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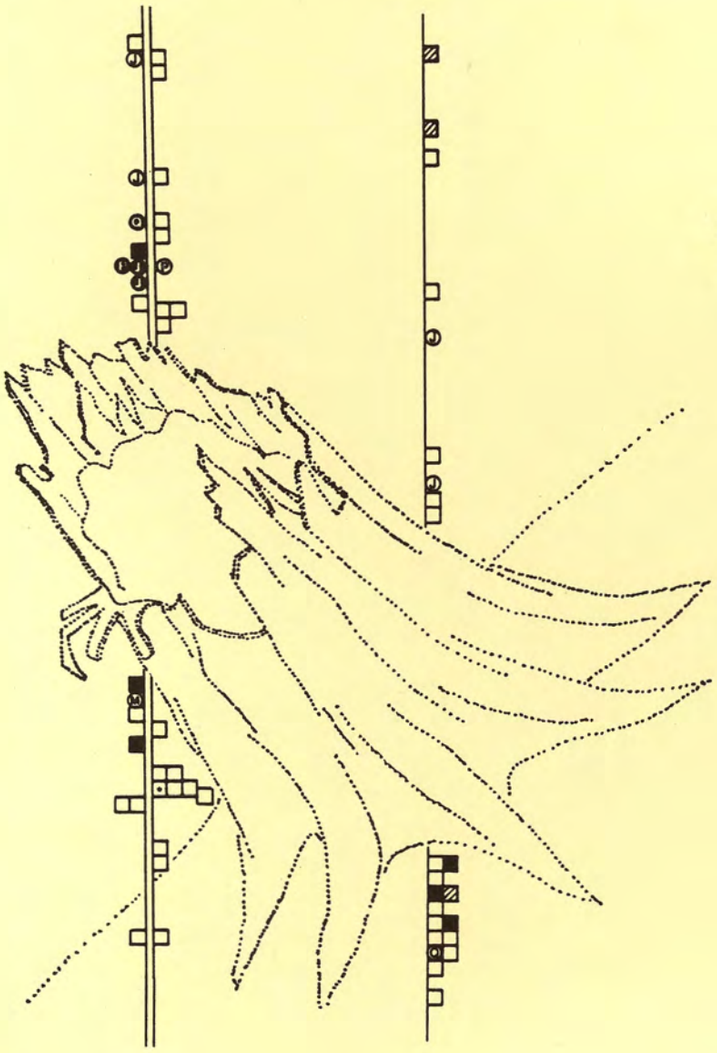
THE GEOMORPHOLOGY AND ARCHAEOLOGY OF CARNEGIE CANYON

Ft. Cobb Laterals Watershed, Caddo Co., Oklahoma



by
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Oklahoma Conservation Commission Archaeological Research Report No. 10

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THE GEOMORPHOLOGY AND ARCHAEOLOGY OF CARNEGIE CANYON FORT COBB LATERALS WATERSHED, CADDO COUNTY, OKLAHOMA.

By

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ABSTRACT

Downcutting of a small stream is currently threatening a county road within the Fort Cobb Laterals Watershed in Caddo County, Oklahoma. Stabilization plans propose the construction of Drop Structure 101, and the relocation of the road atop the dam.

A survey of the project area in February, 1981, located an historic homestead (34Cd-121) on the flanking slopes, and several hearth features, small quantitites of cultural materials, and portions of a human cranium within a deep canyon in the valley (34Cd-76). The present creek is incised 11 m into the valley floor; however, core drilling along the proposed dam axis indicates that the valley fill is over 32 m deep.

Geomorphic studies were concerned with correlating stratigraphic sequences throughout the valley and determining the age and rate of deposition of sediments in the canyon. In addition, 24 molluscan species, 63 buried tree stumps, which were dated between 2600 and 3200 years ago, and carbonate deposits within some paleosol layers were available to develop a preliminary paleoenvironmental model of the valley during the last 3000 years. A predominance of buried juniper stumps suggests that the water table was several meters below the valley floor during a period 2600-3200 years ago. During this relatively dry period the rate of sediment deposition averaged approximately 0.8 cm per year, even though several minor paleosol horizons are present. Between 1000 and 2000 years ago, the water table rose nine meters and a perennial stream flowed through the canyon. Evidence for the high water table level is reflected in a fossil spring conduit, the presence of at least seven aquatic molluscan species, high carbonate precipitates on the canyon walls, and the development of a thick paleosol horizon believed to correspond to the Caddo County paleosol defined for Delaware Canyon. The sedimentation rate in the valley slowed to between one-third and one-tenth the former deposit rate. Subsequent alluviation and formation of a weaker paleosol have occurred unconformably over the Caddo County paleosol horizon. The deep canyon cutting is relatively recent, and the level of the present water table is apparently four meters below the level during formation of the Caddo County paleosol.

The present geomorphic studies were based on data within the deep canyon north of the proposed impact area. Most of these deposits will not be affected during project development. The presence of sand lenses and diluted paleosol horizons from lateral tributaries near the proposed dam axis indicated that this section of the canyon is not representative of the geomorphic trends necessary to successfully correlate the various stratigraphic units.

Archaeological studies focused on examining an early statehood homestead site (34Cd-121) within the proposed emergency spillway, and testing at several specific localities at prehistoric site 34Cd-76.

Archaeological examination of the historic locality (34Cd-121) revealed that the area has experienced erosion with deflation of 60 cm of soil. Furthermore, the distribution of materials on the bedrock surfaces has been culturally altered. The dimensions of the cultural features were recorded. No further work is recommended for the site.

Several aspects of site 34Cd-76 were examined. A total of 32 one-meter units were used to test the upper valley fill within the proposed borrow pit, near the dam axis and emergency spillway overflow areas along the east side of the valley. Excavations focused on a possible bison kill/butchering area, three exposed hearth features, a disarticulated deer skeleton, an area where fragments of human cranium were found, and a limited testing of the lower valley fill. In all instances, cultural materials were very sparse. The results of testing suggest that a diverse range of short term activities were conducted by different groups in the valley. Functional/temporal diagnostic materials were scarce; consequently, most occupations must be dated stratigraphically. Radiocarbon dates of A.D. 410±100 (Beta-3090), 440±100 B.C. (Beta-2622), and 530±50 B.C. (Beta-2623) from the hearth features and a series of twelve dates from buried tree stumps that grew in the valley between 670 and 1200 B.C. were obtained. These dates suggest that any accessible cultural materials in the valley would date no earlier than the late Archaic period.

Additional activity areas and features may be present at the site. Because of the logistical and financial constraints imposed by the depth of deposits and the small quantities of cultural materials present, no further excavations are recommended. This recommendation is in accordance with established federal guidelines (Advisory Council on Historic Preservation 1980: 18, section B(2)a). Since other features or stumps may be exposed during the development of the project, an archaeologist should be present to monitor construction. Sites 34Cd-76 and 34Cd-121 are not considered to be eligible for nomination to the National Register of Historic Places.

Archaeological site 34Cd-244 within the same canyon was visited to monitor the extent of erosion. Previous excavations at this site were conducted by Archaeological Research Associates of Tulsa to remove human burials in conjunction with the development of Structure 2. The recent check revealed that the original bulldozer cut is presently an eight meter gulley, and additional human remains were located. A reanalysis of all skeletal remains from the site is also included.

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Laboratory processing of the artifacts and the messy tasks of flotation and waterscreening were cheerfully and efficiently accomplished by Jane Dye at the Oklahoma Conservation Commission Archaeological Laboratory in Norman. Dr. Archie Hood examined and commented on the human skeletal remains (Appendix B), and Dr. Paul Minnis, University of Oklahoma, Anthropology Department, analyzed floral remains from the hearths. Dr. George Goodman of the Bebb Herbarium, University of Oklahoma, identified the wild garlic bulblets from Feature 6. Drs. Murry Tamers and Jerry Stipp, Beta Analytic Inc., provided the radiocarbon date determinations for the project (Appendix C).

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TABLE OF CONTENTS

		Page
ABSTRACT		i
ACKNOWLEDGEMENTS		iii
LIST OF FIGURES		vii
LIST OF TABLES		xi
MANAGEMENT SUMMARY		viii
CHAPTER 1.	INTRODUCTION (Christopher Lintz)	1
CHAPTER 2.	BACKGROUND (Christopher Lintz)	3
	Regional Physical and Environmental Setting	3
	Conditions Within Carnegie Canyon	4
	Previous Research and Investigative Strategy	9
CHAPTER 3.	GEOLOGY OF HOLOCENE SEDIMENTS AND BURIED TREES OF CARNEGIE CANYON (Stephen Hall)	15
	General Geology	17
	Caddo Canyon Morphology	17
	Carnegie Canyon Stratigraphy	17
	Paleosols	21
	Reference Section	23
	Buried Trees	26
	Radiocarbon Dates	28
	Canyon Sedimentation	32
	Canyon Filling and Soil Development	36
	Molluscan Paleoecology	38
	Prehistoric Water Table Levels	40
	Paleoclimate as Inferred from Fluctuating Water Tables	45
	Geologic Synthesis	46

Page

CHAPTER 4. ARCHAEOLOGY OF CARNEGIE CANYON (Christopher Lintz) . . . 47

34Cd-121 50

Introduction 50

Field Methods 50

Features 50

Material Assemblage 51

Analysis and Interpretation 71

Historic Component 71

Chronological Evidence 71

Site Function 72

Family Structure 74

Prehistoric Component 75

Summary 78

34Cd-76 79

Introduction 79

Field Methods 80

Stratigraphy 83

Features 86

Material Assemblage 97

Analysis and Interpretation 117

Site Limits As Indicated by Surface Material Distribution 117

Extent, Integrity and Age of Cultural Deposits of the Upper Portions of the Canyon 122

Extent, Integrity and Age of Cultural Deposits of the Lower Portions of the Canyon 140

Lithic Resource Utilization 148

Summary 150

Page

OTHER MATERIALS FROM CARNEGIE CANYON 151

34Cd-244, The Takoah Site 151

Isolated Localities 154

CHAPTER 5. SUMMARY OF INVESTIGATIONS (Christopher Lintz) 155

CHAPTER 6. RECOMMENDATIONS (Christopher Lintz) 159

REFERENCES CITED 163

APPENDIX A. THE TREE STUMPS OF CARNEGIE CANYON (Christopher Lintz) . . 175

Background and Collection Procedures 176

Conditions of Buried Stumps in Carnegie Canyon 182

Sources of Displaced Wood in Carnegie Canyon 184

Fluctuating Water Tables: Supplemental Information . . . 185

Additional Comments on Paleosols from the Lower Portions of Carnegie Canyon 192

APPENDIX B. EXAMINATION OF HUMAN BURIALS FROM CARNEGIE CANYON (Archie Hood) 197

Methods 198

Burial Descriptions 201

Pathological Findings and Discussion 203

Conclusions 209

APPENDIX C. RADIOCARBON DATES FROM CARNEGIE CANYON (Christopher Lintz) 211

APPENDIX D. FEDERAL PERMIT 221

LIST OF FIGURES

		Page
FIGURE 1.	VEGETATION COMMUNITIES AROUND CARNEGIE CANYON	5
FIGURE 2.	FORT COBB LATERALS WATERSHED AND LOCATION OF PROPOSED STRUCTURE 101	6
FIGURE 3.	GENERAL VIEWS OF CARNEGIE CANYON	8
FIGURE 4.	ARCHAEOLOGICAL RESOURCES IN CARNEGIE CANYON, CADDO COUNTY, OKLAHOMA	10
FIGURE 5.	EXCAVATION AREAS AND TREE STUMP LOCATIONS NORTH OF THE SECTION ROAD NEAR PROPOSED STRUCTURE 101	12
FIGURE 6.	EXCAVATION AREAS AND TREE STUMP LOCATIONS SOUTH OF THE SECTION ROAD NEAR PROPOSED STRUCTURE 101	13
FIGURE 7.	LOCATION OF CARNEGIE CANYON TO OTHER GEOMORPHIC STUDY AREAS IN CADDO COUNTY	16
FIGURE 8.	GEOLOGICAL STUDY AND COLLECTION AREAS IN CARNEGIE CANYON	18
FIGURE 9.	CROSS SECTION OF CARNEGIE CANYON	19
FIGURE 10.	COMPOSITE STRATIGRAPHY OF CARNEGIE CANYON FILL	20
FIGURE 11.	REFERENCE SECTION FOR CARNEGIE CANYON FILLS STRATIGRAPHY	24
FIGURE 12.	BURIED TREES IN CARNEGIE CANYON	27
FIGURE 13.	AGE DISTRIBUTION OF BURIED TREES	30
FIGURE 14.	STRATIGRAPHY OF SUPERIMPOSED DATED BURIED TREES 28 & 29	31
FIGURE 15.	STRATIGRAPHY OF SUPERIMPOSED TREES 3, 4 & 5	34
FIGURE 16.	BURIED TREE AND HEARTH DEPTH VERSUS RADIOCARBON AGE . . .	35
FIGURE 17.	SPRING CONDUIT	42
FIGURE 18.	LATE HOLOCENE WATER TABLE POSITIONS	44
FIGURE 19.	CHRONOLOGY OF WATER TABLE FLUCTUATIONS	45
FIGURE 20.	HISTORIC BUTTONS AND SNAPS FROM 34Cd-121	59
FIGURE 21.	SODA, MEDICINAL AND MOLDED CONDIMENT GLASS	63

Page

FIGURE 22. FRUIT JAR AND LID LINERS FROM 34Cd-121 64

FIGURE 23. SUNDRY BOTTLES FROM 34Cd-121 66

FIGURE 24. DOMESTIC FURNISHINGS AND ACCESSORY GLASS 67

FIGURE 25. IRONSTONE MAKER'S MARKS FROM 34Cd-121 69

FIGURE 26. SELECT CHRONOLOGICAL INDICATORS FROM 34Cd-121 73

FIGURE 27. SELECT PREHISTORIC MATERIALS FROM 34Cd-121 77

FIGURE 28. LOCATION OF SURFACE COLLECTION AREAS AND UNITS AT 34Cd-76 81

FIGURE 29. STRATIGRAPHIC RELATIONSHIP OF FEATURES 1, 2, 3 AND 4, WEST SIDE OF CARNEGIE CANYON 84

FIGURE 30. LOCATION OF FEATURES AT 34Cd-76, CARNEGIE CANYON 87

FIGURE 31. PLAN VIEW OF HEARTH FEATURES 2 AND 6, 34Cd-76 89

FIGURE 32. WEST CANYON WALL NEAR PROPOSED DAM AXIS 90

FIGURE 33. PLAN VIEW OF FEATURE 3, DEER SKELETON 92

FIGURE 34. PLAN AND PROFILE OF FEATURE 5 (Bison Bone Area), 34Cd-76 94

FIGURE 35. DISTRIBUTION AND IDENTIFICATION OF BISON ELEMENTS IN AND AROUND T.P. N165-E2, FEATURE 5, AT 34Cd-76 95

FIGURE 36. THIN, CHIPPED STONE TOOLS FROM 34Cd-76 101

FIGURE 37. HEAVY, CHIPPED STONE TOOLS FROM 34Cd-76 105

FIGURE 38. GROUND STONE, CERAMIC, SHELL, AND BONE TOOLS FROM 34Cd-76 110

FIGURE 39. HORIZONTAL DISTRIBUTION OF EXCAVATED HISTORIC AND FAUNAL REMAINS FROM 34Cd-76 124

FIGURE 40. HORIZONTAL DISTRIBUTION OF EXCAVATED PREHISTORIC LITHIC AND NONLITHIC ARTIFACTS FROM 34Cd-76 125

FIGURE 41. MATERIAL PROVENIENCE FROM GRID A, EAST SIDE OF VALLEY NEAR PROPOSED DAM 126

FIGURE 42. MATERIAL PROVENIENCE FROM GRID A, WEST SIDE OF VALLEY NEAR PROPOSED DAM 133

Page

FIGURE 43. MATERIAL PROVENIENCE FROM GRID A, NEAR BISON BONE BED . . 137

FIGURE 44. MATERIAL PROVENIENCE FROM GRID B, WITHIN PROPOSED FLOOD-POOL AND BORROW PIT AREAS 141

FIGURE 45. BOATSTONE FROM 34Cd-244 154

FIGURE 46. LONGITUDINAL SECTION OF CARNEGIE CANYON 183

FIGURE 47. SPLINTER ORIENTATION ON STUMPS FROM CARNEGIE CANYON . . . 187

FIGURE 48. ORIENTATION OF STUMPS FROM CARNEGIE CANYON 189

FIGURE 49. DEPTH OF BURNED AND UNBURNED STUMPS FROM CARNEGIE CANYON 191

FIGURE 50. TENTATIVE CORRELATIONS OF PALEOSOLS ACROSS LOWER PARTS OF CARNEGIE CANYON 194

LIST OF TABLES

		Page
1.	RADIOCARBON DATES ON BURIED TREES AT CARNEGIE CANYON	29
2.	HEIGHTS OF RADIOCARBON DATED TREES AND HEARTHS ABOVE MAY 1981 STREAM LEVEL AT CARNEGIE CANYON	33
3.	SOIL TEST RESULTS FROM SELECTED SEDIMENTS AT CARNEGIE CANYON	37
4.	MOLLUSKS FROM THE CADDO COUNTY PALEOSOL AT CARNEGIE CANYON . .	39
5.	ARCHAEOLOGICAL COMPLEXES OF WESTERN OKLAHOMA	48
6.	LITHIC RESOURCES RECOVERED AT CARNEGIE CANYON SITES	49
7.	HISTORIC MATERIALS FROM THE SURFACE OF 34Cd-121	52
8.	PREHISTORIC MATERIALS FROM THE SURFACE OF 34Cd-121	76
9.	METRIC MEASUREMENTS OF SELECT PREHISTORIC ARTIFACTS FROM 34Cd-121	77
10.	ORGANIZATIONAL OUTLINE AND GENERAL PROVENIENCE OF MATERIALS FROM 34Cd-76	98
11.	METRIC MEASUREMENTS OF SELECT PREHISTORIC ARTIFACTS FROM 34Cd-76	100
12.	IDENTIFICATION OF FAUNAL REMAINS FROM THE SURFACE OF 34Cd-76	104
13.	EXCAVATED HISTORIC MATERIALS FROM 34Cd-76	118
14.	DISTRIBUTION OF SURFACE MATERIALS BY COLLECTION AREAS AND UNITS AT 34Cd-76	120
15.	COUNT AND ADJUSTED DENSITY OF MATERIALS FROM T.P. 3, LOWER CANYON FILL AT 34Cd-76A	147
16.	IDENTIFICATION OF LITHIC MATERIALS FROM 34Cd-76	149
17.	SURFACE MATERIALS FROM 34Cd-244	152
18.	DENSITY OF ARTIFACTS FROM VARIOUS AREAS AT 34Cd-76	160
19.	IDENTIFICATION, SIZE, ORIENTATION AND PROVENIENCE OF OLD TREES FROM CARNEGIE CANYON	178
20.	SPLINTER ORIENTATION ON *IN-SITU* STUMPS FROM CARNEGIE CANYON	186
21.	ORIENTATION OF *IN-SITU* STUMPS FROM CARNEGIE CANYON	188

Page

22. 34Cd-244 Burials, Post-Cranial Metric Measurements 199

23. Cranial Metrics and Indices of Burials from 34Cd-244 . . . 200

24. Caries and Abscesses Observed on Burial from 34Cd-244 . . 206

25. Non-Metrical Cranial Variants Observed on Burials from 34Cd-244 208

MANAGEMENT SUMMARY

Purpose of the Report

This report is provided to the U.S.D.A., Soil Conservation Service, Stillwater office. It details the results of a survey conducted in February 1981 and limited archaeological testing conducted during May 18-29 and July 20-30, 1981 at two archaeological sites in western Caddo County, Oklahoma. The survey and testing was initiated in conjunction with the proposed development of Drop Structure 101, Fort Cobb Laterals Watershed.

