dull-brown (7.5 YR 6/3)d, dull-reddish brown (5 YR 4/3)w to dull-brown (7.5 YR 5/4)w; very fine horizontal clay-silt laminations, fissile; slightly hard; visible reaction; few sand to silt interbeds at base, occasionally reduced dull-yellow (2.5 Y 6/3)d, yellowish-brown (2.5 Y 5/3)w; occasional flat seams of charcoal and decayed flora along laminations; equivalent to units e <sup>1</sup> and d of Antevs (1941, p. 51).	210
I1b and I1a	Sand and gravel, grayish-brown (7.5 YR 6/2)d to dull-brown (7.5 YR 6/3)d, brown (7.5 YR 4/3)w; sub-rounded to subangular, medium arkosic sand with pebble gravel interbeds; loose; audible reaction; limonite staining; no equivalent unit.	100+
E2	Sandy clay, grayish-brown (7.5 YR 5/2)d, dark-brown (7.5 YR 3/4)w; medium prismatic to medium subangular blocky structure, dispersed fine to medium sand in clay matrix, vuggy; hard; visible reaction, hard <2-cm CaCO <sub>3</sub> nodules; base massive; no equivalent unit.	260
Dc	Sand to silty sand, dull-orange (7.5 YR 6/4)d, brown (7.5 YR 4/3)w; poorly sorted, subangular to angular, fine to coarse arkosic sand with dispersed small to large pebble gravel; very hard; visible reaction, sparse <2-cm CaCO <sub>3</sub> nodules; limonite staining; cross-bedding; equivalent to unit c of Antevs (1941, p. 51).	120
Db	Sand and silt, dull-brown (7.5 YR 6/3)d, dull-brown (7.5 YR 5/4)w to brown (7.5 YR 4/4)w; very fine, subangular arkosic sand, minor gravel lenses; slightly hard; audible reaction; equivalent to unit a (upper) of Antevs (1941, p. 51).	220

Arizona FF:10:14 (GP Sonora F:10:17) and  
Tortoise and Bull Localities--Continued

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
Da	Gravel and sand, dull-yellow-orange (10 YR 7/2)d, dull-yellowish brown (10 YR 4/3)w; moderately sorted, angular to subangular, medium to coarse arkosic sand and well-rounded small pebble to small cobble gravel, average large pebble; loose; no reaction; some cross-bedding; limonite and manganese staining; equivalent to unit a (lower) of Antevs (1941, p. 51).	235
A	Clay, dull-reddish brown (5 YR 5/3)w; hard; persistent reaction, CaCO <sub>3</sub> nodules; no equivalent unit.	150+

Arizona FF:10:16

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
P2	Silt to very fine sand, dull-brown (7.5 YR 5/3)d, brown (7.5 YR 4/3)w; horizontally laminated, platy structure; soft; visible reaction.	70
N2b	Clay, grayish-brown (5 YR 5/2)d, grayish-brown (5 YR 4/2)w; medium subangular blocky structure; hard; audible reaction, sparse small CaCO <sub>3</sub> nodules; interbedded clayey sand.	160
N2a	Clay, grayish-brown (5 YR 5/2)d, grayish-brown (5 YR 4/2)w; fine blocky to fine prismatic structure; hard; audible reaction, sparse CaCO <sub>3</sub> nodules; interbedded clayey sand.	110
M	Clay, gray (7.5 Y 5/1)d to grayish-olive (7.5 Y 5/2)d, gray (7.5 Y 4/1)w to grayish-olive (7.5 Y 4/2)w, massive; hard; audible reaction; gastropods.	60+

Crystal Locality

<u>Unit</u>	<u>Description</u>	<u>Maximum Thickness (cm)</u>
J2	Silty clay, grayish-brown (5 YR 5/2)d, grayish-brown (5 YR 4/2)w; strong, medium prismatic structure; hard; visible reaction, <2-cm CaCO <sub>3</sub> nodules.	80
J1	Clay-silt, grayish-brown (5 YR 5/2)d, dull-reddish-brown (5 YR 5/3)w; alternating clay-silt horizontal laminations, upper 50 cm coarse to medium prismatic to blocky structure with <3-cm CaCO <sub>3</sub> nodules; shells; transitional into unit J2.	180
Db	Silt and very fine sand, dull-brown (7.5 YR 6/3)d, brown (7.5 YR 4/3)w; horizontally laminated to massive; soft; audible reaction.	110
Dd	Clay, dark-bluish-gray (10 BG 3/1)d, bluish-black (10 BG 2/1)w; very coarse prismatic structure to massive; hard; audible reaction; gypsum crystals; shells.	200
Db	Silt and sand, dull-brown (7.5 YR 6/3)d, brown (7.5 YR 4/3)w; soft; audible reaction.	10+

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