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PALEO

YEAR

1

FINAL

PHASE I REPORT

QUATERNARY STUDIES: GLEN CANYON NATIONAL
RECREATION AREA AND CANYONLANDS NATIONAL PARK

Contract # CX-1200-4-A062

for

The National Park Service
Rocky Mountain Regional Office
Denver, Colorado

Dr. Larry Agenbroad, Principal Investigator
Department of Geology
Northern Arizona University
Flagstaff, Arizona

Prepared under the supervision of Dr. Larry D. Agenbroad, Principal Investigator

March, 1986

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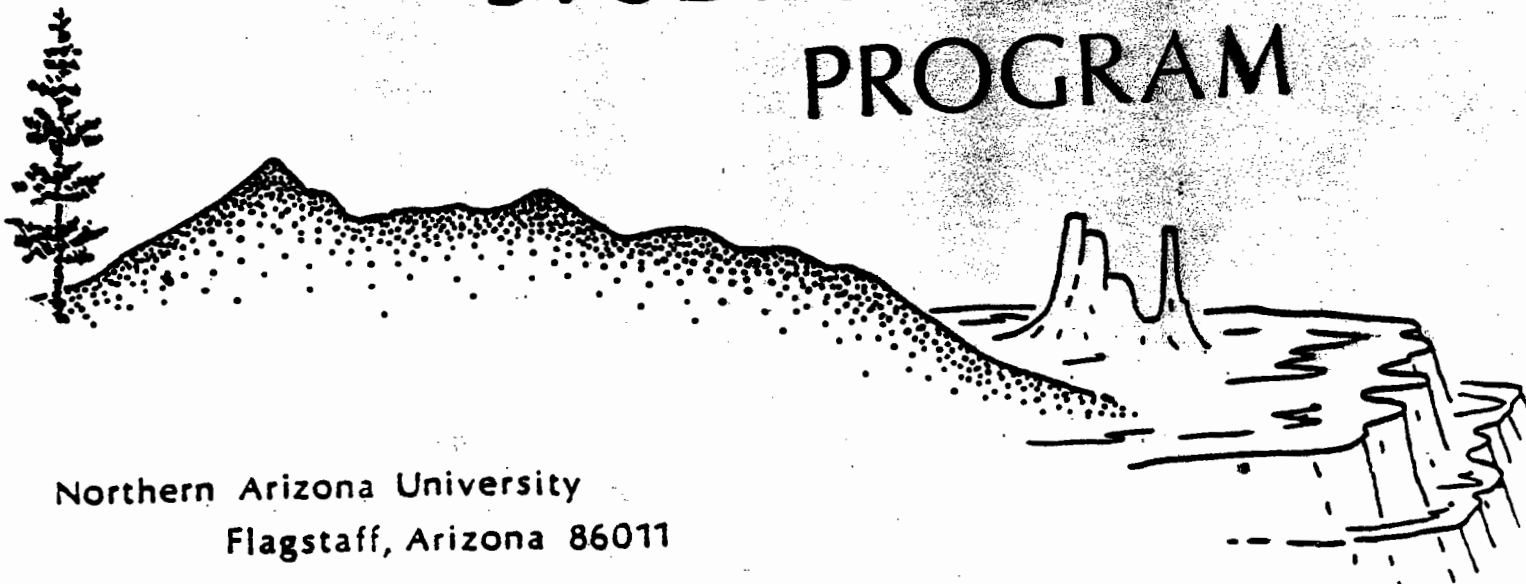
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QUATERNARY STUDIES PROGRAM



Northern Arizona University
Flagstaff, Arizona 86011

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Support by National Park Service personnel, especially A. Anderson, V. Vierra, L. Belli, prior to this contract was vital to the early investigation of Bechan cave. The management and staff of Glen Canyon National Recreation Area, Canyonlands National Park, and Natural Bridges National Monument have been outstanding in their interest and support during the contract phase.

Nickens and Associates, PIII, and the NAU archaeological contractor have also aided in our efforts.

FOREWORD

This report compiles the results of one field season of research by an interdisciplinary team of researchers and graduate students. It conveys the information gained in that field season. It is not to be interpreted, or judged, as a compendium of the Quaternary of the Colorado Plateau. It is a start in that direction. The task of the research team was to provide a C-14 controlled geochronologic framework of the lands administered by (and adjacent to) the National Park Service. Human occupation, adaptation to, exploitation of, and movement within the natural environment could then be related to this framework, which would also provide causal relationships for human activities through time.

The alluvial record provides the repository in which the evidence of the environment and its temporal setting were preserved. Charcoal, and plant and animal materials preserved in the alluvial sediments provided the C-14 samples giving temporal control. Cycles of erosion and deposition were also recorded in the alluvial material preserved in the canyons. Temporal control of those events allows interpretation of the climatic change through time.

Soil study documents and interprets the periods of stability of the canyon floor, which provided graze, gathering potential, or horticultural-agricultural activity, or its potential. Buried soil horizons reflect a change in environmental conditions, providing alluvium at a rate greater than soil development.

Paleohydrologic information is present in the alluvium as cut and fill sequences, water table fluctuations, marsh (cienega) deposits and small impoundments (lakes or ponds). The fluctuation of the water table through time is intimately related to the climatic and geologic changes taking place.

Pollen studies provide evidence for the types of botanical communities present at a location, through time. With temporal control, we were able to document environmental change, as a result of climatic change, resulting in changing habitat. Environmental or habitat change requires different exploitation strategy by the fauna (human, or non-human) who are utilizing the botanical base.

Packrat midden analysis serves as an independent check of the pollen (and to some extent the paleontological) record of the area. Packrats build a nest of botanical and faunal remains which becomes cemented by their urine. These cemented nests (middens) become more erosion resistant than the adjacent rock and provide a sampling of botanical and fauna specimens at a specific locality through time.

Paleontological remains document fossil life forms (plant and animal) at a study locality through time. Paleontological material is not abundant in alluvial deposits of the nature being investigated in Phase I. However, caves, alcoves, etc. do provide unique, highly significant deposits, or remains. These data provide a cross-check on models built by the methods outlined above.

Buried archaeological remains, also preserved in the alluvium, provide evidence of human utilization of the natural resources of an area. The depth of burial, its temporal position, and its nature of deposition provide important insights as to geologic processes during the human occupation of the study area.

A report on an initial year of field work cannot provide a management manual for NPS personnel. It can make resource management personnel aware of the types, amounts and locations of significant deposits, exposures and data bases. That, in turn, can help in preparing policy or procedures that will

reduce impact to these areas or localities. Perhaps in the third and fourth years of the contract specific suggestions/recommendations can be made, based on an increased amount of field data.

L. Agenbroad

Chapter 1
INTRODUCTION
L. Agenbroad

The Purpose

The Quaternary studies of Glen Canyon National Recreation Area and Canyonlands National Park were undertaken to assess the exposures of Late Quaternary/Holocene geology and interpret the paleoenvironment of the area. From this information the ultimate purpose of these investigations was to provide a geochronological framework for interpreting the aboriginal occupation of the parks. The study was (and is) being done in close cooperation with the archaeological contractors for each park.

Specific areas of research were to include: 1) study of the Late Quaternary alluvial geology; 2) paleohydrology and sedimentation; 3) paleontology; 4) palynology; 5) study of paleoenvironmental change; 6) soils research.

Pleistocene/Holocene Research Needs for the Areas of Glen Canyon National Recreation Area and Canyonlands National Park Include:

1) The Quaternary geologic history of the area is little known. Recent work on the Escalante River by Boison and Patton (1985) and Webb (1985); a very preliminary paper on Lake Canyon (Lipe et al. 1975) and a preliminary analysis of Bechan Cave (Davis et al. 1984, Agenbroad et al. 1984) are the only studies available, other than those of the now drowned Colorado River Canyon (Cooley 1960, 1961, 1962, 1975). There are studies more regional, or more removed from the designated areas of concern, such as Agenbroad (1975), Biggar, Harden and Gillam (1982).