Objectives of the Report

The major goal of this study was to locate, evaluate and determine if any archaeological sites within the proposed impact area may be considered eligible for nomination to the National Register of Historic Places, and to make further mitigation recommendations if appropriate. Minor aims of this report varied due to the complexity of paleoenvironmental conditions encountered within the canyon. Preliminary geomorphic and paleoenvironmental studies based on numerous paleosols, buried tree stumps and molluscan remains were conducted, and an extensive radiometric program was undertaken to develop preliminary models of the age and past environmental conditions for the region.

Limited controlled testing was used to evaluate the density of cultural materials and integrity of the deposits. Minor archaeological aims were to determine temporal and cultural affiliations, wherever possible, and to postulate activity sets and general site fuction. In addition, archaeological site 34Cd-244 located in the same canyon system and tested in conjunction with Fort Cobb Laterals Structure 2 was visited to monitor the effects of erosion.

Constraints of the Investigations

The major constraints were imposed by the excessive erosion of deposits overlying the Rush Springs Sandstone flanking the canyon and the depth and accessibility of deposits within the canyon. Archaeological site 34Cd-121, flanking the canyon, had lost at least 60 cm of deposit since 1918, and most of the cultural remains rested on bedrock exposure. Further, the linear arrangements and fragmentary condition of glass and ceramic artifacts and the absence of coins and other items of value suggested that considerable rearrangement of materials had occurred, preventing meaningful systematic collection of items by controlled methods. Finally, most of the structural remains were probably moved or salvaged, leaving no information about the number, spatial patterning, or nature of this early statehood farmstead.

Accessibility proved to be the greatest obstacle in evaluating site 34Cd-76 within the canyon. Core drilling indicated that deposits extended to a depth of 32 meters, yet recent erosion exposed only a 10.8 m deep canyon. Since the age of the lowest accessible deposit was only 4500 years old, other buried cultural components might have been present in the unexposed deposits. The distribution of materials exposed in the canyon walls created serious logistic problems. The different depths and locations of exposed features indicated that the canyon collectively represented a highly stratified sequence of cultural occupations; however, no single locality represented the entire cultural sequence. Finally, the extreme depth of the canyon and the loose consistency of the sandy deposits along with occasional slumping of the walls meant that any excavations to obtain a continuous sample of cultural materials were dangerous and logistically difficult. Testing was largely confined to examining the uppermost deposits. A series of features were examined in the lower portions of the canyon; however, logistical difficulties hampered the ability to obtain an adequate sample size to completely evaluate cultural horizons in the lower deposits.

Study Results

Geomorphic and archaeological studies in Carnegie Canyon have discovered 3200 years of environmental change and limited human activities. The combination of several paleosols, a rich molluscan assemblage and at least 63 buried tree stumps suggested that between 3200 and 2600 years ago, the canyon bottom was wooded. The predominance of juniper trees suggested that the water table was several meters below the canyon floor, except for a brief spell approximately 2900 years ago. Although four to six minor paleosols were noted in these lower deposits, the average deposition rate was approximately 0.80 cm per year. Between 2000 and 1000 years ago, the level of the water rose to near the surface, and the deposit rate slowed to only 0.09 to 0.27 cm per year. The higher water table level was reflected by the presence of at least seven aquatic molluscan species, the lack of buried tree stumps and high carbonate coating on sands in the paleosol zone. The valley might have been a marshy meadow with a perennial stream flow; however, the carbonate zone also reflected minor fluctuations in the water table. A portion of the environmental sequence had been eroded away after *ca.* 1000 A.D. Overlying strata reflected drier conditions, and the present water table level was four to seven meters below the pre-1000 A.D. level.

Archaeological studies were frustrated by scarcity of diagnostic materials and extremely small artifact sample with which to reconstruct tool kits and artifact assemblages. Nevertheless, a series of three hearth features, one human burial, portions of a bison kill/ initial processing area, and several limited late Archaic through late prehistoric acitivities surfaces were examined. Most of the occupations seemed to reflect very limited intermittant procurement and processing activities; however, artifact and bone samples were generally of insufficient size to document significant changes through time.

Significance of Results

The paleoenvironmental more than the cultural aspects of this study have contributed to an understanding of western Oklahoma's prehistory. The present study along with other investigations in Delaware and Cedar canyons are beginning to show a consistent environmental pattern. Carnegie Canyon is unique in containing accessible highly stratified deposits from a period 2600-3200 years ago. The collection of a series of buried tree stumps for these lower levels may provide further detailed dendro-climatological studies for western Oklahoma during the first millenium B.C. The extensive documentation of the kinds of molluscan, faunal and paleosol conditions within a well dated context are provided in the hopes of stimulating additional research in the canyon.

Despite the paucity of artifacts recovered through testing, the range of features suggests a number of activities occurring near the heads of short, deeply incised lateral tributaries of the Washita River. This information supplements the knowledge of activities occuring on the major Washita River terrace and upland site situations. The habitation sites historically are located outside the deep canyons, and a similar pattern may have occurred during earlier periods.

Recommendations

The geomorphic studies indicate that paleosols near the proposed dam axis are diluted and bifurcated by the influx of sediments from side channels. The stratigraphy in this portion of the canyon is unrepresentative and generally difficult to correlate with other portions of the valley. Construction impacts are not thought to seriously jeopardize further geomorphic studies since more representative sections of the valley are present downstream from the project area. All 63 stumps have been collected to prevent further deterioration from weathering and drying. Consequently no further paleoenvironmental work need be conducted in conjunction with the development of drop Structure 101. Should additional stumps be encountered during construction, the location, depth, and orientation should be recorded before they are dislodged, and all specimens should be saved.

Archaeological investigations were conducted at an early statehood farmstead (34Cd-121) within the proposed overflow spillway on the east flank of the valley. The context had been previously destroyed through extensive erosion and subsequent rearrangement of artifacts. The sample of materials and observations of the extant structural features are thought to sufficiently document this historic site.

A wide range of activities at 34Cd-76 were disclosed by the archaeological work within the canyon. Testing within the proposed impoundment pool demonstrated the near total absence of cultural materials within the upper two meters (approximate depth of the proposed barrow pits). Apparently this portion of the canyon was not extensively utilized during the late prehistoric period. Testing on both sides of the canyon near the proposed dam axis (north of present roadway) located greater quantities of prehistoric

materials. However, only 0.3 to 6.9 prehistoric artifacts per cubic meter were obtained from this area. Somewhat greater quantities (10.0 items per m^3) were obtained from the lower deposits. Although several hearths and remains of a burial were documented from this area, the logistical aspects of searching for features at random was prohibitive. Much of the area containing cultural materials is situated outside the construction limits and should only be indirectly impacted by runoff changes caused by the overflow spillway realignment. No further work is required for the dam axis construction area as indicated by established federal guidelines (Advisory Council on Historic Preservation 1980:18, Section B(2)a). However, notification of an archaeologist prior to the start of work is strongly recommended so that he/she can monitor any stage of the construction activities. Furthermore, the project inspector is to notify the archaeologist of any potential archaeological remains encountered during construction.

Other individuals are encouraged to conduct further investigations at the bison bone locality (Feature 5) or at geological deposits within the valley. These resources will only be indirectly impacted by runoff until valley walls stabilize. They are generally beyond direct impact areas associated with development of the drop structure.

Finally, monitoring of the Takoah site (34Cd-244) recently located additional human skeletal elements. It is recommended that the Oklahoma Archaeological Survey or some other concerned agency occasionally monitor this locality for evidence of additional burials.

CHAPTER 1

INTRODUCTION

Christopher Lintz

The archaeological perspective on the prehistory of western Oklahoma has shifted dramatically during the last 20 years. Prior to 1960, the majority of archaeological reports from the western part of the state consisted primarily of site assemblage descriptions which provided the foundations for developing local and regional sequences. In lieu of absolute dates, the chronological relationships between sites were primarily conjectural. Also, the scarcity of federally supported projects in western Oklahoma meant that the amount of new information has lagged behind that from the eastern third of the state. The cultural sequences of western Oklahoma were so poorly understood that the currently accepted outline of basic cultural stages (Paleo-Indian, Archaic, Woodland, Village and Historic) was not formalized until 1966 when the Woodland stage was documented for the Pruitt site (Barr 1966; cf. Bell 1961; Pillaert 1963). Since then, a number of radiocarbon dates have become available. As a result, a number of taxonomic sequences involving specific complexes, foci, aspects and phases have been proposed, and modified (Richards 1971, Lintz 1974, Lawton 1968, Harden 1975, Cox 1979, Briscoe 1979, Hofman 1975, 1978, Baugh and Wyckoff 1982).

Once the general sequencing of specific cultural assemblages had been successfully ordered and chronologically supported, archaeological interests shifted towards attempting to interpret the variations between site assemblages and taxonomic units. One of the most commonly used approaches was adopted from cultural ecology (Helm 1962, Vayda and Rappaport 1968, Anderson 1973, and Damas 1969). This approach examines the adaptive relationships of a culture within its changing environmental setting. Ecologically, an environmental setting includes both cultural interrelationships (economics) and culture-physical environmental interactions (exploitations).

Early discussions of cultural interrelationships were couched in terms of generalized notions of migrations or trade without examining the structural mechanisms and impacts behind such concepts (Bell 1961; Pillaert 1963). Similarly, early attempts at assessing the impact of the physical environment on the regional sequences in western Oklahoma were limited by a lack of empirical information. Such attempts were forced to borrow and modify paleoenvironmental models based on information from adjacent areas (Lintz 1974). The resultant constructs remained untested. Since then, research in western Oklahoma has made significant advances in both aspects. On the one hand, the cultural interactions of the various Southern Plains late prehistoric groups with the adjacent Caddoan and Southwestern groups have been cogently modeled (Baugh and Swenson 1980 and Baugh 1982). On the other hand, interdisciplinary studies conducted at archaeological sites have begun to gather and integrate empirical paleoenvironmental information at several localities across the Southern Plains (Ferring 1982,

Henry 1978; Henry, Butler and Hall 1979; Hall 1979, 1980a, 1980b, 1982a, 1982b; Albert 1981; and Duffield 1970). The study of Carnegie Canyon is contributing to this later aspect by providing detailed paleoenvironmental information from one small canyon in western Oklahoma for the last 3500 years.

This report is concerned with the results of geomorphic and archaeological testing of the portion of the canyon that will be impacted by development of proposed Soil Conservation Service Drop Structure 101, Fort Cobb Laterals Watershed, sponsored by the South Caddo Conservation District and the West Caddo Conservation District.

CHAPTER 2

BACKGROUND

Christopher Lintz

This chapter briefly describes the modern physical and environmental setting of the Carnegie Canyon region, and more specifically describes the location and the 1981 conditions within the canyon. It also details the history of previous research and the present investigative strategy in Carnegie Canyon.

REGIONAL PHYSICAL AND ENVIRONMENTAL SETTING

Carnegie Canyon is within the Central Redbed Plains physiographic provenience and is geomorphically within the Western Sandstone Hills province (Curtis and Ham 1972). This region is characterized by soft, flat-lying red Permian sandstones which form gently rolling hills cut by steep walled canyons. Very shallow, moderately developed, well drained soils belonging to the Lucien-Dill series have developed in the uplands over the sandstone bedrock near the canyon. In contrast, the valley soils are developed on Quaternary alluvium and are characterized by deep, gently sloping, well drained soils belonging to the Noble series (Moffatt 1973: 15-17). The sandstone bedrock is part of the Rush Springs formation and acts as a major aquifer for the region (Curtis and Ham 1972:8). The amount of discharge depends on the precipitation rate and fossil water resources. The water table depth for the Washita River valley at the mouth of Carnegie Canyon is 10-15 feet deep and the rate of discharge from wells in the region is in excess of 500 gallons per minute, making the local Rush Springs Sandstone one of the major aquifers in Oklahoma proper (Blanchard 1951; Anonymous 1957).

The region typically has a dry, subhumid continental climate with mild winters and long, hot summers (Oklahoma Water Resources Board 1968). The mean annual precipitation rate for western Caddo County is about 28 inches, of which about two inches is lost to runoff. Seasonal variations in precipitation are pronounced. Over 70 percent of the moisture falls during the warm growing season (April-September). Most of it is associated with violent thunderstorms. The strong winds, low humidity and hot summers produce a high evapo-transpiration rate, leaving little water to recharge the aquifers. Winters are drier with alternating short, very cold spells dispersed throughout a generally cool season.

The drainage pattern of the region is dendritic with major rivers flowing towards the southeast. Near Carnegie Canyon, lateral tributaries ranging from one to seven miles in length enter the Washita River at approximately 0.7 mile intervals. Nevertheless, surface water is fairly restricted. The Washita River is incised into the modern floodplain, and seepage from the numerous springs at the heads of canyons is absorbed by valley alluvium before it reaches the river.

Over 98 percent of the vegetation in the three counties surrounding Carnegie Canyon (Caddo, Kiowa, Washita) belong to four plant associations. From east to west, these consist of:

1) the Post Oak/Blackjack Oak Forest Association (17.2 %);
2) the Tall Grass Prairie Association (30.1 %);
3) the Mixed Grass Eroded Plains Association (49.8 %); and
4) the Woodland for Creek and River Associations (2.5 %).

The remaining communities comprise other minor plant associations (Duck and Fletcher 1943, 1944:16-19). All four dominant plant associations occur within five miles radius of Carnegie Canyon, and would have been within easy exploitation distance for pedestrial groups (Figure 1).

The vegetation in the canyon is attributed to the Woodland for Creek and River Association (Duck and Fletcher 1943). Dominant woody plants in this association include American elm, chinquapin oak, white oak, post oak, black willow, salt cedar, bitteroot, Chickasaw plums, pecan, and occasionally, sycamore. Grasses and forbes include inland salt grass, switch grass, nut-grass, rush, cockle burr, camel and smartweed. Aquatic plants include cattail, smartweed, spike rush and water clover (Barber 1975 and Kuchler 1964 in Baugh 1982; Duck and Fletcher 1944:23). The upland regions around Carnegie Canyon consist of a mosaic of Post Oak and Blackjack Oak Association and the Tall Grass Prairie Association. The major plants of the Post Oak/Blackjack Oak Association include post oak, blackjack oak, black hickory with an understory of predominantly bluestem grasses; whereas the Tall Grass Prairie Association includes big and little bluestems, Indian grass, switch grass and more rarely, buffalo grass, side oats and blue gramma. The Mixed Grass Eroded Plains Association does not presently occur in the immediate vicinity of Carnegie Canyon, but is less than five miles to the west. The dominant species include buffalo grass, blue gramma, side oats and more rarely, little bluestem, tridens and a wide range of forbes and woody shrubs (cf. Baugh 1982: Tables 5 and 6).

Numerous birds, reptiles and mammals are present in the region. The main animals most likely sought and used by prehistoric groups include bison, pronghorn, deer, elk, rabbit, prairie dog, turtle, freshwater mussels, and to a lesser extent, bear, bobcat, raccoon, badger, otter, weasel, skunk, woodrat and ground squirrel (for a more complete list, see Baugh 1982).

Conditions Within Carnegie Canyon

Carnegie Canyon is one of numerous short lateral tributaries of the Washita River (Figure 2). The canyon is only 1.7 miles (2.7 km) long and is so short that the U.S.G.S. has not named it. The name "Carnegie Canyon" was proposed since it is located only 2.3 miles (5.15 km) southeast of Carnegie (SE¼ of SE¼ of Section 10, and NE¼ of NE¼ of Section 15, T7N, R13W). Furthermore, the "Carnegie Church" is on the drainage divide west of the basin (Lintz 1981).

The tributary is presently a filled canyon cut into Rush Springs Sandstone. Near the project area, the canyon is only 200 feet (60 m) wide with gently sloping sandstone bluffs rising 30 ft (9 m) above the filled valley floor. The "Old Indian" road crosses the head of the valley immediately below the confluence of two arms of the tributary and serves as a major farm-to-market artery in the area. Upstream (south) of the road, the tributary arms have incised channels approximately 26 ft (8 m) wide and 13 ft (4 m) deep into the sand filled valley. However, north of the

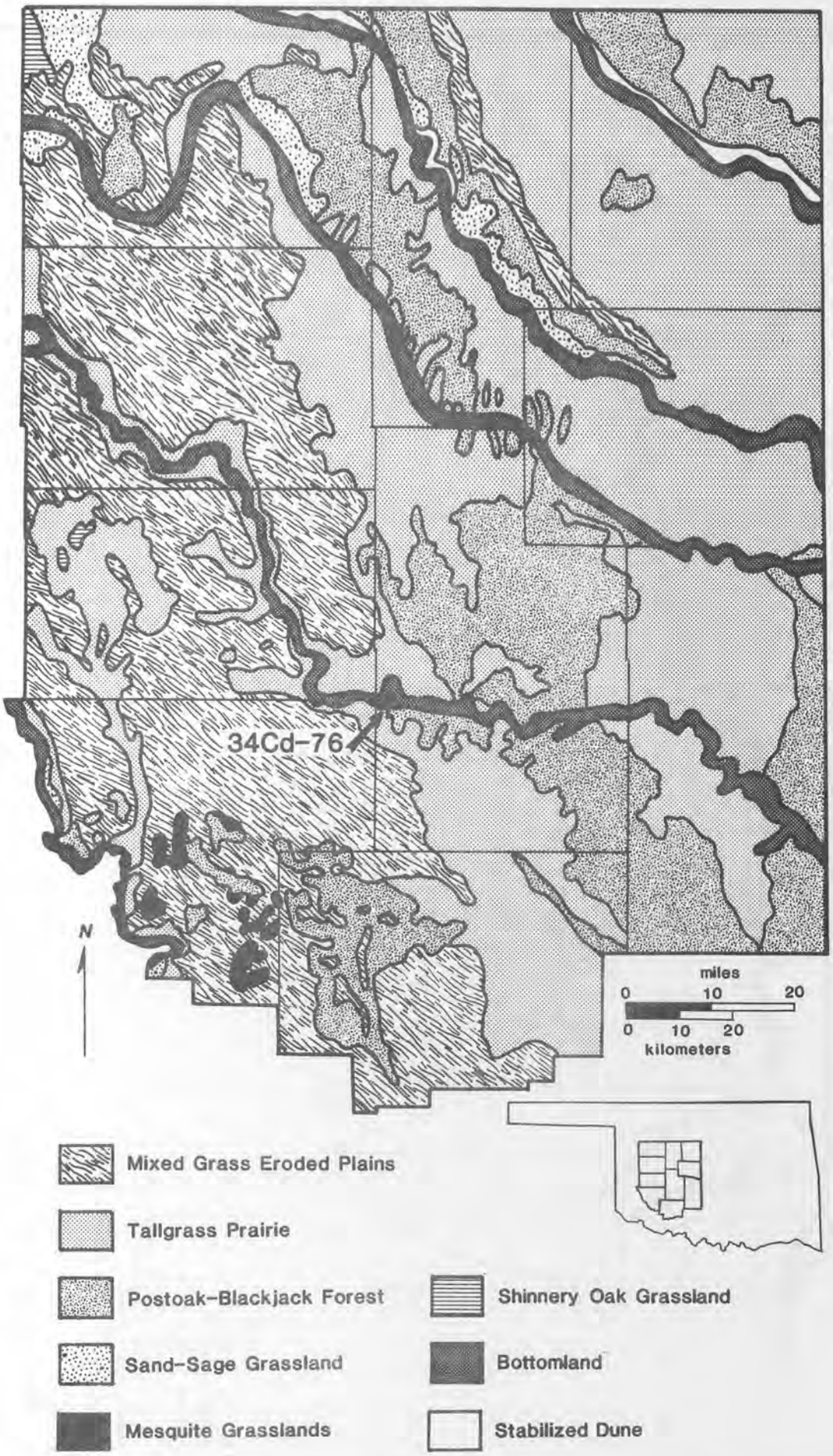


Figure 1. Vegetation Communities Near Carnegie Canyon (after Duck and Fletcher, 1943).

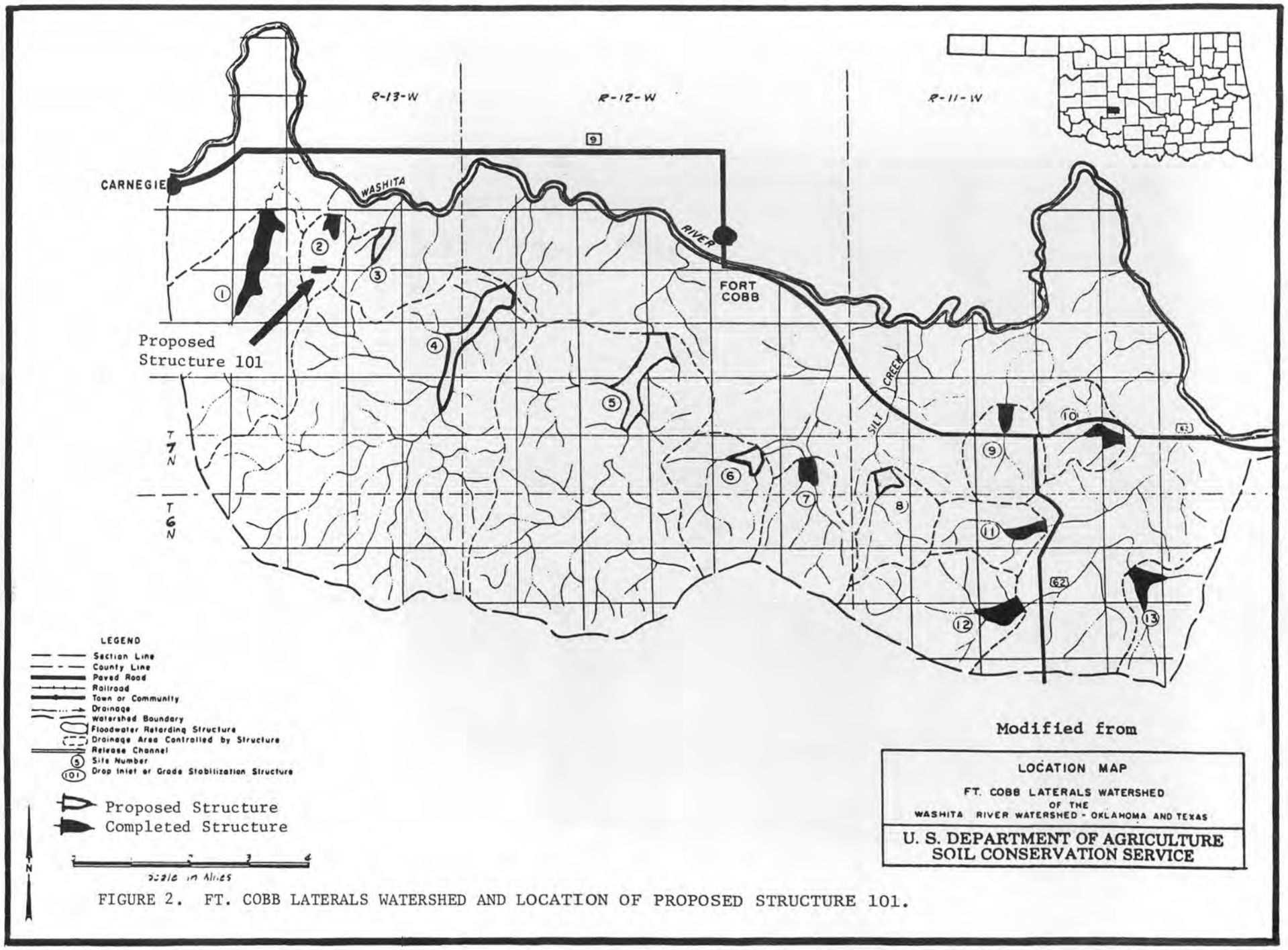


FIGURE 2. FT. COBB LATERALS WATERSHED AND LOCATION OF PROPOSED STRUCTURE 101.

road, the incised channel is 110-115 ft (30-35 m) wide and averages 34.5 ft (10.8 m) deep (Figure 3A). The depth of channel erosion is presently stabilized by a concrete road culvert; while north of the road, the erosion depth is partially checked by the present water table.

From surface indications, the sandstone margins of the valley are relatively straight, but the modern canyon within the sandy fill meanders slightly. In cross section, the modern canyon is essentially V-shaped. The upper seven to eight meters of the canyon have vertical walls, but the lower part of the canyon is not as steep. Near the road, the canyon is unstable. Large slump blocks of sand still collapse from the walls at weekly or monthly basis, and mantle portions of the lower canyon. Remnants of a linear brush pile consisting of old, displaced and recently fallen trees are present in portions of the first 250 m of the canyon north of the road. The displaced brush probably marks the location of the initial eroded channel within the canyon. The modern channel meander has cut through the brush piles and removed segments of the linear pile.

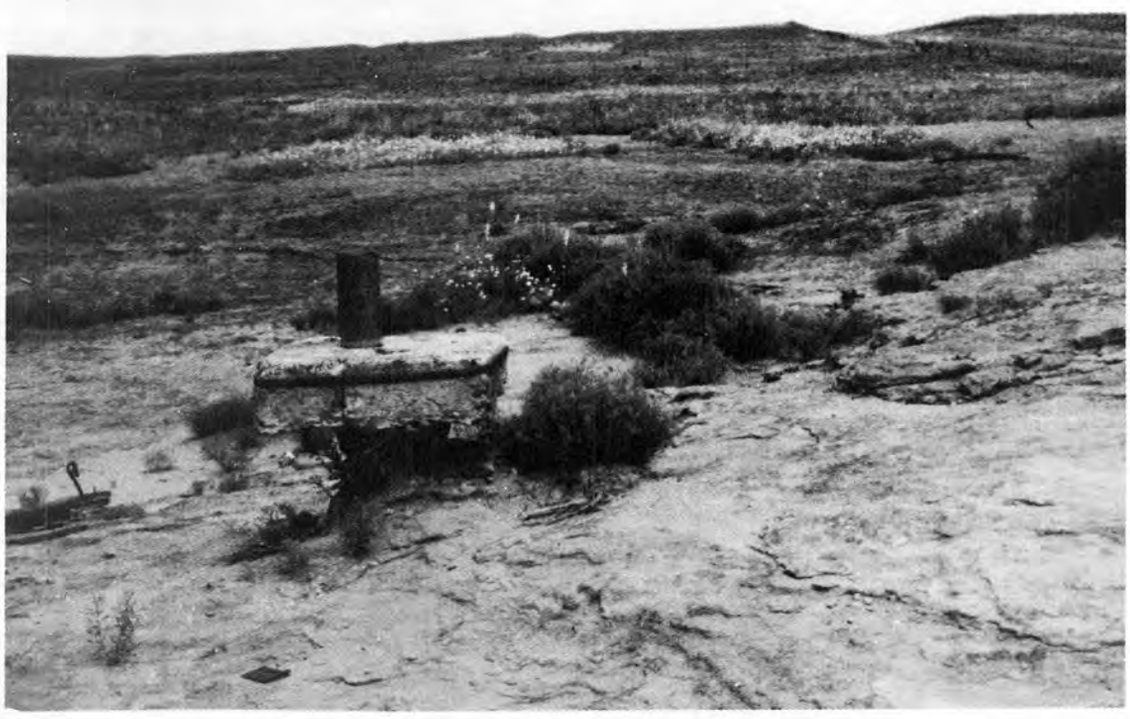
Some of the vegetation in the valley has been modified by historic activities. The entire filled valley south of the road is in dense woody bottom cover consisting mainly of oak, hickory, juniper, greenbriars and poison ivy. North of the road, the filled valley floor has been cleared. Although the sandstone flanks of the valley are wooded, the valley floor is in pasture. A linear undulation across the valley floor perhaps marks an old fence row. The deep canyon is sparsely vegetated with cattails, various grasses and small willows for the first 100 m north of the road. Scattered stands of small willows and cottonwoods are present in broader portions of the canyon between 100 and 250 m from the road. Beyond this, the canyon becomes wider, is more stabilized and supports more established plant associations.

The extensive erosion up to the road is a fairly recent phenomenon. The galleria forest north of the road was cleared during the historic period, suggesting that the headwater tributary was not very deep. Aerial photographs *ca.* 1965 indicate that the deep erosion was approximately 2100 ft (366 m) north of the section road (Moffatt 1973: map sheet 64); and a survey of the valley in 1974 places the head of the deep canyon approximately 650 ft (198 m) north of the road (Charles Wallis, personal communications). Early concerns for the channel erosion are reflected by the Soil Conservation Service plans to construct "Drop Stabilization Structure 102" approximately one-third of a mile north of the road (Soil Conservation Service n.d.).

Despite these plans, the rapid erosional cutting has continued unchecked to the extent that it is threatening the county road. Riprap has been dumped along the road to retard erosion; however, solution cavities are forming beneath the bridge, and the drainage culvert is presently cracked.

Presently proposed Drop Structure 101 will attempt to stop the entrenching channel. Plans call for the construction of a dam to be built along the section line which will replace the existing threatened roadway. The principle spillway (elevation 1377 ft mean sea level (msl) is projected where the present culvert is located, and an emergency spillway (elevation 1385.5 ft. msl) is projected along the upper east side of the sandstone bluffs and will empty into an existing erosional cut. The section line road will be relocated on top of the drop structure (Coppock 1981). The major areas to be impacted by the project include:

A



B

Figure 3. General Views of Carnegie Canyon.
A. Carnegie Canyon (34Cd-76) Facing North from Road.
B. Erosion Below Pipewell at 34Cd-121.

1) both sides of the canyon near the present road which will be affected during dam construction;

2) the upper east side of the canyon which will be affected by emergency spillway construction and a change in drainage patterns during high run-off periods; and,

3) the valley fill south of the road below 1386 ft msl which may be a source for borrow fill, as well as periodic inundation and/or increased ground water saturation.

Geological studies indicate that two borrow pit areas may be involved. Preliminary evaluation of the soils indicate that the borrow pit on the west tributary may be 12 ft deep, while the borrow pit on the east tributary may be only 4 ft deep (Fields 1981).

Previous Research and Investigative Strategy

The earliest recorded investigations in Carnegie Canyon were conducted by Tyler Bastian for the Museum of the Great Plains in 1964. On the basis of archaeological materials reported by Mr. Elvie Mandrell, Mr. Bastian visited the canyon and recorded site 34Cd-76 near the Old Indian road on the west edge of the valley (Bastian 1964). Apparently Mr. Mandrell recovered two large *Gary* points, but during Mr. Bastian's visit only five pieces of quartzite and two flakes were recovered.

The second archaeological investigations occurred in conjunction with the cultural survey of proposed Soil Conservation Service Impoundment No. 2, located at the mouth of the canyon (Wallis 1974). The survey mainly focused on the areas of impact located approximately one-half to one mile north of the Old Indian Road (Figure 4). The surveyor revisited 34Cd-76, located two new sites (34Cd-242 and 34Cd-244), and noted portions of a bison skeleton buried nine ft (2.75 m) deep (assigned locality number 34Cd-0/15). Field notes indicate that two other bone localities (34Cd-0/18 and 34Cd-0/19) were found, but they were not mentioned since they occurred outside the impact area (Wallis n.d.). Localities 34Cd-0/15 and 34Cd-0/18 were near the mouth of the canyon, whereas locality 34Cd-0/19 was on the east bank, some 703 ft (215 m) north of the Old Indian road. The recovery of a small *Gary* point from 34Cd-242 (east side of the canyon) was the only diagnostic item from the canyon. No additional work was recommended for the three isolated bone localities. At 34Cd-244, portions of two human skeletons and an ash filled lens along the west edge of the canyon were found approximately 2600 ft (790 m) north of the Old Indian road. Burial removal was recommended for the site (Wallis 1974:7).

In 1975, the National Park Service awarded a contract to Archaeological Research Associates, Tulsa, to investigate and remove the burials from the Takoah site, 34Cd-244 (Cheek 1975 and 1976). The burials were at an approximate depth of 2.6 and 4.8 m on each side of a bulldozer cut through the west bank of the canyon. No diagnostic grave goods were directly associated with the burials; however, a *Scallorn*-like point (60-80 cm deep), and three *Gary* points (180-220 cm deep) were recovered above the burials. The burials

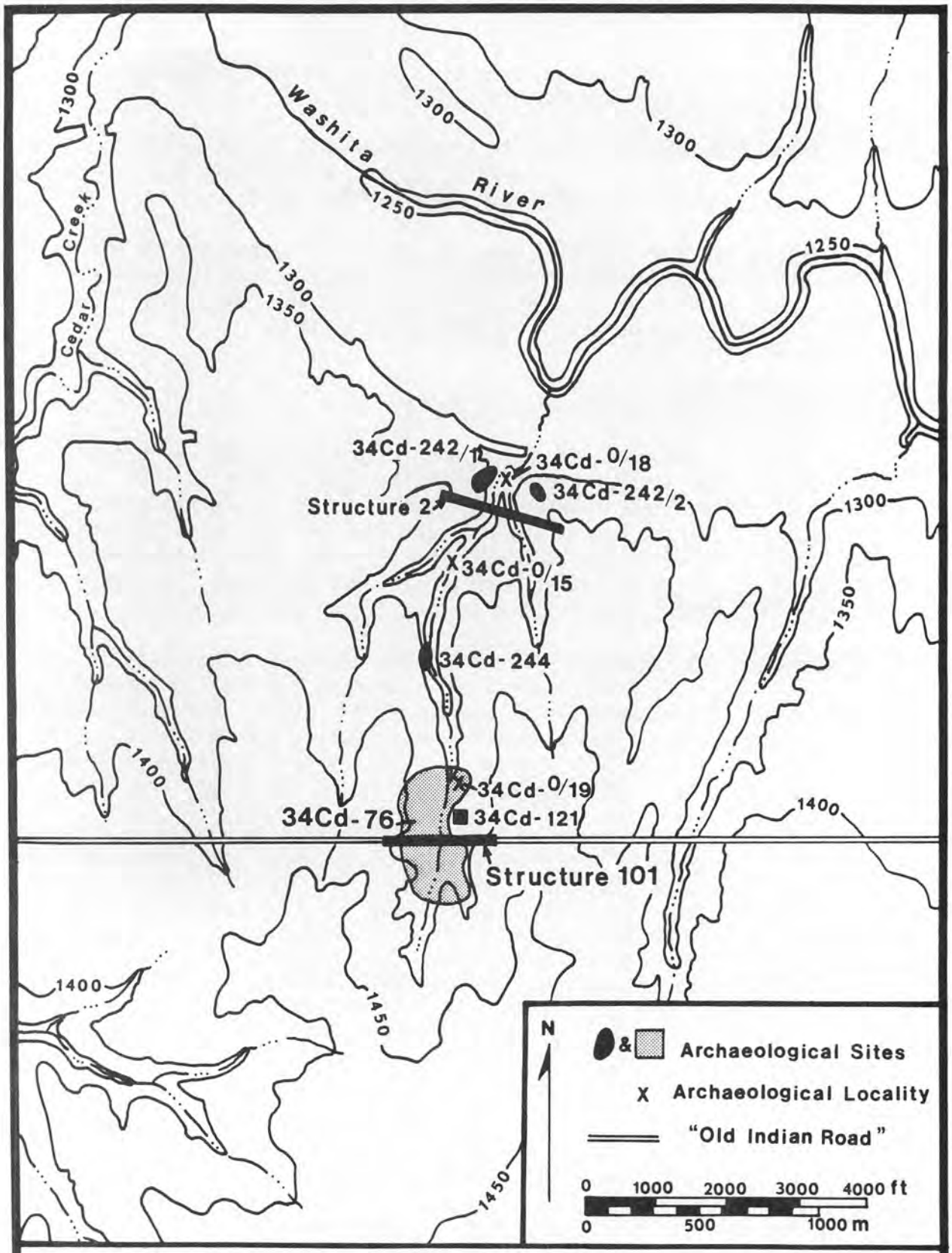


Figure 4. Archaeological Resources in Carnegie Canyon, Caddo County, Oklahoma.

were thought to be Late Archaic (1000 B.C. - A.D. 1), presumably because of the great depth of the burials, their location below a cultural horizon containing mostly large contracting stemmed points, and their position above a "gray-blue" buried soil which was erroneously thought to relate to the Pleistocene age clay at the Domebo site (Cheek 1976:4). Palynological analysis of the sediments associated with Burial 2 indicated that pollen preservation in the valley was poor (Scott 1975).

The present research was initiated when the canyon head was resurveyed by Charles Wallis, Jr. on February 13, 1981, in conjunction with the development of Drop Structure 101. This survey located a severely eroded early Statehood homestead site (34Cd-121) within the proposed emergency spillway alignment (Figure 3B). A fire hearth was found at a depth of some 5 m, and minor amounts of burned bone, heat fractured quartzite nodules and flakes were collected from scattered localities and various depths within the canyon north of the road. The previously recorded bison bone locality, 34Cd-0/19, was also revisited. South of the road, another hearth was noted, and minor amounts of prehistoric cultural materials were recovered from the creek channel. Within the deep canyon, north of the road, several paleosols and both terrestrial and aquatic molluscs were observed. The vague site boundaries of 34Cd-76 were expanded to include the discrete hearth features and the various activity areas within the canyon (Figures 5 and 6).

On February 19, 1981, archaeologists from the Oklahoma Conservation Commission and the director of the Oklahoma Archaeological Survey visited the canyon to make a stratigraphic description of the west canyon wall and to collect charcoal samples for dating. Surface examination showed that the cultural materials occurred in small quantities. Portions of a human cranium were found scattered down the east canyon slope, some 50 m north of the road. No *in situ* bones could be located. On the basis of these two trips, it appeared that Carnegie Canyon contained a wealth of paleoenvironmental information, some cultural features, but a paucity of artifactual remains. For these reasons, it was decided that the evaluative phase should include a geomorphologist to examine the paleoenvironmental aspects of the valley. Dr. Hall was contracted to conduct these studies. The buried tree stumps were first noted during a preliminary examination of the geomorphic potential of the canyon.

The initial archaeological evaluation of the canyon was supervised during May 18-29, 1981 to coincide with Dr. Hall's geomorphic studies of the canyon. Since delays were encountered in obtaining the appropriate federal permit (Appendix D), excavations on Indian-owned land south of the road were not conducted until July 20-30, 1981. A total of 134 man-days was spent in the field examining the cultural resources of the canyon. The site was also spot checked intermittently throughout the fall and winter of 1981 and the spring of 1982. The buried tree stumps were collected between November 16 and December 17, 1981 for future dendrochronological and paleoenvironmental studies (Appendix A).