2) The goal of this study and a critical need for late Pleistocene and Holocene research of the Park Service areas is the establishment of a

geochronologic framework for a basis for interpretation of the aboriginal occupation, utilization, and abandonment of the region. Most previous research has been devoted to older geologic units for mineral resource analysis, to areas currently inundated by Lake Powell, or to site-specific studies, archaeological survey, or geologic reconnaissance. The Quaternary deposits are becoming increasingly more important as our knowledge of the prehistory of the area increases, i.e., the recent discovery of the dung and hair of Pleistocene megafauna in Bechan Cave; the continued (and accelerated) erosion of extensive Pleistocene/Holocene deposits in areas such as Bowns Canyon, Lake Canyon, and others; the increased impact of public recreation facilities, modes of travel and access; and continued destruction of geologic and cultural materials by natural processes, evidenced by the increased erosion of Quaternary deposits since the 1880s. It is also needed as a resource tool and framework for the management of the Park Service natural resources to assess areas of heavy impact, and to conserve, limit access, or set aside areas of particular scientific importance such as the recently discovered deposits of Bechan Cave. Areas immediately adjacent to Park boundaries were relatively inaccessible ten years ago, but with improved roads and improved means of travel, plus increased hiking activity, even the once remote areas are becoming increasingly visited. The deposits/sites of these areas should be investigated and recorded/reported prior to severe cultural impact or increased natural degradation.

3) Recent multidisciplinary studies such as those at Chaco Canyon, New Mexico; Black Mesa, Arizona; or Cedar Mesa, Utah indicate that there is a cause-response relationship to human occupation-adaptation-migration patterns that is discernible from the geologic-botanical-paleontological records preserved in the Quaternary deposits. This data base and its effect on

prehistoric human and animal populations and the evidence of climatic change is crucial to understanding the prehistory of the area, as well as modern phenomena, and can serve as a predictive tool for the future. Many key deposits have been relatively undisturbed, due to their remoteness, in the past. The access provided by Lake Powell and new or improved roads and means of transport threaten the existence and preservation of such deposits. An example is the attempted protection of Rampart Cave in the western portion of the Grand Canyon, with the resultant forced entry and fire (vandalism or accidental makes no difference) that destroyed a "one-of-a-kind" deposit of extinct sloth dung (Nothrotheriops shastense). The threat of a similar occurrence for the mammoth dung blanket at Bechan Cave is just as real and would be just as damaging. This example is a paleontological cave deposit but similar cases can easily be cited for archaeological or geological resources. All have paleoenvironmental significance and should be evaluated scientifically before they are modified extensively, or destroyed.

The Technical Approach

The research plan contains the geological/paleoenvironmental investigations needed to determine a geochronologic time scale and determine the effect of paleoclimatic change on the prehistoric inhabitants of Canyonlands National Park and Glen Canyon National Recreation Area. These studies include the analysis and examination of the biological basis (faunal and floral) for human utilization of this portion of the Colorado Plateau and Canyon country.

The basis for the determination of the geochronologic framework for the area and a paleoenvironmental reconstruction related to that framework included field and laboratory investigations. Basic to the study is geologic/geomorphic field mapping using acetate overlays for air photos.

Photo mapping was transferred to a base map of the areas of investigation. Mapping was concentrated on the areas specified in the RFP, for archaeological survey and investigation. It was also extended outside the specified areas, to help create a regional model. Areas not designated in the proposal but considered pertinent to the geologic studies were also investigated if they had the potential of supplying basic data for the formulation and refinement of the geochronologic/paleoenvironmental models as proposed by Hack (1942), Antevs (1955) and others.

Evidence from the geochronologic and paleoenvironmental models was used to address anthropological problems such as: 1) the availability of arable land at given time intervals in the Holocene (land available for agricultural/horticultural use by prehistoric peoples in the area); 2) water resources for domestic and possible horticultural usage, including analysis of water table fluctuations controlled by aggradation or degradation of the channels in the valley fill; 3) the demographic changes based on changes in the natural environment and human responses to those changes; 4) the source and utilization of local lithic and clay sources, and any other geologic or environmental factors observed that may have elicited human response.

The geochronology was derived from the identification, dating and analysis of a chronology based on alluvial studies (sedimentation and degradation); pedological analyses (paleosols represent periods of land surface stability); paleontology (vertebrate and invertebrate) to assess the environment present at a given time and serve as relative time markers; the hydrologic regime as evidenced by aggradation/degradation, particle size analysis, soil types, and pollen assemblages; environmental data from pollen analysis, packrat midden analysis, and chronology; palynology/ dendrochronology as relative and absolute botanical chronometers and evidence

for paleoenvironmental reconstruction, and from cultural materials included within the alluvial units. A relative sequence was the first level of analysis, to be chronologically refined with radiocarbon dating where possible.

Paleoenvironmental change and character was derived from analysis of the botanical response to prevalent climatic conditions. Changes in the botanical composition was reviewed in response to climatic controls, and geologic/geomorphic response to climate and climate change was evidenced by changes in the alluvial/degradational record, terrace sequences, and cut and fill sequences which were mapped and evaluated. Packrat middens, C-14 controlled for representative age intervals, were studied for macrobotanical and macrofaunal evidence as to the local environment at given elevations; the results gave added insight into paleoenvironmental conditions. Evidence of cyclicity in geologic processes was examined for paleoenvironmental control; zoological and anthropological evidence was studied for evidence of abandonment, migration, or invasion of the study area by various species which may be related to paleoenvironmental causes.

Paleontological investigations included vertebrates (megafauna and microfauna), invertebrates (malacology), palynology, and paleo-macrobotany (packrat midden, and fossil plants in the alluvium). Alluvial geological studies included transport mechanisms (water, wind); sediment size analysis and hydrologic or eolian characteristics dictated by the size fractions; lacustrine units (impoundments) and their causes and destruction; and the paleohydrologic conditions dictated by the above. The presence, or absence, of the Altithermal drought postulated by Antevs (1955) was also addressed.

The above analyses were carried out by field work including mapping, collecting, field examination, photography, measuring sections, geomorphic

studies and detailed field records. Collections were analyzed in the laboratory, and results will be tabulated, graphed, drafted, photographed and recorded for use in construction of the geochronologic time scale, and for the synthesis.

Because of the interdisciplinary nature of Quaternary studies in general, and this project in particular, a team of experts were involved in the field and laboratory analyses.

Principal Investigator:

Larry Agenbroad: geology, paleohydrology, geomorphology, paleontology
(megafauna)

Associated Specialists:

James Mead: paleontology (microfauna), paleoecology from packrat midden
analysis, malacology

Richard Hevly: palynology, botany

Eric Karlstrom: soils, geomorphology

Julio Betancourt: paleoclimatic reconstruction from packrat midden
analysis

Larry Middleton: sedimentation

Background and Previous Work

The Phase I report has a great deal of information not supported by the NPS Quaternary Studies contract. These data reflect the research efforts that initiated interest in the Quaternary (and pre-ceramic Holocene) resources of the parks. The Bechan Cave and canyon work was initiated in 1983. Glen Canyon National Recreation Area (GCNRA) provided initial logistic support for the preliminary testing. Two National Geographic Society grants (#2711-83; #3016-85) were received for more detailed investigations of the Bechan Cave

deposits and initial efforts at analysis of the alluvial fill of the adjacent canyon system.

Information generated from these studies was enhanced by the NPS contract work in Phase I of this contract. This alluvial sequence was selected for detailed study because: 1) it had the highest potential for containing the entire Holocene and late Pleistocene alluvial record; 2) this alluvium had datable horizons within it, to give a chronologic base for the paleoenvironmental changes through this time period; 3) this alluvium contained buried cultural sites, allowing prehistoric human occurrences in the canyon to be tied to the absolute chronology and the environmental record; 4) Bechan Cave contained not only prehistoric, extinct, megafaunal remains, but the last 8,000 years of human prehistory was documented as well; 5) the cave data could be correlated directly to the alluvial record from the same drainage system - a first in such studies - and would serve as a cross check of the data derived from the alluvial studies, alone.

Areas designated to be investigated by the Park Service in Phase I were picked for reasons other than the Quaternary studies. Rainbow Bridge had little Quaternary deposits other than talus and sand dunes. Lee's Ferry had main stream Colorado River terraces which were utilized as lithic material sources by prehistoric human groups that left little evidence of their place in the temporal span of the area prehistory. The Colorado River canyon from Glen Canyon Dam to Lee's Ferry had a combination of terraces, talus and dunes which did not appear conducive to forming a "master key" chronology. The Orange Cliffs area had an entirely different geomorphic character, one that had hints of early human activity (Cowboy Cave; Jennings 1980), but lacked "key" sections suitable for great time depth combined with pedologic, palynologic, and paleontologic records. Canyonlands National Park had two

area-specific research efforts: 1) Salt Wash Pocket; and 2) Devil's Lane, as specified by the contract and the archaeological consultant. In addition, we surveyed several additional drainages and initiated detailed studies in the Big Pocket area. Alluvial dates resulting from the initial year of study indicated that lower Salt Creek Drainage did not exceed $\pm 4,000$ B.P.: 2,050 B.C. in antiquity in the alluvial deposits.

Quaternary research involves the last 1.67 million years of prehistory. It was subdivided into the Pleistocene epoch (1.67 to 0.1 million years ago) and the Holocene (the last 10,000 years). To fully understand human adaptation to, and exploitation of, the natural environment, and their effect on that environment, a view of what that environment was like prior to human interaction is needed. The only potential record for that information is in the cave fills and alluvial records, whether or not they contain obvious evidence of human culture.

Considering only the Holocene, less is known about the first 8,000 years (10,000-2,000 years ago) than the last 2,000 years. In effect, the ceramic cultures have suffered from "archaeological overkill" - with undue attention paid to the last 2,000 years, with little effort expended on the preceding 8,000 years - which are critical to understanding human presence in the area and adaptation to a changing environment. The results of those changes in the last 2,000 years are preserved for us as the Puebloan cultures, their expansions and contractions of areas of influence and exploitation and the ultimate abandonment of the region. These latter events were also environmentally controlled and only part of the record of the factors involved will be derived from archaeological analysis alone.

The task of the Quaternary Studies contract was the production of a geochronologic framework to which the paleoenvironmental change and cultural

record could be correlated, for a better understanding of each. The first year of contract has produced a basic framework for a key area and has been and will be extended to other areas, adjacent and remote, temporally and physically from the key area.

Those areas of investigation that predate 10,000-15,000 years ago will be funded by contracts and/or grants from agencies outside the current NPS contract.

Specific Areas of Research: Phase I (10/84-10/85):

Glen Canyon National Recreation Area.

1. Areas specified by the National Park Service and the archaeological contractors.
 - A. Lee's Ferry (1200 acres)
 - B. Rainbow Natural Bridge (160 acres)
 - C. Orange Cliffs (3220 acres)
 - D. Bowns Canyon (1000 acres)
2. Areas specified by the Quaternary Study group.
 - A. Bowns Canyon
 - B. Long Canyon
 - C. The Colorado River canyon from Glen Canyon Dam to Lee's Ferry
 - D. The mouth of the Paria River

Canyonlands National Park.

1. Areas specified by the National Park Service and the archaeological contractors.
 - A. Salt Creek Drainage (4000 acres)
 - B. Devils Lane (Needles area) (400 acres)

2. Areas specified by the Quaternary Study group.

A. Big Pocket in the Salt Creek Drainage

B. Helicopter reconnaissance of Elephant Canyon and Big and Little Spring Canyon.

Chapter 2

RESEARCH DESIGN

L. Agenbroad and J. Mead

Introduction

This project is part of a multiyear program to study the aboriginal occupation and use of Canyonlands National Park and Glen Canyon National Recreation Area. Its general purpose is to develop a geochronological framework for understanding area prehistory through study of the late Quaternary alluvium, soils, paleontology, palynology, paleohydrology and sedimentation, and other data sources relevant to interpreting the paleoenvironment. Because of its relationship to the study of areal prehistory, this project of necessity focuses heavily upon those areas where archaeological survey is underway and addresses those problems specific to the interpretation of regional prehistory. There are two ultimate goals of the study:

1. Establishing a regional paleoenvironmental history and sequence of events tied to an absolute chronology; and
2. Correlating the archaeological record with the paleoenvironmental and absolute chronological framework.

This, then, allows interpretation of the human utilization, exploitation, habitation, and demography, as tied to the environment and to environmental change, from the advent of the Paleoindian megafauna hunters through Archaic, agriculturalist, historic, and modern human groups.

Background

The natural deposits (alluvium, cave fill, packrat middens) comprise the preserving medium and the physical repository for the prehistory of the area, of which the archaeology is but one aspect. Without the analysis of the

paleoenvironmental evidence, the archaeological report does little more than record the artifactual materials left at a given locality at an approximate time (often derived only by relative typology of the artifacts recovered). The Quaternary deposits are the mechanism of preservation and the temporal-physical framework to which the archaeology must be related for optimum understanding of human presence, exploitation and adaptation/modification of the area resources. The inundation of the main stream Colorado River canyon by the backwaters from Glen Canyon Dam effectively destroyed the potential of study of the major alluvial system of the area. Paleoenvironmental reconstruction and the chronology of events to which the archaeology is related must be built from smaller (second and third order) drainage systems, which the waters of Lake Powell have made more accessible.

The Quaternary history of the areas is little known. Recent work on the Escalante River (Boison and Patton 1985), a very preliminary paper of Lake Canyon (Lipe et al. 1975), and a preliminary analysis of Bechan Cave (Davis et al. 1984; Agenbroad et al. 1984; Mead et al. 1986) are the only studies available, other than those in the now drowned Colorado River canyon (Cooley 1960, 1961, 1962, 1975), or the studies more regional, or more removed from the designated areas of concern, such as Agenbroad (1975), Biggar, Harden and Gillam (1982).

Recent multidisciplinary studies such as those at Chaco Canyon, New Mexico; Black Mesa, Arizona; or Cedar Mesa, Utah indicate that there is a cause-response relationship to human occupation-adaptation-migration patterns that is discernible from the geologic-botanical-paleontological records preserved in the Quaternary deposits. This data base and its effect on prehistoric human and animal populations and the evidence of climatic change is crucial to understanding the prehistory of the area, as well as modern

phenomena, and can serve as a predictive tool for the future. Many key deposits have been relatively undisturbed, due to their remoteness, in the past. The access provided by Lake Powell and new or improved roads and means of transport threaten the existence and preservation of such deposits. An example is the attempted protection of Rampart Cave in the western portion of the Grand Canyon, with the resultant forced entry, a fire (vandalism or accidental makes no difference) that destroyed a "one-of-a-kind" deposit of extinct sloth dung (Nothrotheriops shastense). The threat of a similar occurrence for the mammoth dung blanket at Bechan Cave is just as real and would be just as damaging. This example is a paleontological cave deposit, but similar cases can easily be cited for archaeological or geological resources. All have paleoenvironmental significance and should be evaluated scientifically before they are modified extensively, or destroyed.