The goal of the present investigation is to document the cultural and paleoenvironmental resource potential near the canyon head, involving a complementary interplay of limited geomorphological and archaeological testing. Since most of the accessible deep geological deposits are downstream and will not be affected by construction of the proposed drop

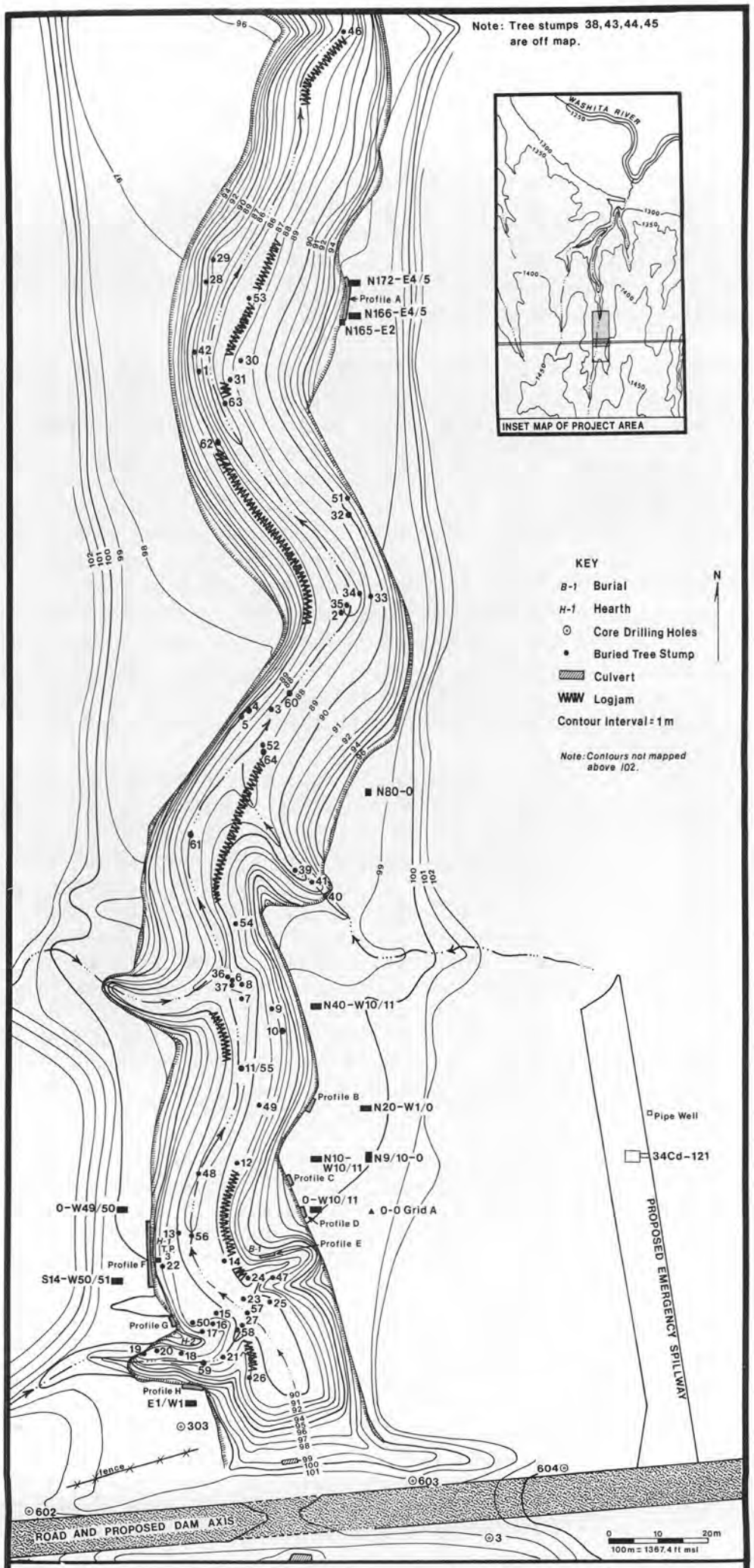


Figure 5. Excavation Areas and Tree Stump Locations North of the Section Road Near Proposed Structure 101.

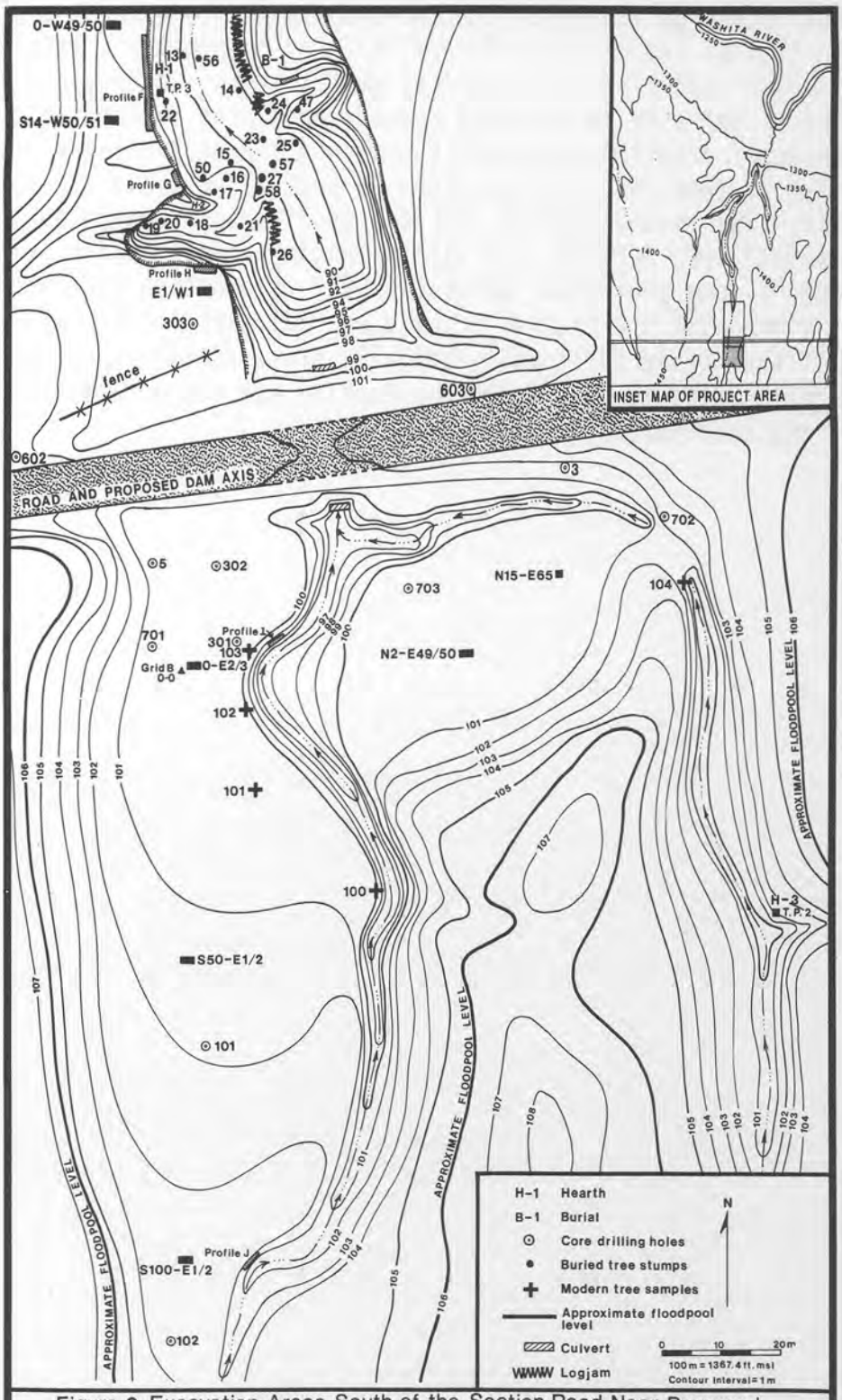


Figure 6. Excavation Areas South of the Section Road Near Proposed Structure 101.

structure, the strategy (within a limited budget) was to develop a detailed chronological sequence for the valley, and to provide a fairly thorough record of the kinds of resources available in the canyon. The geomorphological emphasis is directed towards examining sedimentation rates and paleosol development within the canyon and developing a preliminary climatic model based on evidence of past water table fluctuations in the canyon. The archaeological emphasis is directed towards evaluating the sites 34Cd-121 and 34Cd-76, and with providing complimentary information about the age of some geological deposits. The information generated from this report along with the extensive suite of radiocarbon dates and the sectioning of the buried trees will hopefully prove useful in attracting other kinds of studies to this and other similar canyons of western Oklahoma in the near future.

CHAPTER 3

GEOLOGY OF THE HOLOCENE SEDIMENTS AND BURIED TREES OF CARNEGIE CANYON

Stephen A. Hall

INTRODUCTION

In west-central Oklahoma a canyon system has been carved into the Rush Springs Sandstone (Permian). The history of the Caddo Canyons is of interest to biologists, archaeologists and geologists. The canyons harbor stands of sugar maple (*Acer saccharum*) that are probably relicts from a former period when the maple ranged farther west (Little 1939). The sandstone cliffs also provided shelter for prehistoric man for 2000 years (Lawton 1968). Projectile points of Clovis and Folsom types have been recovered, indicating the canyons were frequented by Early Man (Bell 1954 and Hofman 1980a).

The erosion of the canyons and their subsequent filling with sand have been the subject of speculation among geologists (Albritton 1966; Blanchard 1951; Goss *et al.* 1972; Retallick 1966; Strain 1937; Tanaka and Davis 1963; Skinner 1960 and Nials 1977). The canyons are cut 30 to 60 meters (100 to 200 feet) into the soft Rush Springs Sandstone (Goss *et al.* 1972 and Harlin 1982). The oldest dated sediment within the canyons is the 11,200-year Domebo Paleo-Indian site (Leonhardy 1966a). Closer to the project area (Figure 7) are 8,500 to 9,650 year old sediments in Cedar Canyon (Nials 1977). These dates indicate that bedrock scouring extended no later than late glacial time. Thus, the canyon system may have been eroded during the Pleistocene. The deep sand fill of the canyons has only recently been investigated. Delaware Canyon, about five kilometers (3 miles) east of Domebo Canyon in Caddo County, contains a fill sequence exposed to about a nine meter (30 feet) depth and dates no older than 3000 years B.P. (Hall 1980a). This suggests that the thick sand deposits in some canyons may be a great deal younger than previously guessed.

In May 1981, the geology of Carnegie Canyon was investigated in conjunction with archaeological studies conducted by the Oklahoma Conservation Commission (Figure 8). Carnegie Canyon (E ½, Sec. 10, T7N, R13W) about four kilometers (2.5 miles) east of Carnegie, is a small tributary of the Washita River, extending only about 2.7 km south of the Washita River Valley. The Carnegie Canyon studies reported here verify the geologic history obtained from Delaware Canyon. In addition, the discovery of over 60 buried juniper trees brings a new perspective to the geomorphic and paleoclimatological history of the Caddo Canyon region.

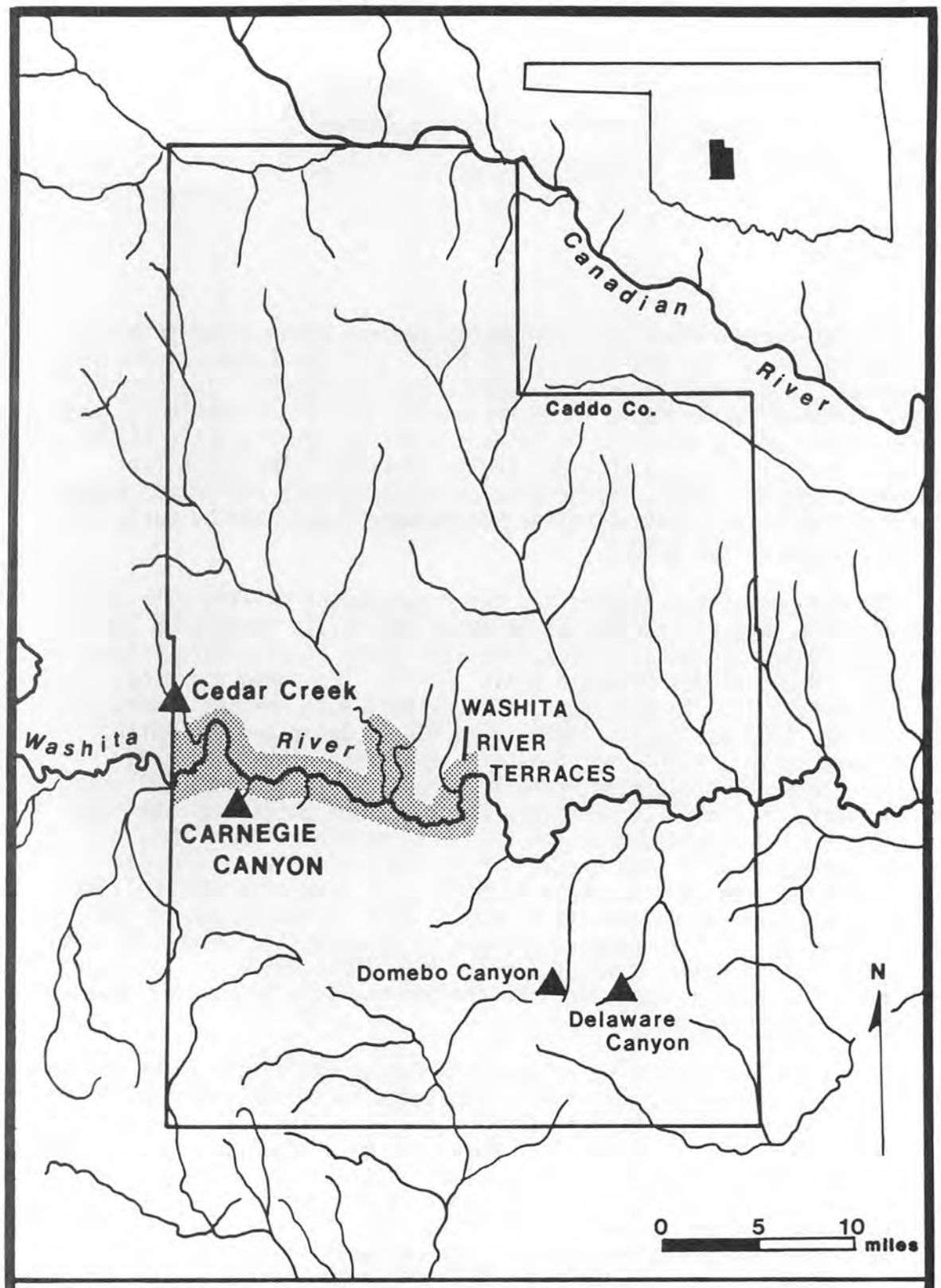


Figure 7. Location of Carnegie Canyon to Other Geomorphic Study Areas in Caddo County.

GENERAL GEOLOGY

The Caddo Canyons are cut into the Rush Springs Sandstone, the uppermost formation of the Whitehorse Group (Permian). The sandstone ranges from 60 to 100 meters (200 to 330 feet) thick and outcrops over a wide area of west-central Oklahoma. It is a reddish-brown, silty, very fine quartz sand with iron oxide and calcite cement. The Rush Springs Sandstone is a regional aquifer (Tanaka and Davis 1963). Rapid weathering of the sandstone produces vast quantities of loose sand and a thick sandy soil on hillslopes. In places, small dunes, now stabilized, have accumulated. A Pleistocene soil extends over two meters depth on drainage divides and is exposed in gulleys along section roads. Today, some hillsides are completely denuded of sand, exposing the red sandstone bedrock or "sand rock" as it is called by local residents.

CADDO CANYON MORPHOLOGY

The canyons, cut during the Pleistocene, were almost completely filled with sand during the Holocene. Recent erosion has removed a great deal of the sand fill, exposing vertical sandstone canyon walls. A series of drill holes to bedrock shows that the alluvial fill in the Washita River Valley extends 100 feet below the modern floodplain (Goss *et al.* 1972). If the elevation of the bedrock on hillslopes above the valley is included, the total depth of the sandstone canyon is 200 feet. Also, cross-sectional reconstructions show that the buried margins of the Washita Valley are nearly vertical.

At Carnegie Canyon, a series of cores paralleling the proposed dam axis were drilled through alluvium to bedrock along the south side of the paved road (Figure 8). A bedrock profile shows a vertical walled canyon 120 meters (390 feet) wide and 30 meters (100 feet) deep, excluding the adjacent hillslope (Figure 9). During Pleistocene downcutting, the Washita River and its tributaries formed a remarkable system of vertical walled canyons.

CARNEGIE CANYON STRATIGRAPHY

The prehistoric canyon fill of Carnegie Canyon is divided into three units, each unit separated from the other by an erosional unconformity in accordance with traditional stratigraphic procedures in alluvial geology. A fourth unit of historic age is differentiated on the basis of wire, glass and other modern materials found in the sediment (Figure 10).

Unit C. The oldest unit exposed in Carnegie Canyon is colluvial Unit C. It is composed of sandstone blocks and gravels, occurring along the margins of the canyon walls and originating locally from the Rush

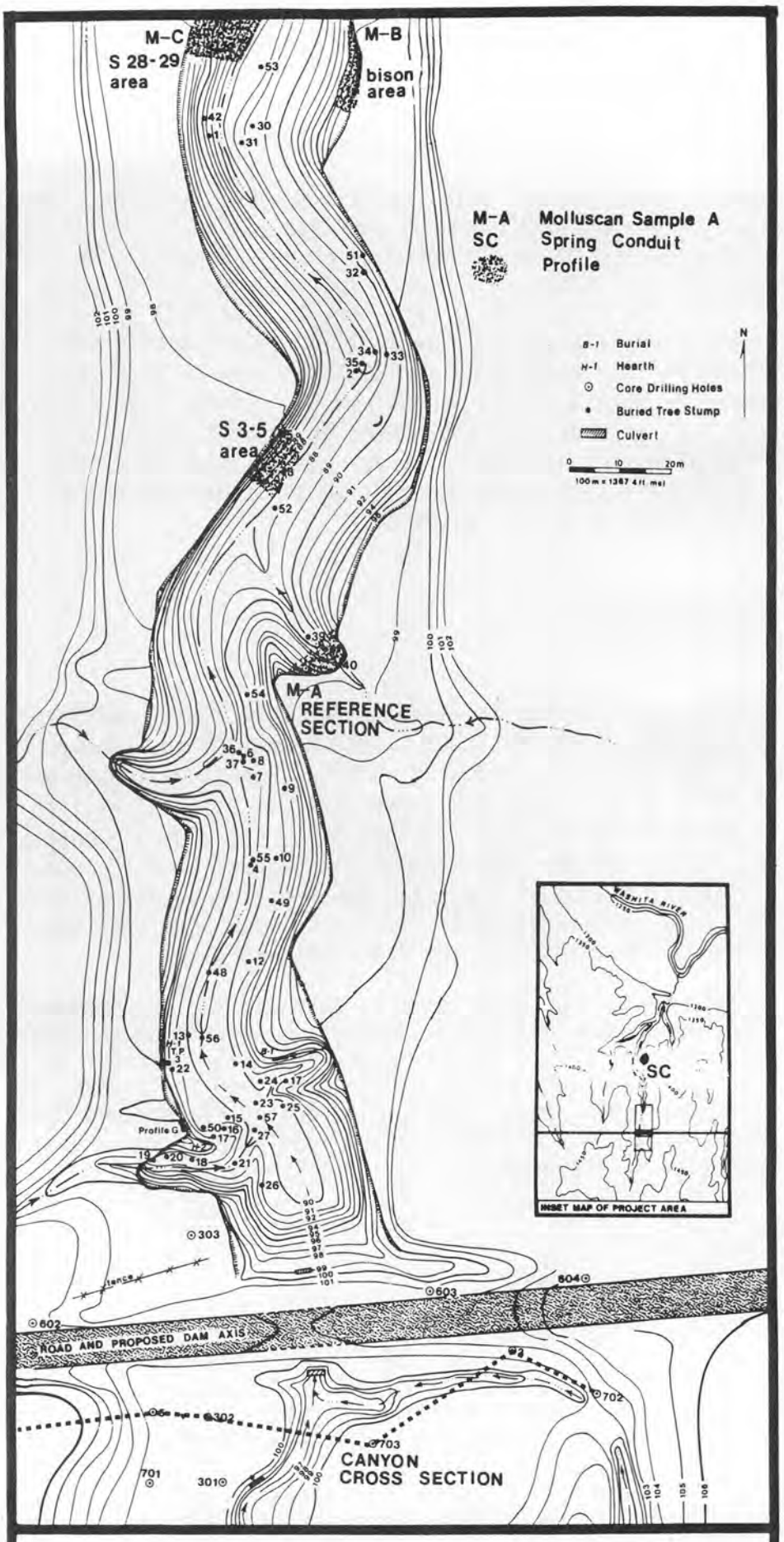


Figure 8. Geological Study and Collection Areas in Carnegie Canyon.