Theoretical Framework/Paradigm/Model

It has been amply demonstrated that there is a cause-response relationship between man and the environment that is discernible in the Quaternary record, evidenced mainly as geological, botanical, palynological, and cultural data. Therefore, we assume that (1) understanding this record is crucial to understanding area prehistory, and (2) extracting this record from the Quaternary deposits is possible. Recent work on the Colorado Plateau (including Year I of this study in Canyonlands National Park and Glen Canyon National Recreation Area) has shown that key drainages contain alluvial fill sequences that document vegetational, faunal, climatic, and cultural change for the past 15,000 to 20,000 years. Analyses of these data permit:

1. Reconstruction of the paleoclimate;
2. Reconstruction of the paleoenvironment;
3. Creation of an absolute chronology of events;

4. Documentation of geologic, climatic, faunal, floral, and cultural change in the area;
5. Interpretation of area cultural history and environmental utilization;
6. Correlation of the Bechan Cave depositional sequence to the canyons' alluvial sequence.

Work in Bechan Cave, Glen Canyon National Recreation Area, has documented a 15,000 year history of change in flora, fauna, climate, and culture for the cave fill. The Quaternary record is contained in the canyons adjacent to the cave. It consists of up to 15 m of alluvium evidencing cut and fill sequences, fluctuating water tables, paleosols, standing bodies of water, paleontological remains, and archaeological materials. It is hypothesized that analysis of this record will enable (1) tying the record to an absolute chronology, (2) correlating the record with widespread climatic, botanical, and cultural events, and (3) tying the events in the canyons to the events recorded in Bechan Cave fill. The result of this study would be the creation of a "Master Key" for correlation with other canyons, adjacent and distant, on that portion of the Colorado Plateau occupied by Glen Canyon National Recreation Area and Canyonlands National Park and would help achieve the goals of the study.

ASSUMPTIONS

Table 1 presents the research model in a tabular format; specific hypotheses and methods of testing these hypotheses follow, later. The relationship between independent variables and dependent variables presented in Table 1 revolve around four physical factors: 1) time, 2) change in climatic character with time (cyclicity); 3) moisture availability; 4) temperature. A

TABLE 1: Outline of the Research Model:
PALEOCLIMATIC CHANGE AND ITS EFFECT ON THE NATURAL AND CULTURAL ENVIRONMENT

<u>INDEPENDENT VARIABLES (EFFECT)</u>	<u>DEPENDENT VARIABLES (EVIDENCE)</u>	<u>DATA SOURCES & LOCATION</u>
I. REGIONAL PALEOCLIMATE		
a. SYSTEMATIC VARIABLES		
1) Temporal cyclicity	vegetation	pack rat middens, pollen and macro-botanical remains from cave fill, alluvium, cultural deposits
b. ENVIRONMENTAL VARIABLES		
1) moisture	vegetation	pack rat middens, pollen, macroflora from caves, alluvium, cultural deposits
	fauna	dung, bones, teeth, hair from caves, middens, alluvium, and cultural deposits
	cultural remains	presence or absence of arch. sites
2) temperature	vegetation	pack rat middens, pollen, macroflora from caves, alluvium, cultural deposits
	fauna	dung, bones, teeth, hair from caves, middens, alluvium, and cultural deposits
	cultural remains	presence or absence of arch. sites
3) temporal stability	soils	alluvial profiles
	geomorphology	cut and fill sequences, presence of sand dunes
	cultural remains	presence or absence of arch. sites
II. MICROENVIRONMENTAL VARIABLES		
1) Canyon configuration and elevation	aspect	presence or absence of alluvial fill to drainage area gradient

Table 1
Page 2

INDEPENDENT VARIABLES (EFFECT)	DEPENDENT VARIABLES (EVIDENCE)	DATA SOURCES & LOCATION
III. CULTURAL FACTORS		
1) Presence or absence	arch. sites	terrace surfaces, dunes, caves, stratigraphic locations
2) Extinction	loss of previous fauna/vegetation	alluvium, caves, middens, arch. sites
3) Erosion	increase/decrease of cut and fill	alluvium

given locality will produce a biological community (floral and faunal) that reflect the above independent variables. For example, the same locality can be demonstrated to have had environmental change - as reflected by the record of its floral, faunal (and geological-hydrological) entities, through time. The modern environment may be a semi-arid high plateau with its characteristic pinyon-juniper scrub forest modified by riparian habitat and biologic community near water sources, or by black brush-steppe in more elevated, less watered environmental locations. By analysis of pollen, fauna, flora, and geohydrologic materials, the same locality can be demonstrated to have been a spruce-birch forest with a different riparian habitat and biological community, and a sage brush-grass steppe as recently as 11,600 B.P.: 9,650 B.C. (Davis et al. 1984; Agenbroad et al. 1984; Mead et al. 1986). Human presence is also recorded intermittently within the last 8,000 years of the record at this locality. The presence or absence of prehistoric people is intimately tied to the environment and its resources as a function of the hydrogeologic processes in action at a given time interval.

The interpretation and understanding of the paleoenvironment as derived from the evidence preserved in remnant geologic deposits provide the key to understanding the presence or absence of human groups at the study locality.

HYPOTHESES GUIDING FIELD RESEARCH

The specific hypotheses guiding field research have been developed to provide the information necessary for (1) creating the "Master Key" discussed above, and (2) addressing the goals of the project. These hypotheses will be tested by the field data and revised as necessary. New hypotheses may be developed as new data are acquired.

Hypothesis I:

There is alluvium in canyons of GCNRA and CNP (Canyonlands National Park) that records paleoenvironmental data, chronologic material, paleontological, cultural evidence of late Pleistocene-Holocene conditions on the Colorado Plateau.

Testing of Hypothesis:

1. Select key canyons containing alluvial fill and:
 - a. map the alluvium;
 - b. establish a chronology by radiometric dating of material within the alluvial units to record episodes of cut and fill, paleoenvironmental data including floral and faunal information;
 - c. study pollen profiles keyed to the dated alluvial units; and
 - d. study pedologic evidence for soil formation, tied to the chronologic framework.
2. Extend the model from "key" localities to other areas, both proximal and distance to verify local or regional trends.

Hypothesis II:

Faunal and floral resources were available on the Colorado Plateau in late Pleistocene times that allowed exploitation of such resources by early human groups.

Testing of Hypothesis:

1. Collect, identify, and correlate to the radiometric chronology any paleontological materials incorporated in the alluvium.
2. Analyze the palynological evidence from radiometrically dated alluvial sequences to document botanical materials.
3. Identify resources or potential resources (both faunal and botanical) for various temporal intervals, for human exploitation.

4. Plot reported distributions of potential game animals, i.e. bison, mammoth, and the cultural entities that exploited this game base, i.e. Folsom, Clovis, etc.

Hypothesis III:

Cave deposits within the study area contain records not often found in alluvial/cultural sites. The investigation, and correlation to the alluvial and surface sites, will provide additional refinement for the reconstruction of the paleoenvironment, its change, and its exploitation by human inhabitants of the area.

Testing of Hypothesis:

1. Correlate the alluvial history/chronology with cave chronologies such as at Bechan Cave (Davis et al. 1984), Cowboy Cave (Jennings 1980), Allan Cave (Betancourt 1984), etc.
2. Conduct paleobotanical investigations (macrobotany and pollen) of the units of selected cave fills and correlate to reported data references in (1) above.
3. Document and date cultural horizons within cave fills.
4. Test selected caves for Pleistocene megafaunal remains such as at Bechan Cave, Cowboy Cave, Bare Ladder (Mead et al. in submission).

Hypothesis V:

A cause and effect relationship exists between climatologic, biologic, and geologic changes on the Colorado Plateau.

Testing of Hypothesis:

1. Adverse climatic conditions caused local portions of the study area to be abandoned by flora, fauna, and cultural entities.
2. Beneficial climatic conditions allowed local portions of the study area to be exploited by flora, fauna, and cultural entities.

3. Evidence of such conditions are recorded in the alluvial and cave fill; it can be documented and tied to an absolute chronology, allowing interpretation of the cultural chronology for the area.

Hypothesis VI:

A synthesis of paleoenvironmental conditions can be constructed based on an absolute chronology from alluvial fill, cave fill, and packrat middens. The synthesis will allow estimates as to biological and geological resources, arable land, and migrational impetus for given temporal intervals for prehistoric cultural entities.

Testing of Hypothesis:

1. Construction of local (a given canyon or drainage) synthesis.
2. Correlation of local syntheses to form a regional synthesis.
3. Interpret paleoenvironmental conditions/factors available to human groups at temporal intervals provided by the absolute chronologic framework.
4. Test the paleoenvironmental data and interpretations with reported archaeological evidence.

DATA COLLECTION PRIORITIES

Those localities which have potential for the preservation of long (temporal) alluvial records are of first priority. The Bechan Cave-Bowns Canyon area provided not only an alluvial record, but a stratified cave fill as well. Key sections within a canyon or study area will contain thick stratified alluvial sequences, with datable (absolute dating such as C-14) material, pollen preservation potential, macroflora and fauna, and cultural remains (hopefully in stratified context). Surficial archaeological remains, while interesting, rarely have great antiquity, or if they are old often

reflect erosional lag deposits lacking the environmental data outlined above. Canyons with great drainage areas will often be denuded of ancient alluvial deposits due to episodic flooding events (Webb 1985; Boison and Patton 1985). Key areas, then, will be canyons containing thick alluvial deposits, with some evidence of great antiquity in the older units. Such areas are sought out by the Quaternary geology contractor and his colleagues, whether or not they coincide with the areas of interest of the archaeological contractor, or the current needs of park management. It will prove, more often than not, that the evidence of human presence will also be documented in such localities and will provide clues to the cultural adaptation to the region not provided by younger, ceramic cultures.

Year I areas of investigation prescribed by the NPS proposal, or the archaeological contractors were investigated, but most often were not optimum localities for paleoenvironmental information predating 4,000 B.P.: 2,050 B.C., omitting much of the Archaic and potentially all of the Paleoindian periods of human prehistory on the Plateau.

Areas with High Research Potential

Any area within GCNRA and CANY having the above criteria has excellent research potential. As noted, Bechan-Bowns is outstanding as a key data point. We have chosen 40 Mile Canyon and Lake Canyon for their thick, ancient alluvial deposits. One contractor critique states "cultural deposits in Lake Canyon are not well studied so (we) can't tie (to) the alluvium, etc." I know there are abundant archaeological remains in and immediately adjacent to Long Canyon. This claim is substantiated by a report by Schroedl (1976) and the area begs for further, serious work. The possibility does exist to tie the cultural information to the geologic, hydrologic, paleoenvironmental framework which is the purpose of the study. The Big Pocket area of CANY has similar

(though probably younger) potential. Forty Mile Canyon has an extremely exciting potential predating most prehistoric cultural potential, so the geologic contractors are seeking outside funding to pursue that research, which will provide a necessary record for the paleoenvironment just prior to the advent of human populations in the area, and just prior to extinction of major species of Pleistocene megafauna, providing a critical test of the overkill hypothesis.

Year I Field Investigations

Field work for the Glen Canyon National Recreation Area was concentrated in the Lee's Ferry, Rainbow Bridge, Orange Cliffs, and Bechan Cave localities. Of particular significance are the studies in the alluvial fill of canyons adjacent to Bechan Cave.

Radiocarbon dates from selected sites and levels in the alluvial fill have produced a sequence of dates ranging from 75 B.P.: AD. 1,875 to 10,020 B.P.: 8,070 B.C., with other dating samples still in process. The dates currently available (Table 2) allow correlation with the post-dung deposits in Bechan Cave (Figure 1); they also put alluvial dates to within less than 1,700 years of the youngest portions of the dung deposit of the cave. Older alluvial units are awaiting laboratory results, which should extend the alluvial chronology 1,000-10,000 years for these canyons. Alluvial units lacking material suitable, or in insufficient quantity, for standard C-14 dates are being dated by TAMS (Tandem Linear Accelerator Mass Spectrometer) methods, and/or by thermoluminescent dating techniques.

Palynological and pedological studies of the alluvial units are in progress, with preliminary interpretations being written. Additional profiles with greater chronological control, and in conjunction with archaeological studies, are planned for Year II.

Table 2. Phase I C-14 dates, GCNRA and CANY.

C-14 DATES NPS QUATERNARY STUDIES CONTRACT # CX-1200-4-A062				
Time (BP) x1000 yrs	Glen Canyon Nat'l Recr. Area			Canyonlands Nat'l Park
	Bechan Cave	Canyon Alluvium	Long Canyon	Alluvium
0		.75		.200 - Big Pocket
	.570 - cultural	.215		
1	.1240	.940		.310 - Salt Cr
2	.1310 } cultural	.950 - cultural		.580 - Salt Cr
	.1400 }			.1640 - Salt Cr
3	.2080 } cultural		.2540	.1735 - Salt Cr
	.2640 }			.2430 - Salt Cr
4		.4025		
		.4090		.4510 - Salt Cr
5		.4965	.5240	.4830 - Salt Cr
6	.5500 - cultural	.5300 - cultural		
7			.6640	
8	.7525 } cultural		.7635	
	.7795 }			
9			.9545	
10		.10,020		
11	.11670			
12	.11850			
13	.12400			
	.12620 } dung			
	.12900 }			
14	.13505			
15			.14,860	
16				
17				
18			.17,430	
19				
20				
21				
22				
23				
24				
25				
> 40,000				