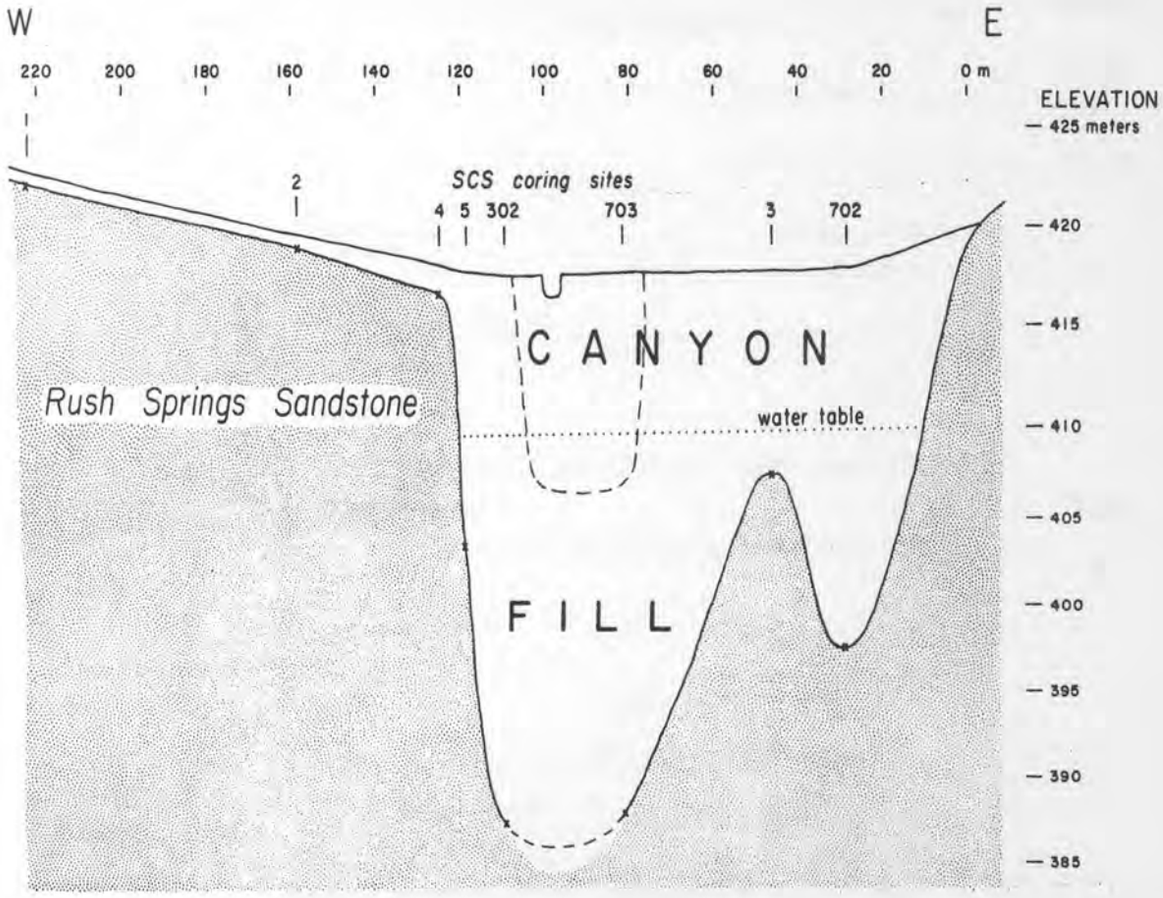


Figure 9. Cross-section of Carnegie Canyon. Small x's indicate contact with sandstone bedrock in Soil Conservation Service bore holes; dashed line channel extending 3 meters below water table represents modern arroyo eroded into canyon fill north of paved road; X4 vertical exaggeration.

Springs Sandstone. The unstratified sandstone gravels and reddish brown sand are weakly cemented with calcium carbonate. Colluvial gravels are generally absent from younger units at Carnegie Canyon and are not accumulating in the canyon today. Neither archaeological remains, fossil shells nor bones have been found in the colluvium. Unit C may have been deposited during a period of colder climate in the late Pleistocene or early Holocene when frequent freezing weather could have increased mass-wasting along sandstone cliffs.

There is little indication of the amount of colluvial fill originally present in the canyon. Unit B alluvium and the Caddo County paleosol drape over Unit C colluvium where the colluvium is preserved in isolated patches against the sandstone canyon walls.

Unit B. The principal fill at Carnegie Canyon, Unit B, is an unbedded, homogenous, yellowish red quartz sand derived from weathered Rush Springs Sandstone, the red color coming from iron oxide coatings on grains.

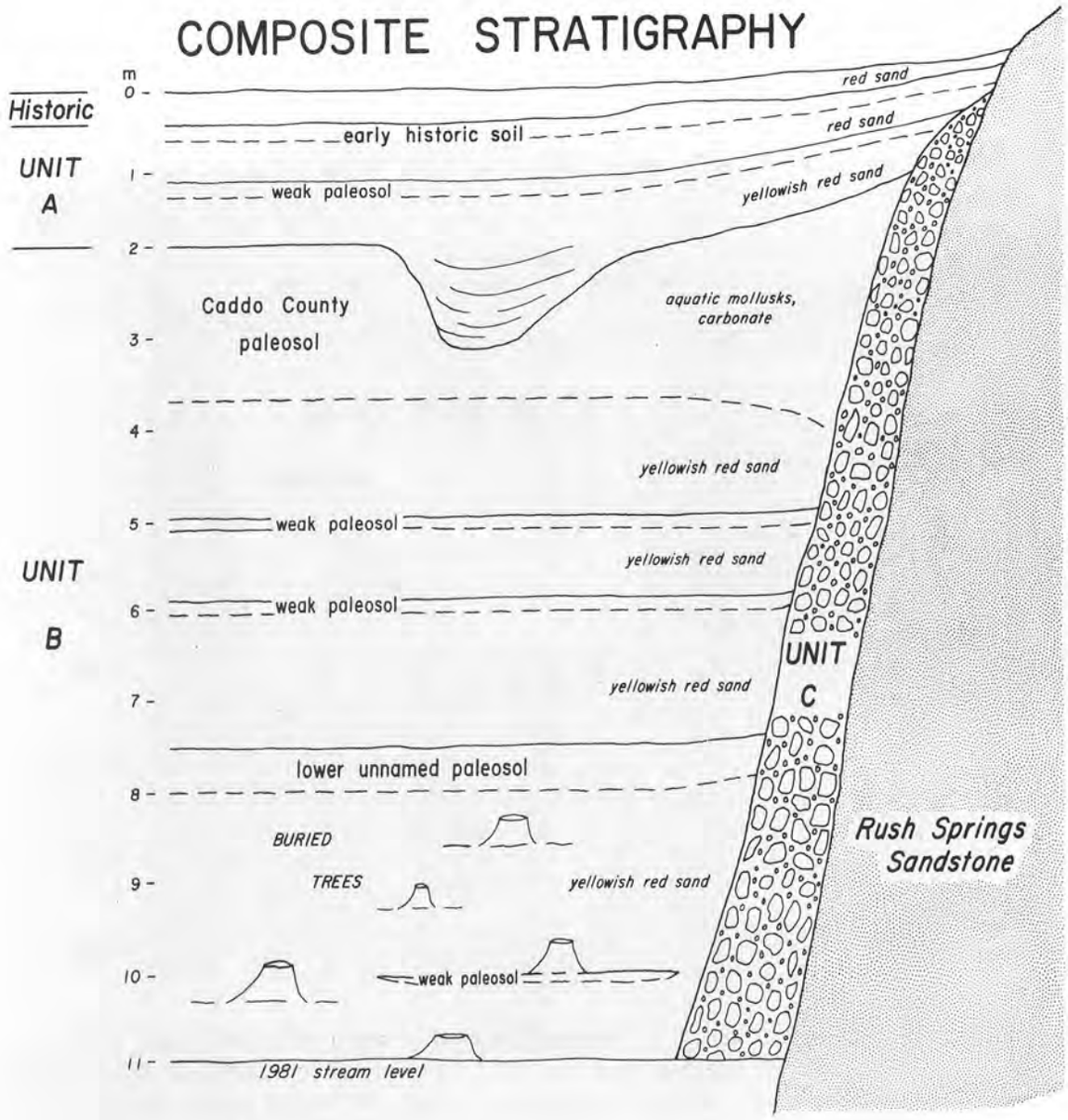


Figure 10. Composite stratigraphy of Carnegie Canyon fill. Unit B extends at least 20 meters below the 1981 incised canyon floor; buried trees occur below 6.5 meters depth at places in the canyon fill, but most are restricted below the lower unnamed paleosol.

Unit B is principally alluvium even though the sediment likely enters the canyon by sheet erosion of adjacent upland surfaces. Several azonal soils are buried in Unit B sand, as are sequences of buried tree stumps, terrestrial and aquatic mollusks, animal bones and, occasionally, archaeological remains. The paleosols and other remains are described later in this report. Inspection of core samples from drill holes sunk to bedrock along the south side of the road and traversing the canyon show that homogenous sand, probably Unit B, extends to about 31 meters in depth. At the top of Unit B is a prominent buried soil which is correlated with the Caddo County paleosol described and dated at Delaware Canyon about 33 km southeast of Carnegie Canyon (Hall 1980a).

The development of the Caddo County paleosol, and further accumulation of Unit B, was terminated by channel trenching of the canyon floor to a depth less than two meters deep. The width of the former channel cannot be determined because a cross-section is not preserved in the present arroyo wall. Erosion of the canyon floor was not uniform; some upper surfaces of the Caddo County paleosol do not appear to be eroded at all and are buried by younger sediment.

Unit A. After the trenching of the canyon floor and the partial removal of the Caddo County paleosol at the top of Unit B, the canyon and channel were filled with sand, carbonate granules, and mollusk shells reworked from Unit B and the Caddo County paleosol. Unit A sands are unbedded, except in channel fills, and lack the calcium carbonate cementation found in older units. The thickness of Unit A ranges from 50 to 225 cm.

Buried within Unit A is a thin, azonal A-horizon similar in stratigraphic position to the Delaware Creek paleosol named and described from Delaware Canyon (Pheasant 1982). The Delaware Creek paleosol is dated 600 to 800 years B.P. at Delaware Canyon but is undated at Carnegie Canyon. The top of Unit A is defined by a soil that was forming at the surface of the canyon fill at the time the area was historically settled. In places the soil evidently has been disturbed and contains historic materials.

Historic Unit. The Historic Unit is defined as the sand that has accumulated on top of and buried the early modern soil (top of Unit A). The sand is unbedded and is colluvial in origin, coming from the hillsides adjacent the canyon. The red sand contains bits of metal, glass and coal from a nearby early homestead and has accumulated to a thickness of about 40 cm.

PALEOSOLS

The term "paleosol", introduced by Hunt and Sokoloff (1951), is defined loosely as an ancient soil; in practice, the term is applied most frequently to buried soils. Several buried soils occur at Carnegie Canyon (Figure 10). All are organic-rich, azonal, cumulic A-Horizons that have accumulated slowly on the canyon floor, quite different from the origin of pedogenic soils by weathering.

Caddo County Paleosol

The Caddo County paleosol is a soil stratigraphic unit as defined by the Code of Stratigraphic Nomenclature (American Commission of Stratigraphic Nomenclature 1961). The informal name "Caddo County paleosol" was introduced in Ferring (1982) in a study of Delaware Canyon in southern Caddo County. The term "paleosol" when used in "Caddo County paleosol" is restricted to lower case spelling in accordance with nomenclatural policy for informal stratigraphic names. In earlier discussions of alluvial

stratigraphy (Hall 1979 and 1980a), the name "Kichai paleosol" was used in reference to what has subsequently become called the Caddo County paleosol by others. The name Kichai paleosol is dropped from usage. The informality of the Caddo County paleosol name is retained for now, owing to incomplete information on the distribution and chronology of the buried soil in the Southern Plains.

The principal buried soil at Carnegie Canyon corresponds to the Caddo County paleosol of Delaware Canyon in its morphology, stratigraphy, paleoecology and chronology. The Caddo County paleosol is not directly dated at Carnegie Canyon but occurs stratigraphically above Hearth 1, charcoal from which is dated 2390±100 years B.P. (Beta-2622), and below archaeological horizons containing projectile points dating post-1000 A.D. Thus, the Caddo County paleosol is bracketed by dated horizons. At Delaware Canyon, where well-defined by eight radiocarbon dates, the Caddo County paleosol formed between 1050 and 2050 years B.P. (Hall 1980a).

The Caddo County paleosol occurs within 50 to 240 cm of the present surface at Carnegie Canyon and is between 80 and 270 cm thick. The paleosol contains calcium carbonate granules up to 4 mm in diameter and a rich assemblage of 24 species of freshwater and terrestrial mollusks. The paleosol appears as a gray band, light gray where carbonate content is exceptionally high. In some places in the canyon, especially near the juncture with small side tributaries, large influxes of sand have diluted the organic matter of the paleosol, making it difficult to recognize and define the soil. Away from the side tributaries, however, the gray band of the paleosol is more easily seen and traceable.

OTHER BURIED SOILS

Three buried soils, in addition to the thicker Caddo County paleosol, and some thinner soils can be traced throughout the canyon. They are discussed in sequence from top to bottom.

Historic Soil. The youngest is a 20 to 30 cm thick soil of historic age that is now buried by as much as 40 cm of red colluvial sand. The sand originates from historic denudation erosion of the hillslope adjacent the canyon. The sand contains wire, glass and other historic items, including coal from a nearby early 20th century homestead (34Cd-121). Historic agriculture and grazing on slopes near the canyon resulted in accelerated erosion down to sandstone bedrock. A water well's cement platform at the homestead site is marked by the date 1918; the platform is now a pillar standing above sandstone bedrock, the 60 cm of weathered sand and soil having been removed since 1918 by erosion. The eroded surficial materials cover the early historic soil.

An Upper Buried Soil. Stratigraphically below the early historic soil and above the Caddo County paleosol is a 15 to 25 cm thick, buried soil. This unnamed paleosol can be traced over much of the canyon. A soil at the same stratigraphic position at Delaware Canyon is radiocarbon dated 400 to 600 years B.P. and is named there the "Delaware Creek paleosol"

(Pheasant 1982). Although possibly equivalent soils, the name is not used in this report. The paleosol is a thin one of short time duration and could be easily misidentified and wrongly correlated owing to the presence of many weak azonal soils in Southern Plains alluvium.

Thin Buried Soils. Within three meters below the Caddo County paleosol are at least two weakly developed soils less than 20 cm thick. Similar weak soils were described from Delaware Canyon (Pheasant 1982). These thin soils probably formed in less than a century and may represent only local stability in a limited portion of the canyon. The bases of trunks of some buried trees are imbedded in similar thin soils.

A Lower Buried Soil. A comparatively thick, buried soil (unnamed) occurs in the canyon's lower fill. Discontinuous exposure of the lower fill due to slumping prevents tracing the paleosol or determining its extent. In a reference section on the east side of the canyon, the paleosol occurs 330 cm below the Caddo County paleosol and is about 78 cm thick, although separated into a lower and upper zone by a 27 cm sand lense. Elsewhere in the canyon the paleosol is stratigraphically nearer the Caddo County paleosol and, in some places, entirely missing, unless thinner and not recognized in isolated and partly slumped exposures. The buried trees all are probably rooted below this lower, unnamed soil, although it is difficult to be positive on this point due to limited exposures. The upper part of the soil contains some carbonate (see "reference section"). This lower paleosol was not found at Delaware Canyon. The paleosol is not directly dated, but if its stratigraphic position above the buried trees is interpreted correctly, it formed during the period of rising water table levels between 2600 and 2000 years B.P.

REFERENCE SECTION

A single exposure that illustrates the typical stratigraphy at Carnegie Canyon has been selected as a reference section (Figure 11). The reference section is a tributary on the east side of the canyon at the site of buried trees 39, 40 and 41 about 120 meters north of the paved road. The site was chosen because headward erosion of the tributary should maintain a clean, deep outcrop for many years. In May 1981, the exposure was described and measured to a depth of 8.61 meters. Mollusks were collected from the Caddo County paleosol at this section and are listed under Column A in Table 4. Sedimentary layers are described from the top of the section to the base. Color descriptions are from the Munsell Soil Color Charts, 1975 edition, and are based on dry samples. Roundness descriptions are

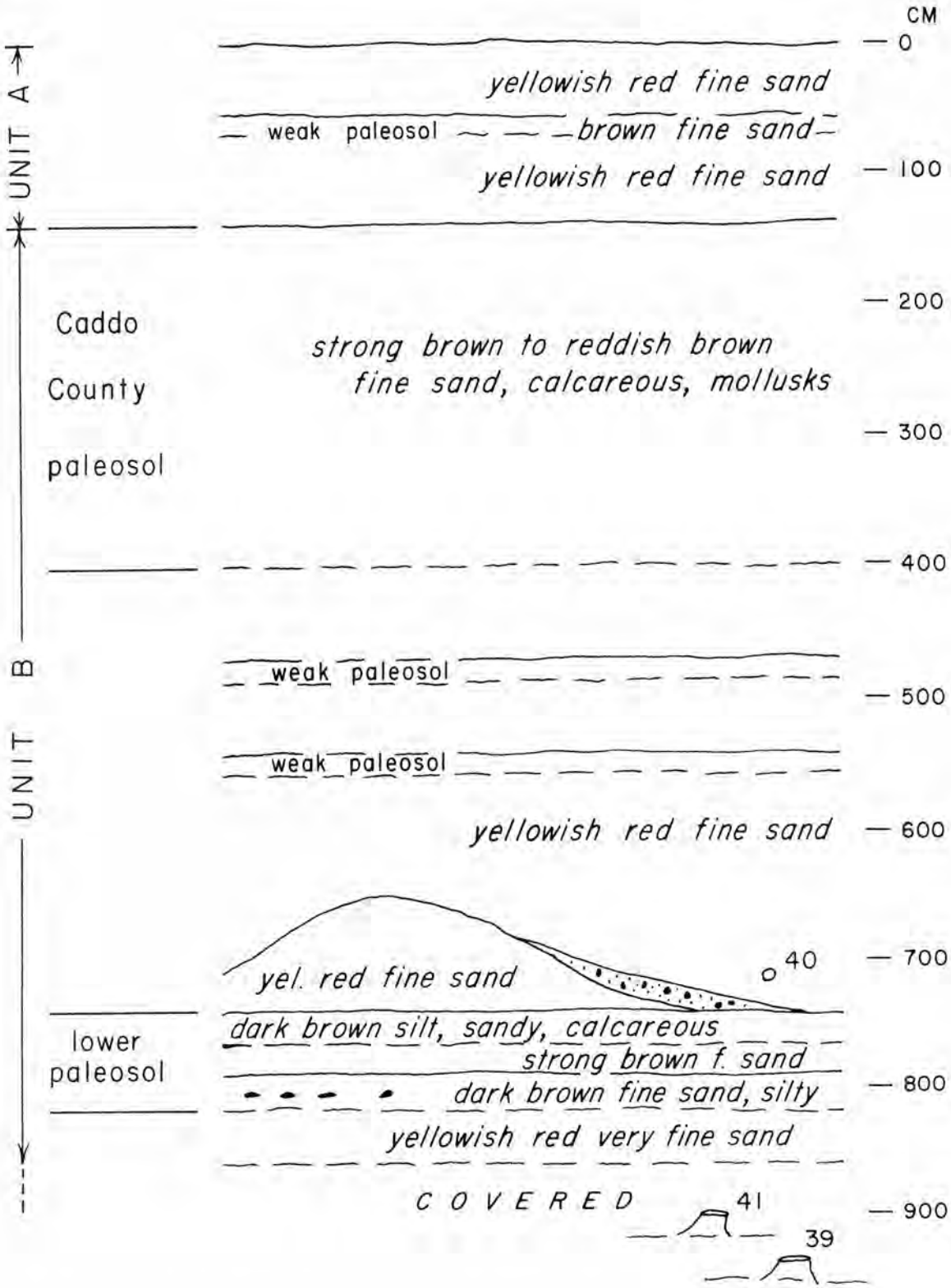


Figure 11. Reference Section for Carnegie Canyon Fill Stratigraphy. Buried trees 39, 40 and 41 are undated; tree 40 is a limb projecting horizontally from Unit B at position shown; lower boundaries of buried soils are gradational as shown by dashed lines; sharp contacts are shown by unbroken lines; lower boundary of Caddo County paleosol is difficult to define; mollusks from Caddo County paleosol at this locality are listed in Table 4, Column A; early historic soil at top of Unit A is missing; Historic Unit is also missing.

from Powers (1953) and grain size categories are from Folk (1968). Sediment descriptions were made using a 30X binocular microscope.