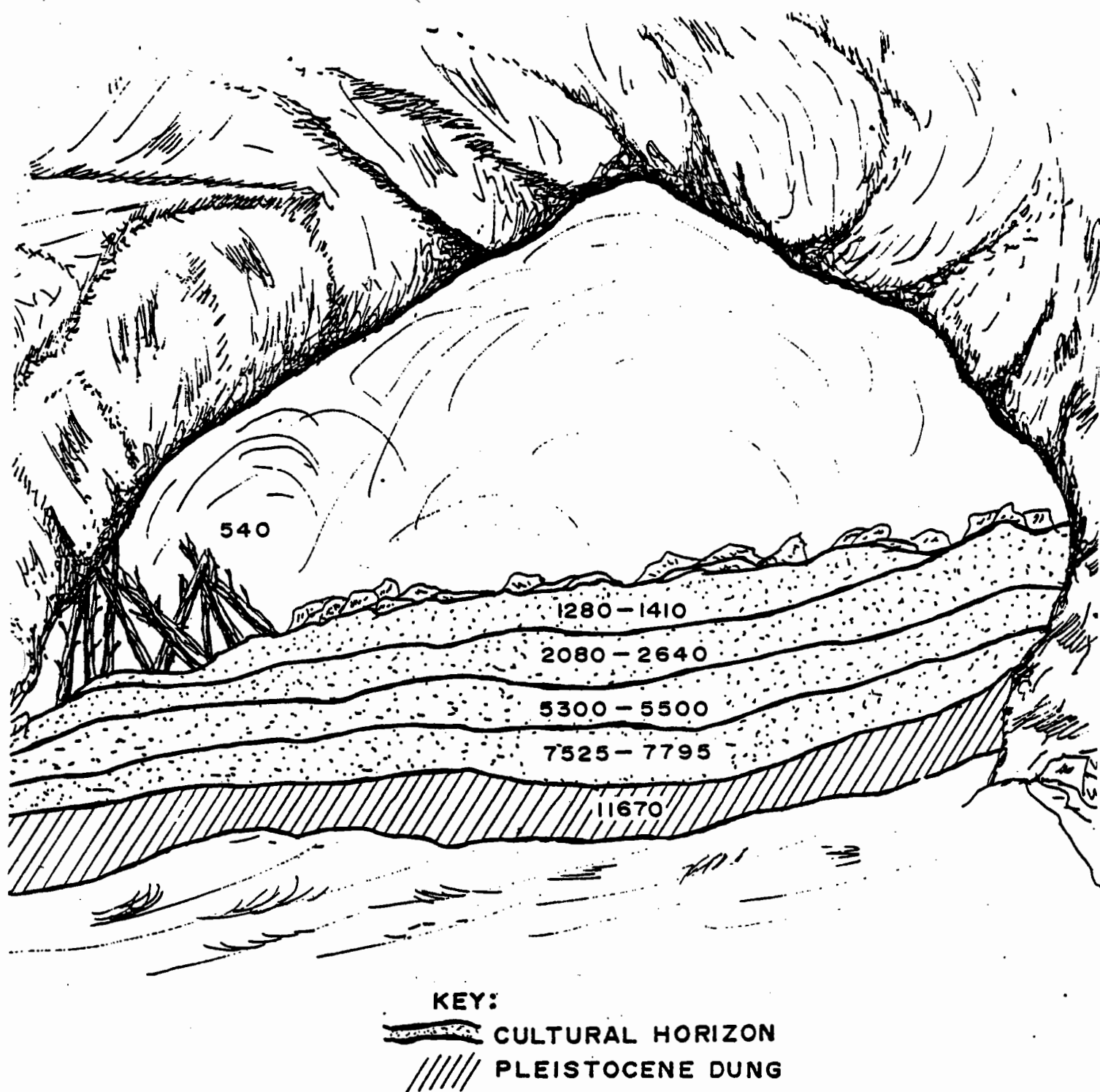


Figure 1. Cross section of the fill deposits in Bechan Cave, with dated cultural horizons.

The ultimate goal of the study is twofold:

1. To establish the paleoenvironmental history and sequence of events tied to an absolute chronology;
2. To tie the archaeological record to the paleoenvironmental and absolute chronologic framework in (1) above. This will allow an interpretation of the human utilization, exploitation, habitation, and demography, as tied to the environment and environmental change in the area, from the advent of Paleoindian megafauna hunters, to Archaic, agriculturalist, historic, and modern human groups.

Year II Field Investigations (Project Design)

Using the above data base and experience, it is proposed that key canyons be investigated for their alluvial sequence possibilities. It is proposed that canyons adjacent to the 1984-1985 study area and canyons more removed, geographically, be studied as a further test and an expansion of the data base generated and initially tested in the Bechan Cave area.

Proposed study areas for 1985-1986:

1. Glen Canyon National Recreation Area
 - A. Long Canyon
 - B. Cow Canyon
 - C. Lake Canyon
 - D. 40 Mile Canyon
2. Canyonlands National Park
 - A. Big Pocket
 - B. Salt Wash Drainage
3. Areas specified by the National Park Service and the archaeological contractors.

Years III and IV Investigations

Using the experience and data base generated in Years I and II, the model will be expanded to include other areas of alluvium, cave fill, and packrat midden research. Areas will be selected based on the results of Year II studies and the areas specified by the National Park Service and the archaeological contractors.

A synthesis of all the field data will be correlated to the results of the archaeological contractors to provide a regional synthesis in Year IV.

Chapter 3

ALLUVIAL STUDIES

L. Agenbroad and D. Elder

Introduction

Huntington (1907), Bryan (1926), Hack (1942) and Antevs (1955), among others, have related climatic change to alluvial terrace development, through time, for local and regional areas of study. Hack's paper was a classic model for the Colorado Plateau. In an over-simplified summary, he suggested that the alluvium of many valleys of the Navajo country could be divided into three formations. He described the oldest formation as the Jeddito Formation; it contained remains of extinct fauna, predated Puebloan peoples, and was probably deposited prior to 5,950 B.P.: 4,000 B.C. This was followed by the Tsegi Formation, deposited between 4,950 B.P.: 3,000 B.C. and 750 B.P.: A.D. 1200. The youngest formation he proposed was the Naha Formation, dating less than 650 B.P.: A.D. 1300. He further suggests that each period of deposition is preceded by a period of erosion, and followed by another period of erosion. Hack did not have C-14 dating methods and made his temporal assessments on fossils, cultural artifacts, etc., incorporated in the alluvium.

Antevs (1955) working prior to C-14 control of alluvial events provided a model of climatic change through time for the last 10,000 years. His model was based solely on the geologic character and interpretation of the deposits he studied. His model was an attempt to assist archaeologists to date pre-ceramic cultural material preserved in a geologic context (medium), the alluvium of western valleys and canyons.

Application of controlled methods of sampling, analysis and interpretation of C-14 dates has allowed researchers to construct more detailed

(refined) models of geologic-climatic interactions. Interdisciplinary studies tied to that framework provide paleoclimatic and paleoenvironmental interpretations that were impossible for workers such as Hack and Antevs.

Alluvial studies were initiated in the canyons adjacent to Bechan Cave, with the hope of being able to construct a C-14 controlled alluvial record which could then be correlated to the cave fill. The possibility of such a correlation would be unique in Quaternary/Holocene studies, in that most cave fill represents an isolated "time capsule" of information, usually unrelated to all but the most recent alluvial events preserved in the adjacent canyons or valleys.

This phenomena appears to be due to cyclic aggradation and degradation (cut and fill) of the canyon and valley alluvial deposits. Recent studies in the general area (Boison and Patton 1985; Webb 1985) indicated relatively recent alluvial records, i.e. less than 3500 years old were all that could be expected in the area.

These generalities with respect to alluvial ages within the study area quickly proved to be unsound. The first C-14 date recorded from the Bowns Canyon alluvium was 4090 B.P.: 2140 B.C. Since that time, we have recovered dates as old as 10,020 B.P. :8070 B.C. from alluvium in the same canyon, and have even older samples (stratigraphically) in submission. As the analysis of this one canyon becomes more complete, the antiquity is expected to equal, or exceed, the chronology of the dung bed and post-dung fill of Bechan Cave. Deposits spotted from the air late in the 1984-1985 field season hold promise for being even older, by at least an order of magnitude. These deposits will be investigated in the Phase II research.

There are relatively simple geologic/geomorphologic reasons for the apparent conflict of credible research in the same drainage basin. First,

there is a considerable difference in the size, configuration, geology, and drainage characteristics of canyons within close geographic proximity; second, not all deposits were studied in the research cited above. Adjacent drainages with similar characteristics retain alluvium that will certainly date greater than 10x the ages cited by paleoflood investigators of paragraph two. Even within a single drainage system, remnant alluvium is retained that pre-dates studied segments.

To illustrate point one above, I will use a portion of the Escalante River system as an example to show the differing hydrologic characteristics of adjacent drainages. Figure 2 (from Hunt 1967) depicts an east-west cross section showing the structural control (control of area of drainage, slope of drainage, direction of drainage) of the drainages, as well as the dominant surficial geologic units. The Waterpocket Fold portion of the cross section contains the canyons of the Colorado River, the Escalante River, and many of their tributaries. This area has the Glen Canyon Group (Navajo Sandstone and Kayenta Formation) in surface outcrops. As one proceeds east or west, the San Rafael Group and Morrison Formation become the surficial exposures, which are in turn overlain by the Cretaceous units such as the Dakota Sandstone, Tropic Shale, Straight Cliffs Sandstone, and Wahweap and Kaparowits Formations. To put this in perspective with regard to the Escalante River, the southwestern tributaries drain the Kaparowits Plateau upland, cross the Jurassic and Cretaceous outcrops to join the river in canyons cut into the Triassic-Jurassic Glen Canyon Group (Figure 3). Tributaries draining toward the Escalante River, from the northeast drain Navajo Sandstone and Kayenta Formation uplands with occasional Moenave and Chinle exposures in some of the longer, or deeper canyons.

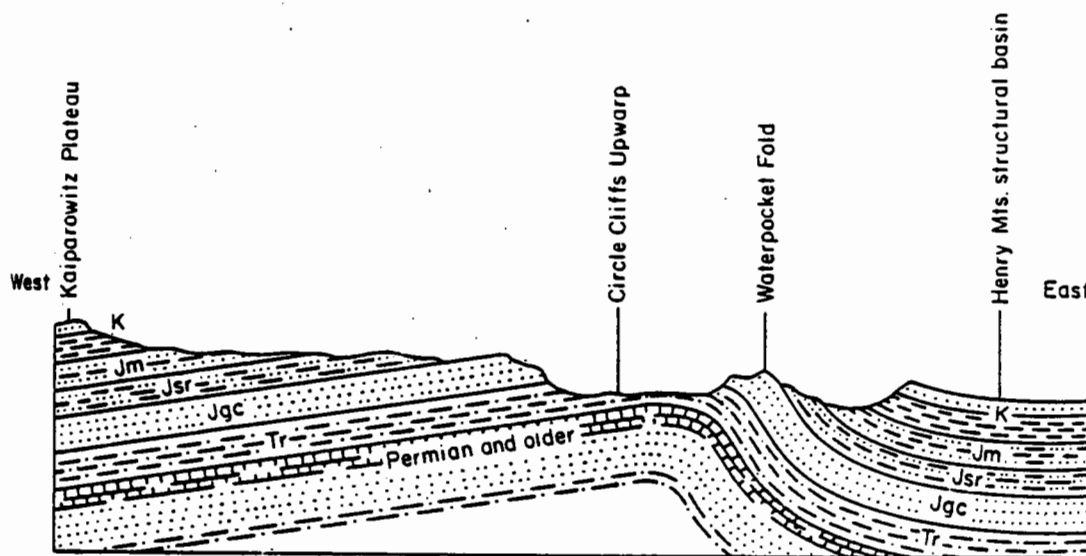


Figure 2. Cross section of the Circle Cliffs Upwarp. Tr = Triassic formations; Jgc = Jurassic, Glen Canyon Group; JsR = San Rafael Group; Jm = Morrison Formation; K = Cretaceous formations. (Hunt 1967)

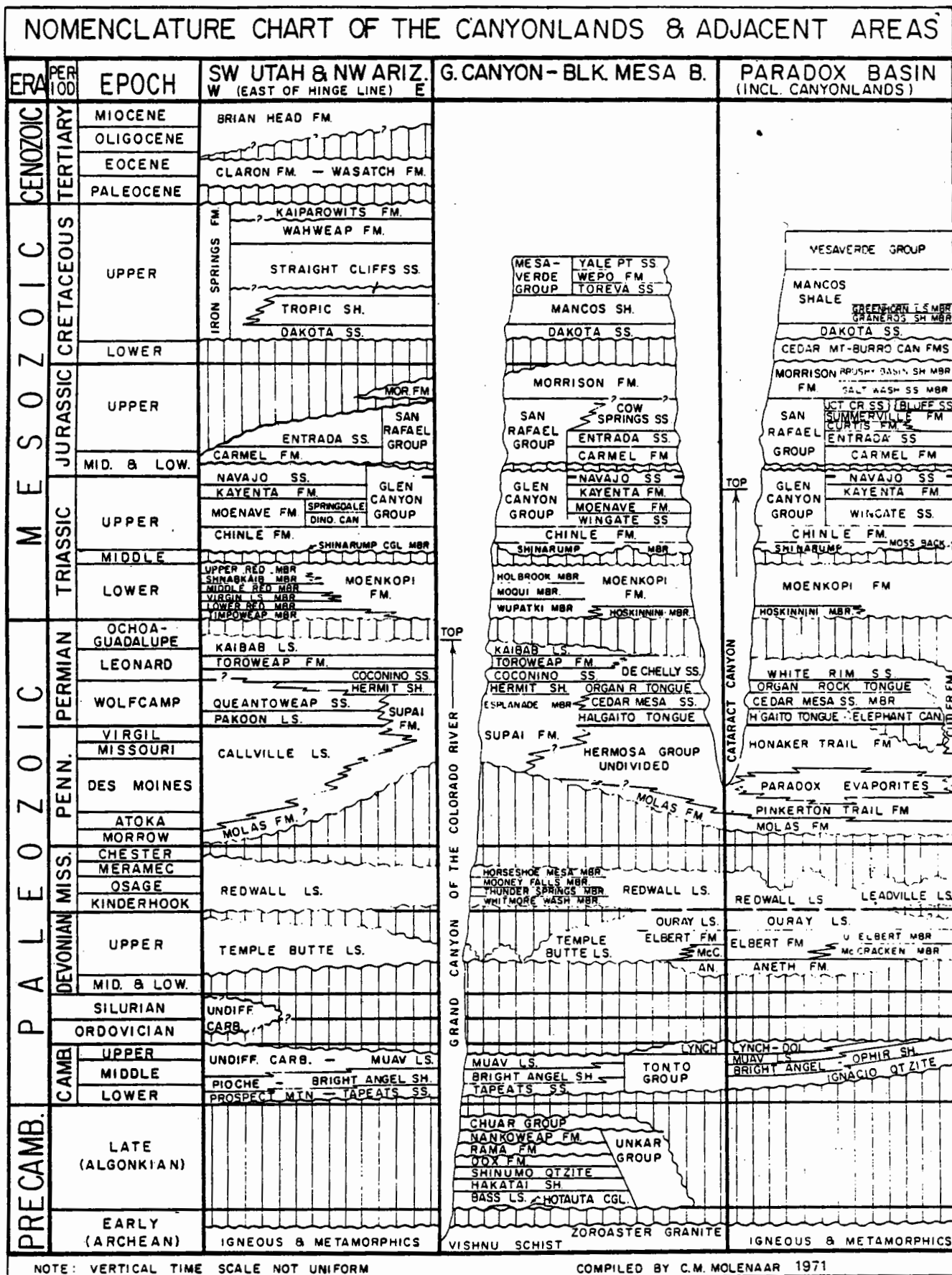


Figure 3. Geological nomenclature chart of the Canyonlands and adjacent areas.

This simplistic geologic difference, both in surficial exposures and structural controls, determines the relative amounts of orographic precipitation, the size of a given canyon's drainage area, and the amount of sediment a stream will carry as alluvium in any given event, or climatic cycle. In general, because of structure and differential erodability of the units, the streams draining toward the Escalante from the slightly inclined units to the southwest (Kaparowits Plateau) will be longer, have greater drainage basin areas, carry higher discharges, and transport more sediment due to the less resistant geologic units exposed in this area. Streams draining from the northeast (Waterpocket Fold - west flank) will be shorter due to the nature of the fold, have much less drainage basin area, usually be box canyons, carry lower discharge, and therefore transport less discharge and sediment load.

As a conclusion, based on these generalities, one could expect a greater frequency of high discharge events (floods) from streams draining from the northeast. Such discharge events would tend to flush alluvial deposits from both types of canyons, but the chance of retaining alluvial remnants of older deposits would be greater in the drainages coming from the northeast of the river, due to smaller discharge magnitude.