Unit A.	Thickness	Depth
Fine to very fine sand, quartz, subrounded, yellowish red 5YR 5/6, moderately sorted, unbedded, noncalcareous, sharp contact with underlying paleosol; historic paleosol and sand missing.	55 cm	55
Paleosol weakly developed to A-horizon, stratigraphic equivalent of Delaware Creek paleosol at West Delaware Canyon; fine to very fine sand, quartz, some coarse silt, brown 7.5YR 5/2, subrounded, unsorted, unbedded, noncalcareous, gradational contact with underlying sand.	15 cm	70
Fine to very fine sand, quartz, yellowish red 5YR 5/6, subrounded, moderately sorted, unbedded, noncalcareous, sharp contact with underlying Caddo County paleosol, erosional contact in places.	70 cm	140
Unit B.		
Caddo County paleosol; fine to very fine sand, strong component of coarse silt, quartz, subrounded, strong brown to reddish brown 7.5YR 4/6 to 5YR 5/3, strongly calcareous, grain coatings and hard calcite granules less than 4 mm dia., carbonate content gives paleosol a gray appearance along outcrop, carbonate concentrated in upper and lower zones within paleosol, moderately consolidated, land and freshwater mollusks listed in Column A in Table 2; soil sample analyses 8 from upper part of paleosol and 7 from lower part of paleosol (Table 3).	270 cm	410
Fine to very fine and medium sand, some coarse silty, quartz subrounded, moderately sorted yellowish red 5YR 4/6, noncalcareous, weakly consolidated, unbedded, unit measures 330 cm thickness from top of unnamed lower paleosol to base of Caddo County paleosol; unit contains two 15 cm thick, buried A-horizon soils; limb of buried tree 40 protrudes from lower horizon of unit; soil sample analysis 6 in Table 3.	330 cm	740

	Thickness	Depth
Fine to very fine sand, some coarse silt, quartz, subangular, yellowish red 5YR 4/6, noncalcareous, weakly consolidated, some sorting and fluvial bedding, unit forms a lense overlying paleosol, some sandstone gravels and charcoal, unit thins out laterally, maximum thickness 90 cm.	0-90 cm	740
Unnamed lower paleosol, upper member; coarse silt, very fine and fine sand, quartz, dark brown 7.5YR 4/2, subrounded, moderately calcareous, carbonate occurs as grain coatings and granules less than 3 mm dia., weakly consolidated, poorly sorted, gradational contact with underlying sand.	23 cm	763
Sand lense in unnamed lower paleosol; fine to very fine sand, some coarse silt, quartz, strong brown 7.5YR 4/6, subrounded, poorly sorted, noncalcareous, unbedded, weakly consolidated, sharp lower contact with lower paleosol member indicating paleosol was buried by rapid influx of sand during period of soil formation.	27 cm	790
Unnamed lower paleosol, lower member; fine and very fine sand and coarse silt, quartz, dark brown 7.5YR 3/4, subrounded, poorly sorted, noncalcareous, weakly consolidated, a few sandstone gravels scattered in unit, contact gradational with underlying sand.	28 cm	818
Fine to very fine sand, quartz, yellowish red 5YR 5/8, subrounded, well sorted, unbedded, noncalcareous, weakly consolidated, basal unit of reference section; buried trees 39 and 41 are rooted below this sand unit.	43+ cm	861+

BURIED TREES

A most remarkable feature of Carnegie Canyon is the presence of 63 trees, mostly large junipers (*Juniperus*), buried by six to eleven meters of canyon fill (Figure 12, Appendix A). The trunks of the trees exhibit growth form similar to that of modern eastern red cedar (*J. virginiana*) which occurs in the area today. The wood of the buried trees is excellently preserved and only very slightly mineralized; the bark is present on some trees. The unique red cedar aroma is given off when the wood is broken or cut with a saw. The old buried trees, when exhumed, are easily

B

Figure 12. Buried Trees in Carnegie Canyon.
A. Relationship of Stump 1 (A) to Caddo County Paleosol (B).
B. Paleosols and Burned Soils Around *In Situ* Stump 41.

recognized and distinguished from recent wood by their dark brown color, both on the surface and in the interior. Many of the buried trees occur as short stumps extending a few decimeters above *in situ* roots. A few examples of longer trunks are present; tree number 2, lying horizontally, is 360 cm long excluding roots. Some of the inventoried trees are limbs projecting out of the eroded bank with the main trunk probably still buried. Thirteen of the buried trees have been burned. The fire, or fires, occurred prior to burial. An historic fire could not be responsible for the burning because the trees have been exhumed only within the past three years, and there is no evidence for recent fires in the canyon (Appendix A).

All but 13 of the buried trees examined are thought to be junipers. The 63 known buried trees are distributed through a distance of 400 meters in the canyon. The estimated width of the canyon, excluding slumped areas where buried trees cannot be seen, is 60 meters. Thus, the density of inventoried, buried trees is about 1.6 per acre per century. This density figure is a minimum number. The excellent condition of the junipers may be differential as non-juniper trees may be more susceptible to decay and less frequently preserved.

Radiocarbon Dates from Buried Trees

Twelve *in situ* trees have been radiocarbon-dated, the ages ranging from 2600 to 3200 years B.P., except tree number 29 which dates anomalously late and tree number 49 which dates too early (Table 1). An additional wood specimen reportedly recovered at a depth of 29 m (95.96 feet) during core drilling near the dam axis produced a radiocarbon date (3040±70 B.P. - Beta-3079) contemporaneous with the higher stump sequence. This specimen may represent a piece of wood that was dislodged during drilling and dropped to the bottom of the hole. It will not be considered in further discussions. Where possible, wood for dating from the *in situ* specimens was chiseled from the several outer growth rings; thus, the ages apply to the time of death of the trees. Ring counts of tree number 1 indicate it is about 40 years old; its diameter is 36 cm. The largest cedar tree, number 28, is 56 cm in diameter and may have been over 65 years old prior to death and burial.

The radiocarbon date distribution of the trees shows the beginning of a bell-shaped curve (Figure 13) and suggests that the trees represent a single stand reproducing itself over a 600 year period. However, this interpretation may be misleading due to the small sample of trees preserved and exhumed and the even smaller number that have been dated.

RADIOCARBON DATES

Sixteen radiocarbon dates have been obtained on charcoal from archaeological hearths and on wood from buried trees (Appendix C). The material

Table 1. Radiocarbon Dates on Buried Trees at Carnegie Canyon.

Specimen Number[1]	Laboratory Number	C-14 Age Yrs. B.P.[2]	C-13/C-12	C-13 Adjusted Radiocarbon Age[2,3] Yrs. B.P.	Uncorrected * Yrs. A.D./B.C.[4]
1	Beta-2624	3060±50	no adjustment made		1110±50[5] B.C.
4	Beta-2775	2810±50	-21.04	2870±50	920±50 B.C.
5	Beta-2776	2600±60	-24.02	2620±60	640±60 B.C.
7	Beta-2777	2990±50	-23.38	3010±50	1060±50 B.C.
13	Beta-2778	3140±60	-24.39	3140±60	1200±60 B.C.
14	Beta-2779	2820±50	-21.56	2870±50	920±50 B.C.
16	Beta-2780	2960±50	-27.87	2910±50	960±50 B.C.
20	Beta-2781	3010±50	-24.08	3020±50	1070±50 B.C.
22	Beta-2782	2730±60	-23.26	2760±60	810±60 B.C.
28	Beta-2783	2680±60	-23.06	2710±60	760±60 B.C.
29	Beta-2784	2320±70	-26.35	2290±70	340±70 B.C.
Drill Core	Beta-3079	3040±70	-26.17	3020±70	1070±70 B.C.
Stump 48	Beta-4637	4550±70	-22.91	4590±70	2640±70 B.C.

[1] See Appendix A for a list of buried trees.
[2] Half-life 5568 years; one standard deviation.
[3] Adjusted ages are normalized to -25.00 per mil carbon 13.
[4] Uncorrected years adjustment based on C-13 values, when available.
[5] No C-13 values available.
* High standard deviation value reflects small sample size.

was analyzed by Beta Analytic, Inc., Coral Gables, Florida. The charcoal and wood samples ". . .were given an extensive hot acid pretreatment to eliminate any carbonates that might have been present. After rinsing to neutrality, the pretreatment was continued by submitting the material to hot alkali solution (2 % NaOH) to extract humic acids. Again rinsing to neutrality, another acid treatment was followed by another neutralization. After this, the benzene syntheses were carried out" (M. Tamers, correspondence). Twelve of the wood samples were further analyzed for carbon-13/-carbon-12 ratio in order to correct for fractionation of carbon isotopes. The resulting corrections were small, ranging from -50 to +60 years and averageing +20 years (excluding Beta-2784).

The dates have been obtained from horizons in Unit B, ranging from 4550±70 (Beta-4637) to 1540±100 years B.P. (Beta-3080). All dates from trees, but that from number 29 and the aforementioned wood specimen from the drill core, are stratigraphically congruent. Trees 28 and 29 are superimposed stumps, number 28 about 130 cm above number 29 (Figure 14).

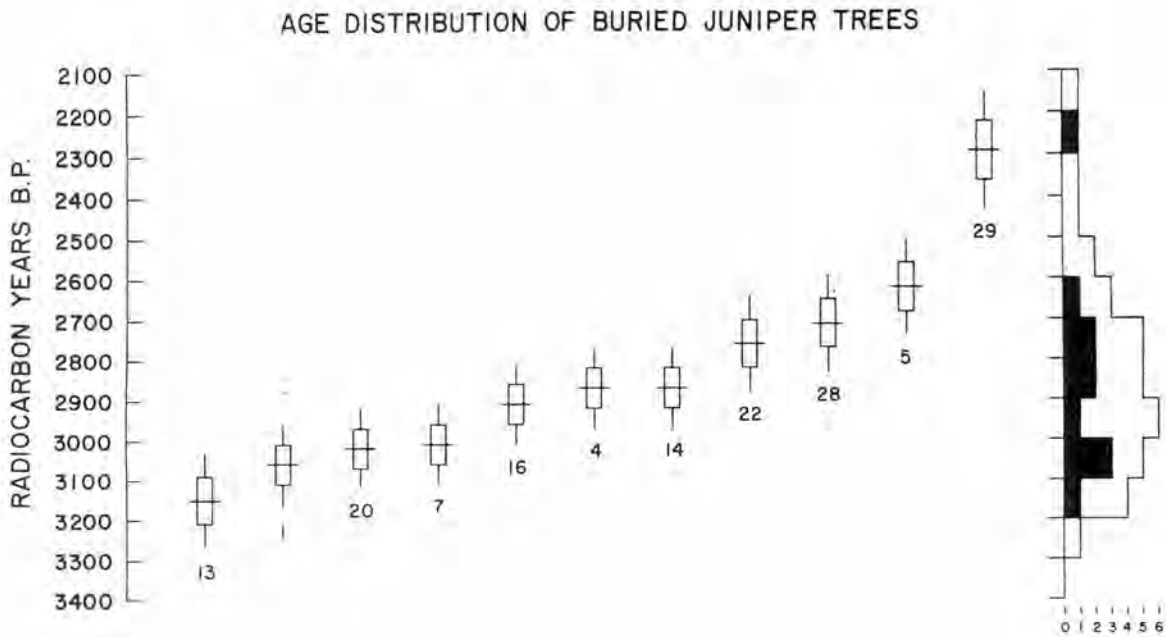


Figure 13. Age Distribution of Buried Trees.
Radiocarbon dates arranged by age (Table 1); horizontal line is radiocarbon age, wide vertical bar is 1-sigma variation, vertical line extending above and below wide bar represents 2-sigma variation; cumulative distribution graph on right shows radiocarbon age per century in black and 2-sigma per century variation in white; tree 29 is anomalously young; tree number (see Table 19) is indicated below each date.

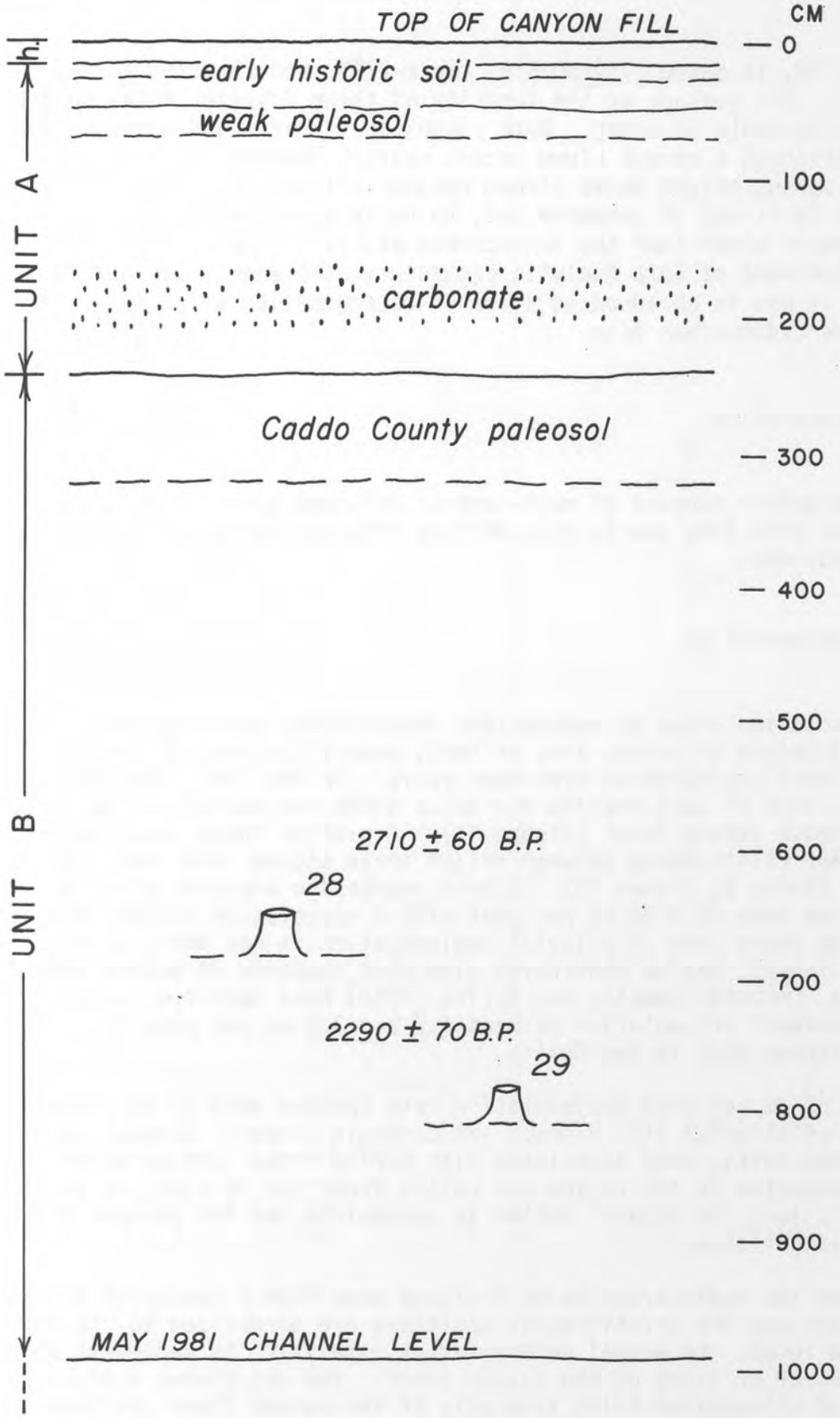


Figure 14. Stratigraphy of Superimposed Dated Buried Trees 28 and 29. Radiocarbon age of tree 29 is anomalously young; carbonate occurs above Caddo County paleosol; h. symbol represents historic unit; land snails from the carbonate zone are listed in Table 2, column C; *in situ* carbonate probably occurs in a sand and low organic facies of the Caddo County paleosol; if correct, the Unit A-B boundaries should be shown at the top of the carbonate zone.

The higher, 28, is dated 2710±60 B.P. (Beta-2783) and 29 dates 2290±70 B.P. (Beta-2784). The geology at the locality of these inverted dates does not indicate which could be wrong. Both stumps are *in situ* and do not exhibit slumping, although a recent slump occurs nearby. However, a plot of radiocarbon age versus height above stream channel (Figure 13) suggests that tree number 29 is out of sequence and, to be in order, would have to be about 600 years older than the radiocarbon analysis shows. Also, during 2 % NaOH treatment at Beta Analytic Laboratory, the wood disintegrated, indicating it was in an advanced state of decomposition which may have affected the radiocarbon date.

CANYON SEDIMENTATION

The sandstone canyons of west-central Oklahoma were filled during the Holocene with fine quartz sand derived from weathering of the Rush Springs Sandstone.

Rates of Sedimentation

Sedimentation rates of nonconstant depositional environments, such as Carnegie Canyon alluvium, are, at best, generalizations of the net annual sediment accumulation over many years. In May 1981, the stratigraphic position of each radiocarbon dated stump and hearth was measured as height above stream level (Figure 15). A plot of these measurements shows a clear relationship between height above stream level and radiocarbon age (Table 2, Figure 13). Linear regression analysis gives a sedimentation rate of 0.80 cm per year with a correlation coefficient of -0.933. The above rate of alluvial sedimentation is not particularly rapid and, indeed, may be considered slow when compared to modern rates. For example, Leopold, Emmett, and Myrick (1966) have measured annual rates of sediment accumulation between 1.2 and 3.0 cm per year in ephemeral stream beds in New Mexico.

The 0.80 cm per year sedimentation rate applies only to the lower six meters of alluvial fill exposed at Carnegie Canyon. Several thin, discontinuous soils, some associated with buried trees, are evidence that sedimentation in the canyon has halted from time to time, at least sufficiently long for organic matter to accumulate and for juniper trees to become established.

Because the radiocarbon dated horizons come from a number of places in the canyon and the stratigraphic positions are normalized to the May 1981 stream level, the actual sedimentation rate value is dependent upon stream gradient or slope of the canyon floor. The calculated 0.80 cm per year rate of alluviation holds true only if the canyon floor gradient during the period of juniper trees presence in the canyon was the same as the gradient measured today. As surveyed by Christopher Lintz in July 1981, along a 250 meter line northward from the paved road, the stream gradient is 1°09', the canyon fill terrace (top) gradient is

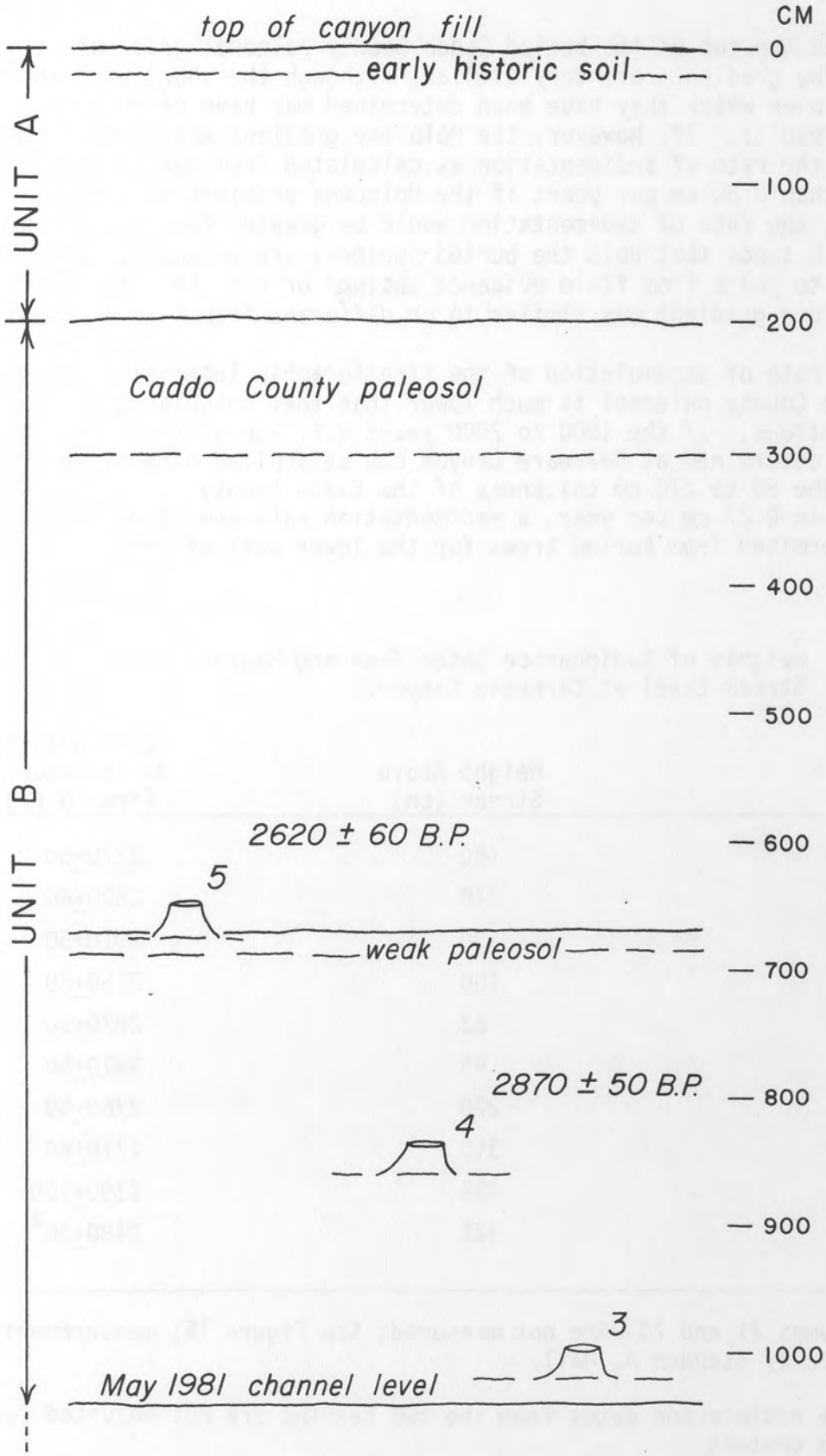


Figure 15. Stratigraphy of Superimposed Trees 3, 4, and 5.

$0^{o}58'$, and the top of the buried Caddo County paleosol gradient is $0^{o}56'$. The gradients are very similar, although the short horizontal distance over which they have been determined may have produced misleading results. If, however, the Holocene gradient was greater than today's, the rate of sedimentation as calculated from buried trees would be less than 0.80 cm per year; if the Holocene gradient was less than that of today, the rate of sedimentation would be greater than 0.80 cm per year, The Unit B sands that hold the buried junipers are unbedded, so it is impossible to judge from field evidence whether or not the late Holocene canyon floor gradient was similar to or different from that of today.

The rate of accumulation of the stratigraphic interval encompassing the Caddo County paleosol is much lower than that calculated from buried tree positions. If the 1000 to 2000 years B.P. age of the Caddo County paleosol determined at Delaware Canyon can be applied directly to Carnegie Canyon, the 80 to 270 cm thickness of the Caddo County paleosol translates to 0.080 to 0.27 cm per year, a sedimentation rate one-third to one-tenth that determined from buried trees for the lower part of Unit B.

TABLE 2. Heights of Radiocarbon Dated Tree and Hearths Above May 1981 Stream Level at Carnegie Canyon.

Dated Feature[1]	Height Above Stream (cm)	C-13 Adjusted Radiocarbon Age (Yrs. B.P.)
Stump 4	180	2870±50
Stump 5	370	2620±60
Stump 7	30	3010±50
Stump 13	100	3150±60
Stump 14	83	2870±50
Stump 16	95	2910±50
Stump 22	270	2760±60
Stump 28	310	2710±60
Hearth 1	485	2390±100[2]
Hearth 2	525	2480±50[2]

[1]Stumps #1 and 20 were not measured; See Figure 16; measurements taken by Stephen A. Hall.

[2]The radiocarbon dates from the two hearths are not adjusted for C-13 content.

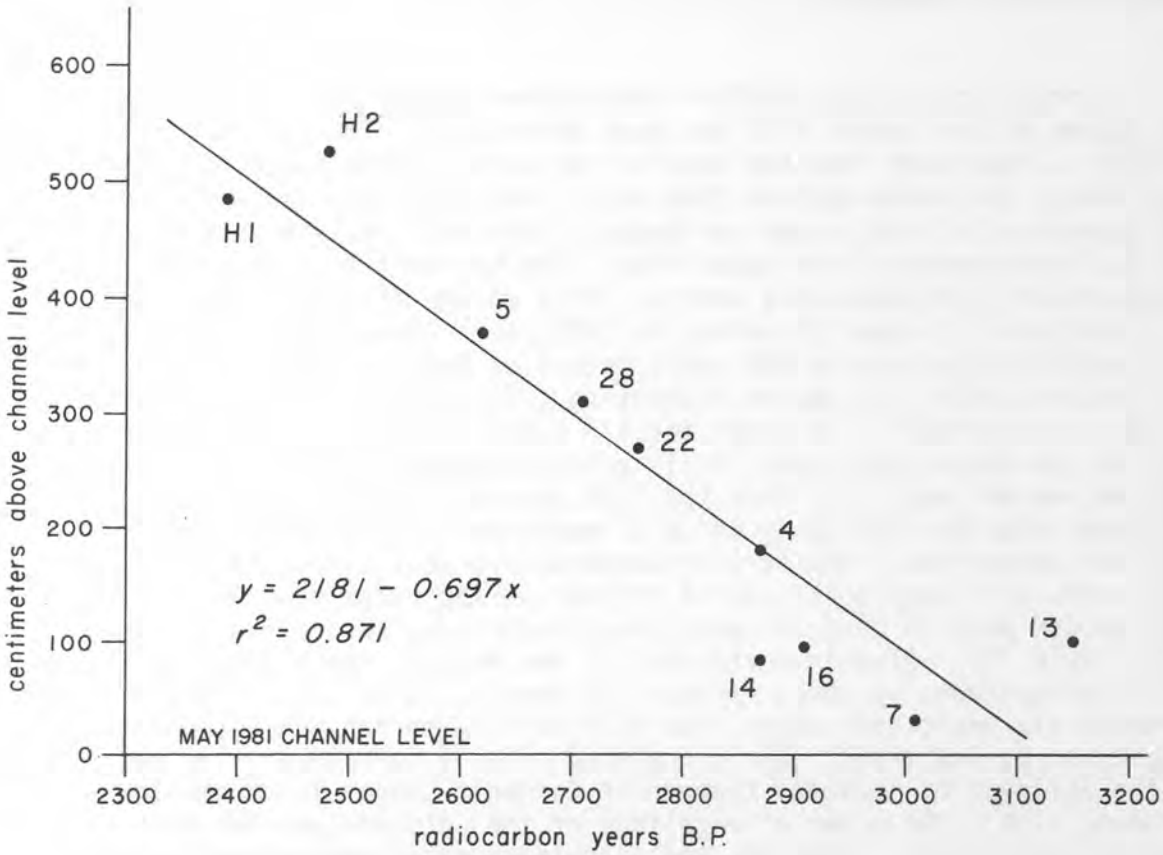


Figure 16. Buried Tree and Hearth Depth Versus Radiocarbon Age. Sedimentation rate is determined to be 0.80 cm per year; data for plots given in Table 2.

The canyon fill extends to a depth of 31 meters, 20 meters below the May 1981 stream level. Extrapolation of the above 0.80 cm per year sedimentation rate to the lower 20 meters gives an age of 5583 years B.P. for the base of the canyon fill. Thus, the entire 31 meters of sand in Carnegie Canyon may have accumlated during only the past 5600 years.

An average sedimentation rate for Holocene alluvium in the Washita River Vally is calculated by Goss *et al.* (1972) as 0.22 cm per year but is in error. This value and the others presented by Goss *et al.* were determined by dividing the depth of the dated horizon by the radiocarbon date. The rates thus assume that the age of the surface is modern, they do not take into account the likelihood that alluvium may contain zones of very different accumulation rates, such as soil versus nonsoil units, and, finally, the reported rates ignore the possibility of the presence of erosional unconformities with comparatively large increments of time missing from the alluvial sequence. The sedimentation rates of Goss *et al.* may be minimum or maximum values, depending upon the combination of the above circumstances. Regardless, the values are misleading and cannot be used for reliable comparison with the results from Carnegie Canyon.

Drainage Basin Denudation

In order to evaluate further the sediment influx in Carnegie Canyon, the volume of the canyon fill has been determined. The volume calculations include all sediment from the base of the Caddo County paleosol to bedrock, using the cross-section from drill core records, extending from the headwaters of the canyon northward to the half-section line fence one-half mile north of the paved road. The sediment volume is estimateed to be 1,720,000 cubic meters. This volume of sand accumulated to a thickness of about 28 meters in 3600 years (from 5600 to 2000 years B.P.) which calculates to 478 cubic meters of sand per year. The drainage basin is only 1.10 square kilometers (272 acres), excluding the area of the canyon itself. In order for 478 cubic meters of sand to accumulate in the canyon each year, it is calculated that 0.0434 cm of sand must be removed each year from the 1.10 square kilometer watershed. Denudation rates for the sandy soils of west-central Oklahoma are not available for comparison. However, in western Colorado, average annual erosion rates of clayey soils over a 19 year period range from 0.057 to 0.15 cm per year on ungrazed and grazed rangeland, respectively (Lusby 1979, Table 10). Also in north-central New Mexico, removal of sandy surficial sediment by sheet erosion has been measured over a period of three to six years and ranges from 0.21 to 0.76 cm per year (Leopold, Emmett and Myrick 1966). The calculated rate of surface erosion based on the estimate of sediment trapped in Carnegie Canyon is on the low side although within the order of magnitude of the Colorado and New Mexico studies cited above. Even so, the calculated rates are probably minimum values for the Carnegie drainage basin. Indeed, the thick sequence of Holocene sediments in the Washita River Valley (Goss *et al.* 1972) can probably be interpreted as evidence that tributaries of the Washita, including Carnegie Canyon, have been suppliers of great volumes of sediment. In other words, the sediment in storage in the tributary canyons is perhaps a small fraction of the total amount of sediment eroded from hillslopes, the larger portion of material having been flushed through the canyons and deposited in the Washita River Valley.

CANYON FILLING AND SOIL DEVELOPMENT

Soils of two completely different origins can be found in alluvial sediments. The first type, dealt with more frequently in the soil literature, is the pedogenic soil formed by weathering on a stable or slowly eroding surface. The second, found almost exclusively in alluvium and largely ignored by soil scientists, is the azonal A-horizon. The A-horizon soil is an accumulation of organic matter on a slowly aggrading surface, such as a floodplain. New influx of mineral sediment is incorporated into the soil and masked by organic matter from decayed and partly decayed plants. As greater amounts of mineral grains, such as quartz silt and sand, are deposited on the valley floor, the organic matter is diluted. If the influx continues, the soil A-horizon will lose its identity, the organic matter insufficiently concentrated to qualify as a soil A-horizon.

All of the buried soils at Carnegie Canyon are cumulic A-horizons. The Caddo County paleosol and the unnamed lower paleosol are comparatively

Table 3. Soil Test Results from Selected Sediments at Carnegie Canyon

Collection Sample No.*	Organic Matter (%)	pH	Nitrogen	Phosphorus (ppm)	Potassium (ppm)	Calcium (ppm)	Magnesium (ppm)
Upper Canyon Fill							
5	0.76	6.3	low	76	92	1720	120
4	1.15	6.9	low	14	68	1680	145
Reference Section							
8	0.64	7.8	low	62	64	> 4000	> 500
7	0.40	7.5	low	96	96	> 4000	255
6	0.36	7.3	low	58	48	1320	55
Buried Tree no. 1 Locality							
1	0.20	5.7	low	5	60	1360	105
2	0.76	6.2	low	20	80	1800	85
3	0.28	3.8	low	19	48	1280	95

Analyses by Soil Testing Laboratory, Texas A & M University, College Station.

*Collection sample provenience listed in descending order:

Upper Canyon Fill
- 5: historic sand above early historic soil.
- 4: early historic soil (top of Unit A).

Reference Section
- 8: upper part of Caddo County paleosol.
- 7: lower part of Caddo County paleosol.
- 6: yellowish red sand adjacent to buried tree no. 40.

Buried Tree no. 1 Locality
- 1: reddish sand above weak paleosol.
- 2: weak paleosol associated with buried tree no. 1.
- 3: reddish sand below weak paleosol.

thick soils, ranging from 80 to 270 cm thick. Thickness generally relates to number of years of accumulation although it can also be related to amount of mineral sediment influx. The dated Caddo County paleosol accumulated over a period of 1000 years with a rate of accumulation from 0.08 to 0.27 per year. Non-soil sand at Carnegie Canyon accumulated three to ten times more rapidly.

The percentage of organic matter was determined for several soil and non-soil samples from Carnegie Canyon (Table 3). The highest organic content measured was 1.15 % from the early historic soil (Sample 4); even this amount of organic matter, however, is comparatively small. The weak soil associated with tree stump 1 has 0.76% organic matter (Sample 2). Two samples from the Caddo County paleosol at the Carnegie Canyon reference section contain only 0.40 (Sample 7) and 0.64 % organic matter (Sample 8). For the small suite of samples analyzed from Carnegie Canyon, non-soil sediment contains less than 0.40 % while A-horizon soil contains 0.40 % or more organic matter.

The buried soils at Carnegie Canyon and elsewhere are recognized by their dark color due to higher amounts of organic matter than generally present in the alluvial sand. The Caddo County paleosol is further recognized by its carbonate content, reflected by greater than 4000 ppm calcium (Table 3).

In the excavation area (34Cd-76) on the canyon west side, the dark colored Caddo County paleosol is not present even though it is well developed directly across on the opposite side of the canyon and is also well developed on both sides up and down the canyon. Sediments are present at the zone in which the paleosol should occur, but, evidently, the sand influx was too great for organic matter to become concentrated in that portion of the canyon. Some thin weak soils are present in places suggesting that sediment influx occasionally slowed for short periods. Present day gulleys in this area follow nicks cut into bedrock that probably funneled sand into the canyon in the past as well, flooding the local area with sand when, elsewhere in the canyon, a soil was developing. This situation illustrates well the principle of field investigations that, in order to understand the alluvial geology at one locality, the neighboring geology must also be studied.

MOLLUSCAN PALEOECOLOGY

Shells of snails are conspicuous in the gray sandy Caddo County paleosol throughout the canyon. Twenty-four species of mollusks have been recovered from the paleosol, including aquatic forms which, at Locality B, are one-fourth the total number of shells (Table 4). The species composition of the Caddo County paleosol molluscan fauna differs from place to place due most likely to the presence of slightly different microhabitats on the canyon floor during the period of soil development. Overall, the fauna is mainly land snails. Some of the snails, such as *Pupoides alibilabris*, *Gastrocopta armifera*, *Hawaiia minuscula*, *Nesovitrea indentata*, *Gastrocopta procera* and *Polygyra texasiana texasiana* are dry habitat species (Metcalf 1962 and Cheatum and Fullington 1971) and may have been washed into the canyon from adjacent hillslopes. The many other land snails of the paleosol fauna live in both moist wooded and moist grassland habitats.

Table 4. Mollusks from the Caddo County Paleosol at Carnegie Canyon.

LOCALITIES*:	A	B	C	D
PELECYPODS				
Sphaerium sp.	3/2	49/2	-	2/2
Unionid, undet.	-	1	-	1
GASTROPODS, AQUATIC				
Amnicola integra	-	1	-	-
Fossaria dalli	2	39	-	5
Gyraulus sp.	-	1	-	-
Helisoma trivolvis	-	-	-	6
Physa virgata	6	39	-	35
GASTROPODS, TERRESTRIAL				
Deroceras sp.	-	2	-	-
Euconulus sp.	-	2	-	-
Gastrocopta armifera	16	4	-	21
Gastrocopta contracta	9	19	3	3
Gastrocopta cristata	4	-	-	-
Gastrocopta procera	2	4	-	3
Gastrocopta tappaniana	10	58	1	-
Hawaiia minuscula	37	136	10	29
Helicodiscus parallelus	5	3	4	12
Nesovitrea indentata	7	11	-	1
Poloygyra t. texasiana	6	5	-	2
Pupoides albilabris	5	2	-	1
Strobilops labyrinthica	3	2	-	1
Succinea sp.	8	66	3	2
Vallonia perspectiva	1	-	-	-
Vertigo ovata	-	3	-	-
Zonitoides arboreus	13	7	-	3
Total shells	137	454	21	126

*A Reference section; see Figure 2.
B Bison site.
C Site of buried trees 28 and 29; see Figure 14.
D Spring conduit; see Figure 17.

The aquatic elements in the fauna provide firm evidence that the canyon floor was moist and probably had seasonal or permanent flowing water. A unionid mussel, the pill clam, *Sphaerium*, and the freshwater snails, *Physa virgata*, *Fossaria dalli*, *Gyraulus sp.*, *Amnicola integra*, and *Helisoma trivolvis* are all present in the Caddo County paleosol, although not at all localities of the paleosol. *Physa virgata* presently (May 1981) inhabits the stream in Carnegie Canyon and can be seen gliding over the sand in 5 to 10 cm of water. Shells of *Helisoma trivolvis*, ranging to 15 mm diameter, were found at a locality interpreted by its stratigraphy as a spring conduit (Table 4) and in the Caddo County paleosol north of the road.

The abundance and diversity of the aquatic mollusks and land snails indicate that the canyon floor was moist, probably wooded in places, and that the water flow was at least seasonal. The unidentifiable unionid shell fragments, unless brought from the nearby Washita River by prehistoric man, suggest a permanently flowing stream in Carnegie Canyon during the accumulation of the Caddo County paleosol.

PREHISTORIC WATER TABLE LEVELS

Higher Water Table

Fluctuations of the water table in the geologic past are generally difficult to document even though, in arid regions, such fluctuations are thought to be important regulators of stream channel cutting and filling. At Carnegie Canyon, four independent lines of evidence (mollusks, paleosol carbonate, carbonate encrustations, spring conduit) suggest a higher water table during the development of the Caddo County paleosol about 1000 to 2000 years ago.

Molluscan fauna. Snail shells can generally be found scattered throughout most alluvial or colluvial valley fill sediments in the Plains. Shells are washed in from the uplands and hillslopes or are picked up by floodwater from wooded floodplains, or, in the case of aquatic forms, scoured from stream banks and shallow floodplain ponds. The general result is shell assemblages with species from several different habitats. At Carnegie Canyon, the concentration of numerous shells in the Caddo County paleosol is unusual, representing a rich molluscan fauna living on the canyon floor in addition to shells that may have been washed from canyon slopes. The fauna contains 24 species, seven of which are aquatic. The diverse freshwater clams and snails of the fauna could not have inhabited an ephemeral canyon stream. Water flow must have been at least seasonal and probably permanent to support the aquatic mollusks. This means that the water table must have been at or very near the level of the canyon floor during the development of the Caddo County paleosol.

Carbonate in Caddo County Paleosol. The Caddo County paleosol has the appearance of a light gray band in many places owing to the presence of calcium carbonate granules and carbonate coatings on sand grains. The carbonate films and granules are not concentrated in a uniform zone of calcic accumulation, such as in pedogenic soil, but instead occur at different stratigraphic positions within the paleosol and, in one case, disseminated in a wide band up to 2.7 meters thick.

The calcium carbonate of the Caddo County paleosol probably originated from the calcareous fraction of eolian-transported dust, from leaching of a carbonate-rich Pleistocene paleosol (not described in this report) that mantles the sandstone bedrock in the upland portion of the small Carnegie Canyon watershed, and from the calcite cement of the Rush Springs Sandstone. The carbonate in solution moves through the sand fill of the canyon and is concentrated in the groundwater. The calcium carbonate is then precipitated on sand grains and in pore spaces between grains as the water table is periodically lowered slightly in response to seasonal or year-to-year fluctuations in precipitation. When the water table later rises, the initially precipitated carbonate is not completely redissolved probably owing to the high amount of carbonate already in solution. Thus, through time, if the water table remains at more or less the same general position and if the groundwater continues to contain carbonate, calcium carbonate will build up in the form of grain coatings and small concretions in a zone corresponding to the position of the fluctuating water table.

The comparatively thick zone (up to 2.7 meters) of carbonate granules associated with the Caddo County paleosol may indicate moderate fluctuation of the water table by as much as the thickness of the carbonate during the general period of high water table levels about 1000 to 2000 years ago.

Carbonate Encrustation on Canyon Wall. The unconsolidated sand fill has been entirely removed in places by lateral erosion, exposing the near vertical canyon walls cut into the red Rush Springs Sandstone. At two localities down canyon from the immediate study area occurs a zone of calcium carbonate encrusting the red sandstone walls. The carbonate is as much as three centimeters thick and cements colluvial sand and sandstone blocks that have accumulated along the sides of the canyon. The carbonate zone is about two meters thick. The base of the zone is almost three meters above the present canyon floor and the top is about three meters below the projected top of the canyon fill. The carbonate zone appears to be stratigraphically below the Caddo County paleosol by as much as about one meter, as well as can be determined: accurate comparison is not possible because the paleosol and associated sediments have been eroded away. Also some of the carbonate crust has fallen away from the canyon wall, making precise measurements misleading. Nevertheless, the presence of the carbonate encrustation is yet another line of evidence for a high water table in Carnegie Canyon.

Spring Conduit. A spring conduit is a cone-shaped passageway formed in sediment, generally vertical and wider at the top, where pressurized groundwater boils upward. A fossil spring conduit has been cut through and exposed by channel erosion on the east side of Carnegie Canyon just south of the half-section fence line (Figure 17). The top of the conduit terminates in the Caddo County paleosol. The conduit extends 2.4 meters below the base of the paleosol. The widest point of

the preserved conduit is 1.5 meters, where the conduit and paleosol join. The conduit matrix is an unbedded brown silty sand containing numerous but unsorted mollusk shells. The species recovered from the conduit are listed under locality D in Table 4. One turtle scute was found weathering out of the spring conduit deposit. A similar assemblage of mollusk shells, including aquatic forms, was observed in the paleosol immediately adjacent the spring conduit. This is the only spring conduit found in the canyon. Others may have been present but removed by erosion. Regardless, the one spring conduit is evidence that the water table was near the surface of the canyon floor at the time the Caddo County paleosol was forming.

Age of Former High Water Table Level. The concentration of calcium carbonate in the Caddo County paleosol does not necessarily mean that the water table was at that position during soil formation. In principle, the carbonate could have accumulated much later by post-depositional precipitation.

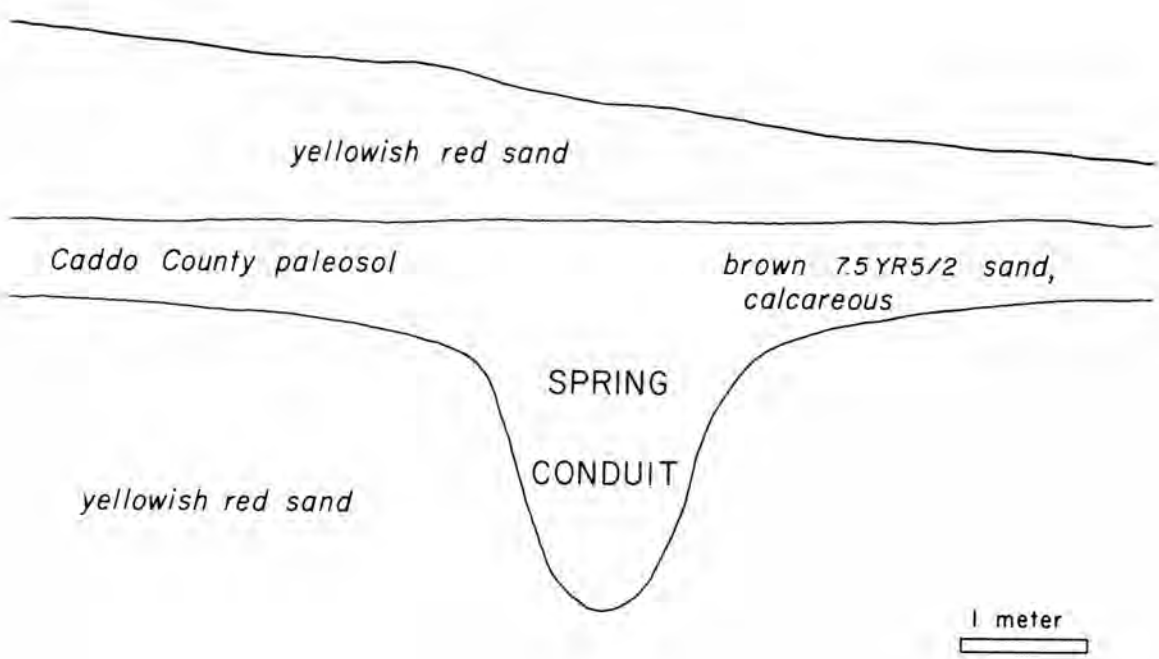


Figure 17. Spring Conduit. Mollusks from conduit listed in Table 4, column D; top of section eroded; meter scale applies to both vertical and horizontal directions.

Two factors, however, suggest a high water table concurrent with paleosol development: (a) the molluscan fauna and (b) stratigraphy. The canyon fill mollusks occur largely in the Caddo County paleosol, and the aquatic forms are restricted to the paleosol. The moisture requirements of these freshwater species point strongly to the presence of the water table at or near the surface of the canyon fill at the same time the Caddo County paleosol was forming. Finally, the carbonate-bearing Caddo County paleosol has been incised by channel cutting and subsequently filled and buried by younger sediment. The channel fill sand does not have *in situ* carbonate accumulations. The carbonates terminate laterally where the paleosol is eroded. The evidence of stratigraphy in conjunction with the molluscan fauna shows clearly that the high water table level coincides with the formation of the Caddo County paleosol, thus about 1000 to 2000 years B.P.

Past High Water Table Position. The water table today (May 1981) is about eight meters below the modern top of the canyon alluvial fill, in the study area, as indicated by the zone of wet sand in the bottom of the eroded canyon caused by water seeping from the sides of the canyon and the water level in the core drill holes. The seepage results in slumping of the arroyo banks and maintains a small flow of water in the canyon.

The Caddo County paleosol and associated carbonate zone occur at various depths owing to different amounts of deposition of post-paleosol sand at different localities in the canyon and to erosion that has removed the top of the paleosol in some parts of the canyon. In the study area, the top of the carbonate zone ranges from about 110 to 200 cm in the canyon fill. The maximum measured thickness of the carbonate zone is about 270 cm at mollusk Site B.

The level of the water table at Carnegie Canyon about 1000 to 2000 years ago, when the Caddo County paleosol was forming, ranged between four and seven meters above the present-day water table position. It may be possible to calculate what this means in terms of annual precipitation difference if the effects of water withdrawal from nearby wells can be taken into account.

Past Lower Water Table Position

The above section deals in detail with the evidence for a higher water table in Carnegie Canyon about 1000 to 2000 years B.P. The presence of juniper trees in the canyon floor 2600 to 3200 years B.P. is a strong testimony that the water table was much lower than it is today. Junipers are common invaders of old fields in the dry uplands of western Oklahoma. They are not found on poorly drained soils where their shallow roots would be drowned.

The Carnegie Canyon buried junipers extend to about 11 meters below the present surface. Thus, the water table at the time of juniper growth

on the canyon floor was probably at least two meters below the canyon floor, placing the water table 13 meters below the top of the canyon fill and as much as five meters below the present water table.

Summary of Water Table Fluctuations

From 2600 to 3200 years B.P., and perhaps earlier, the water table at Carnegie Canyon was at least 13 meters in depth. After 2600 years B.P. the climate changed, resulting in a nine meter rise in water table. During the next 1000 years, from about 1000 to 2000 years B.P., the water table remained at the high position of between one and four meters depth. After 1000 years B.P. the water table dropped; it is now four to seven meters below the pre-1000 B.P. position (See Figures 18 and 19).

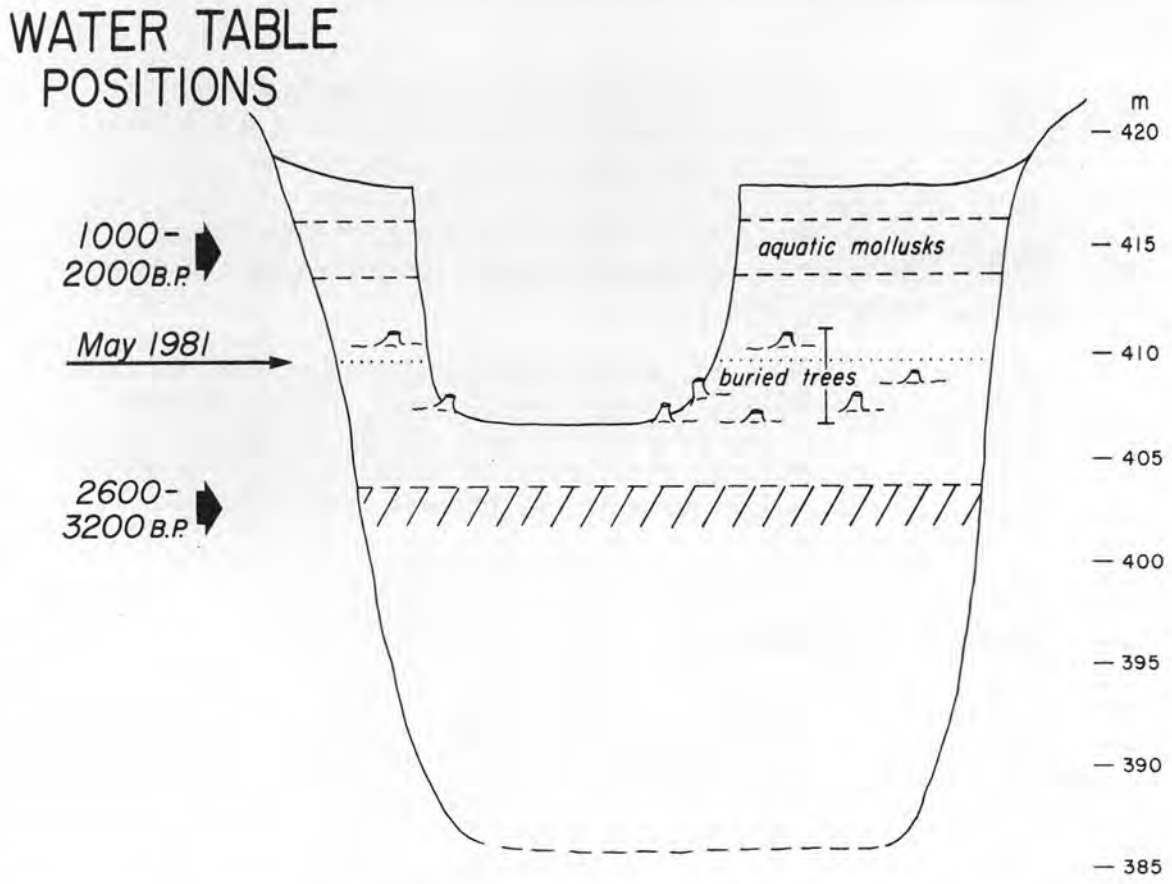


Figure 18. Late Holocene Water Table Positions. The 1000 to 2000 year B.P. water table position is based on aquatic mollusks and carbonate accumulations; the 2600 to 3200 year B.P. position is estimated as three meters below the buried junipers; there is no paleosol, carbonate or molluscan evidence from the cores for a water table below 400 meter elevation; x 2 vertical exaggeration.

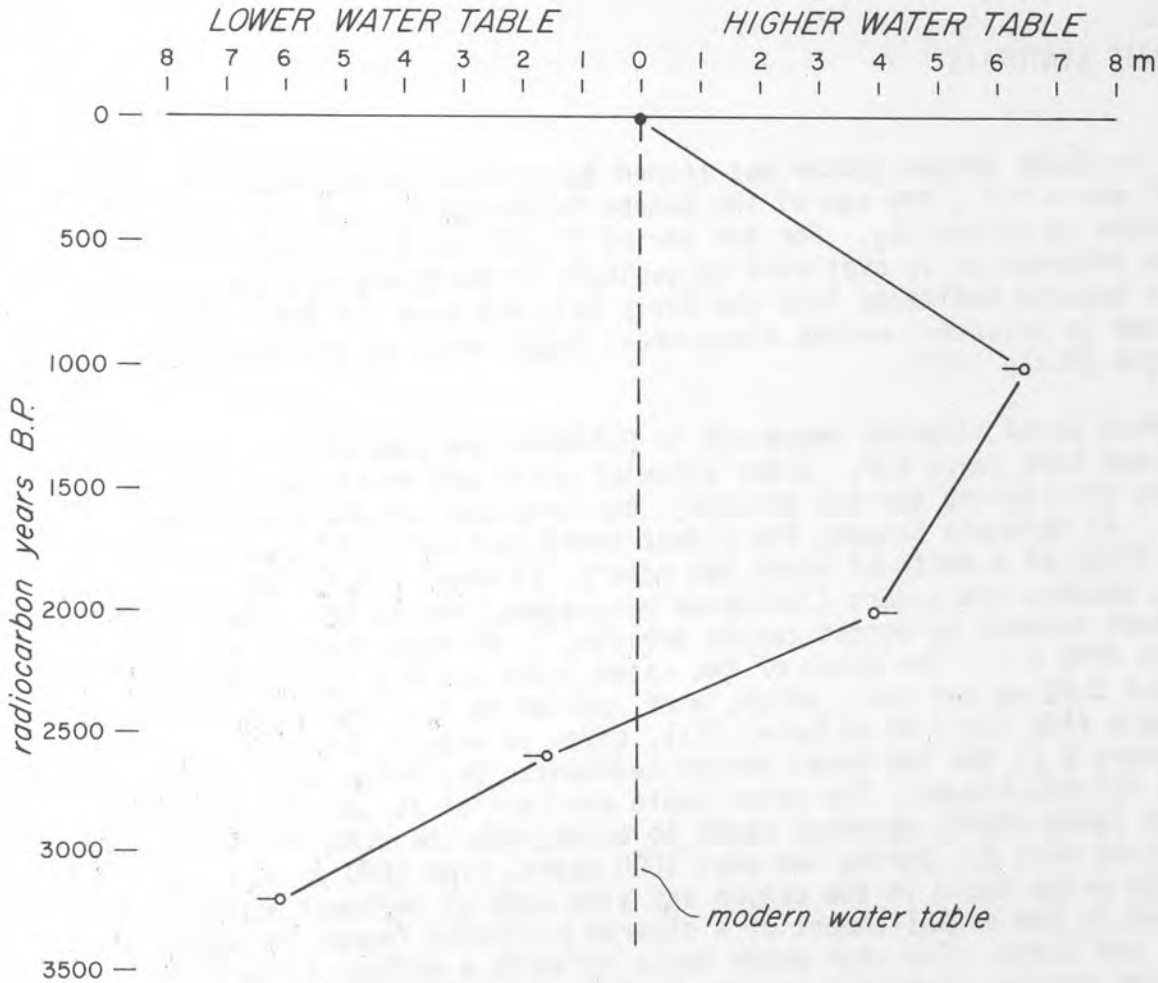


Figure 19. Chronology of Water Table Fluctuations. Scale in meters above and below 1981 water table position; left-pointing lines indicate maximum water table height; right-pointing line indicates minimum water table height.

PALEOCLIMATE AS INFERRED FROM FLUCTUATING WATER TABLE

The history of water table levels at Carnegie Canyon is probably related to past preciptitation. The low water table 2600 to 3200 years B.P. may reflect a climate much drier than that of today. From 2600 to 2000 years B.P. the cimate changed from dry conditions to conditions of more available moisture, which persisted until 1000 B.P. and resulted in a high water table and the formation of the Caddo County paleosol. After 1000 years B.P. the climate changed again, back to drier conditions such as exist today. Pollen and land snail records from northeastern Oklahoma also show that the first millennium A.D. was more moist prior to a change to drier climate around 950 A.D. (Hall 1980b and 1982b). This supports the paleoclimatic record based on water table levels from Carnegie Canyon.

GEOLOGIC SYNTHESIS

The Caddo Canyon system was eroded during the Pleistocene. By 11,200 years B.P., the age of the Domebo Paleo-Indian site, sediments had begun to accumulate. For the period 10,000 and 4,000 years ago, little information is available on geologic or environmental conditions, mainly because sediments from the Early Holocene have not been identified or dated in Oklahoma, except along Cedar Creek north of the town of Carnegie (Nials 1977).

Most dated alluvial sequences in Oklahoma are Late Holocence generally less than 4000 years B.P. Older alluvial units are doubtlessly present (excluding Pleistocene terrace gravels), but they are neither recognized nor dated. At Carnegie Canyon, the oldest dated horizon is 3150±60 years B.P. (Beta-2778) at a depth of about ten meters (33 feet). A series of 50 buried eastern red cedars (*Juniperus virginiana*) and 13 non-cedar specimens have been exhumed by recent canyon erosion, 11 of them radiocarbon dated 2600 to 3200 B.P. The depth of the dated trees gives a sedimentation rate of about 0.80 cm per year, which, when applied to the lower portion of the 31 meters (102 feet) of alluvial fill, gives an extrapolated age of about 5600 years B.P. for the basal canyon sediment. Beginning about 2000 B.P., canyon filling slowed. The water table was near or at the canyon floor, and the Caddo County paleosol began to accumulate the sand fill and paleosol comprising Unit B. During the next 1000 years, from 2000 to 1000 years B.P., the high water table in the canyon and slow rate of sediment accumulation resulted in the establishment of a diverse molluscan fauna, including aquatic snails and clams. The high water table reflects a moister climate than the preceding period. Junipers growing on the canyon floor indicate a lower water table, suggesting a drier climate than today. After about 1000 years B.P. the canyon floor was trenched by a shallow channel. Subsequently, the channel was filled and buried by two meters of sand (Unit A). An early historic soil developed on the top of Unit A. The soil has since become buried by recent colluvial sand containing bits of metal and broken glass (historic unit). The canyon fill has been dissected during the past few years by headwall erosion.