To illustrate this point, I will arbitrarily pick Coyote Gulch and Stevens Canyon (USGS 1:250,000 topographic map: Escalante, Utah; Arizona 1956) which drain from opposite sides of the Escalante River, and join the Escalante at nearly the same spot. The drainage area of Stevens Canyon is approximately 6,734 ha, whereas the drainage area of Coyote Gulch is approximately 31,080 ha. Stevens is controlled by the axis of the Waterpocket Fold, while Coyote roughly parallels the Straight Cliffs (Kaparowits Plateau). Similarly, the length of Stevens Canyon is less than 19 km, while

Coyote Gulch is at least 32 km long. If I were to estimate success in locating old alluvial units in these canyons, I would select Stevens Canyon first, due to the factors noted above. Anomalies exist, such as alcoves, cut-off meanders, etc. which might also provide older alluvial units in the larger drainage, exceeding the <3,500 B.P.: 1,550 B.C. date for alluvium from Coyote Gulch, cited in the second paragraph of this section.

The fact that alluvial records of the late Pleistocene and Holocene remain in canyons of the Colorado Plateau has been well documented by Hack (1942), Agenbroad (1975), Hall (1974), Christenson et al. (1985), Karlstrom (1986), and others. Correlation of such alluvial units on an absolute chronologic scale has not been common. Karlstrom and others (1974) combined archaeology, tree ring chronology, and alluvial studies in the analysis of Black Mesa, Arizona, and the major drainages of that area. Karlstrom (1986) sees local, regional, and world-wide cyclicity in the paleoclimatic events, and the reflection of those events in the hydrogeologic and sedimentational histories of the alluvial records in the canyons and washes.

Bowns Canyon Alluvial Studies

Alluvium in canyons within the lands administered by the National Park Service held as much, or more, promise as did the drainages near Black Mesa. In particular, the alluvium stored in Bowns Canyon showed promise of a radiocarbon controlled sequence of cut and fill events containing sufficient organic horizons for a well-documented history. It had the added potential of allowing correlation of the alluvial record to that of Bechan Cave. Once the sequence in Bowns Canyon was understood, the radiocarbon-controlled alluvial events could be correlated to other canyons and their alluvial fill - in, and out, of the lands administered by the National Park Service.

Phase I results indicate at least four terraces preserved in Bowns Canyon (excluding To, the modern flood plain terrace). A series of radiocarbon dates from the three youngest terraces gives a preliminary sequence of events, as shown schematically in Figure 4. Based on the currently available dates from the Bowns Canyon alluvium, the oldest unit ($>11,000$ B.P.: $>9,050$ B.C.) in the canyon is terrace 4 (T_4). This older alluvium is preserved as remnants only beneath talus blocks, or as high terrace remnants against portions of the canyon wall. Repeated searching of the exposures fails to reveal material suitable for standard C-14 dates. Samples of a small bivalve, Pisidium, have been submitted from the upper portion of T_4 , for a tandem accelerator mass spectrometer (TAMS) radiocarbon date. Samples have also been collected for dating by thermoluminescent dating techniques. Results will not be in from either of these methods until 1986.

Terrace 4 filled the canyon floor to as much as 18 m (± 17 m) above the bedrock of the canyon floor. This aggradation interval has evidence of cyclic deposits indicative of high energy flow (sand) separated by low energy (silts and clays) deposits. Sometime after the aggradation of T_4 , events initiated degradation at $\pm 11,000$ B.P.: 9,050 B.C. causing most of the T_4 sediments to be removed from the canyon during an arroyo-cutting episode. Between 1,000 B.P.: 9,050 B.C. and 10,500: 8,550 B.C. an aggradation cycle began, filling the canyon with alluvium again (T_{3a}). Terrace 3 aggraded to, or nearly to, the level of T_4 and was then subjected to an erosion interval between 9,000 and 6,000 B.P.: 7,050 and 4,050 B.C. Aggradation of this arroyo system provided T_{3b} which filled to ± 15 m above the canyon floor and forms much of the alluvial terraces exposed in the canyon today (Figure 5). Between 6,000 and 5,400 B.P.: 4,050 and 3,450 B.C., T_3 was eroded to the bedrock of the canyon floor. By approximately 4,500 years ago, this episode reversed, causing

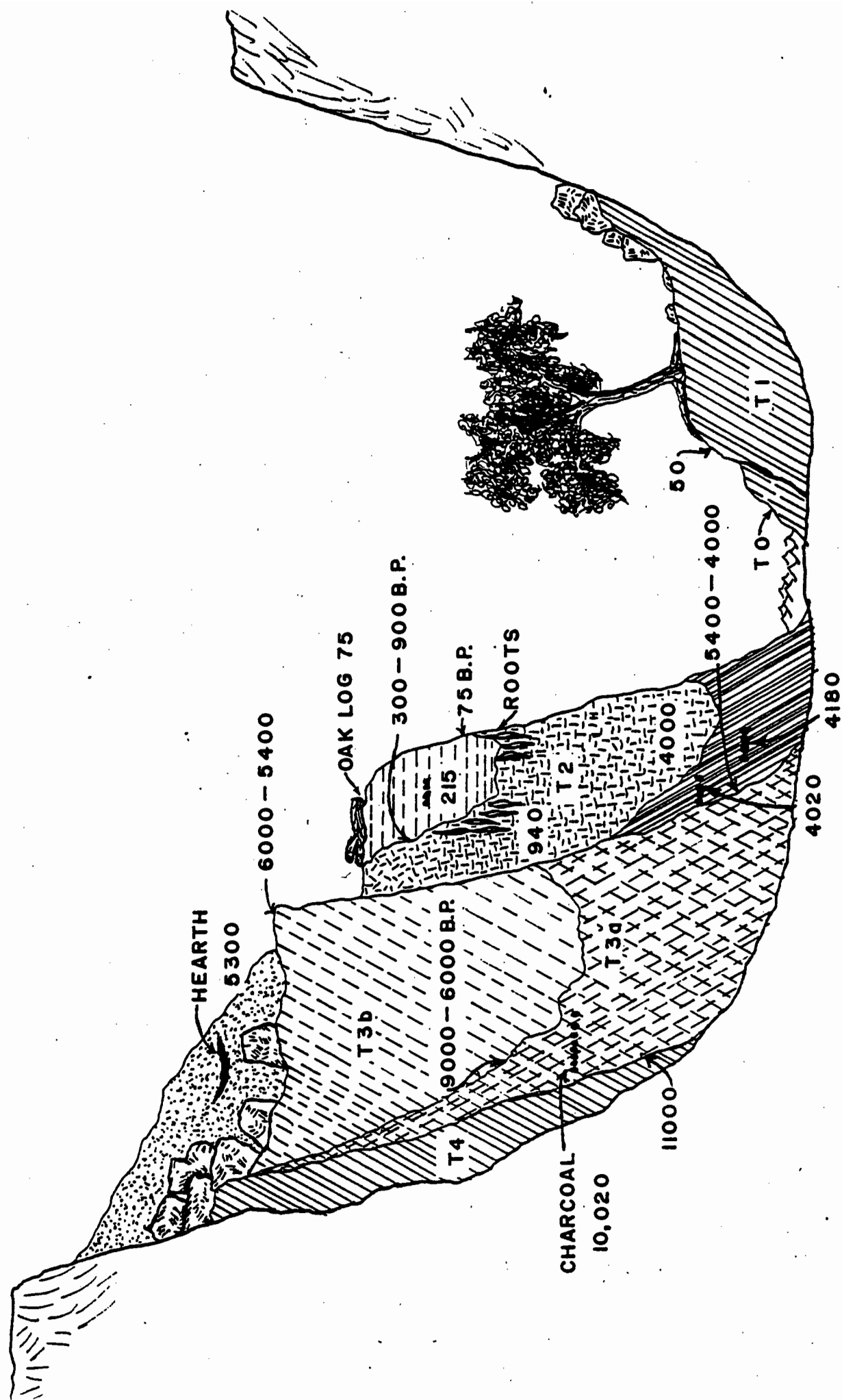


Figure 4. Schematic cross section of the Bowns Canyon alluvium.

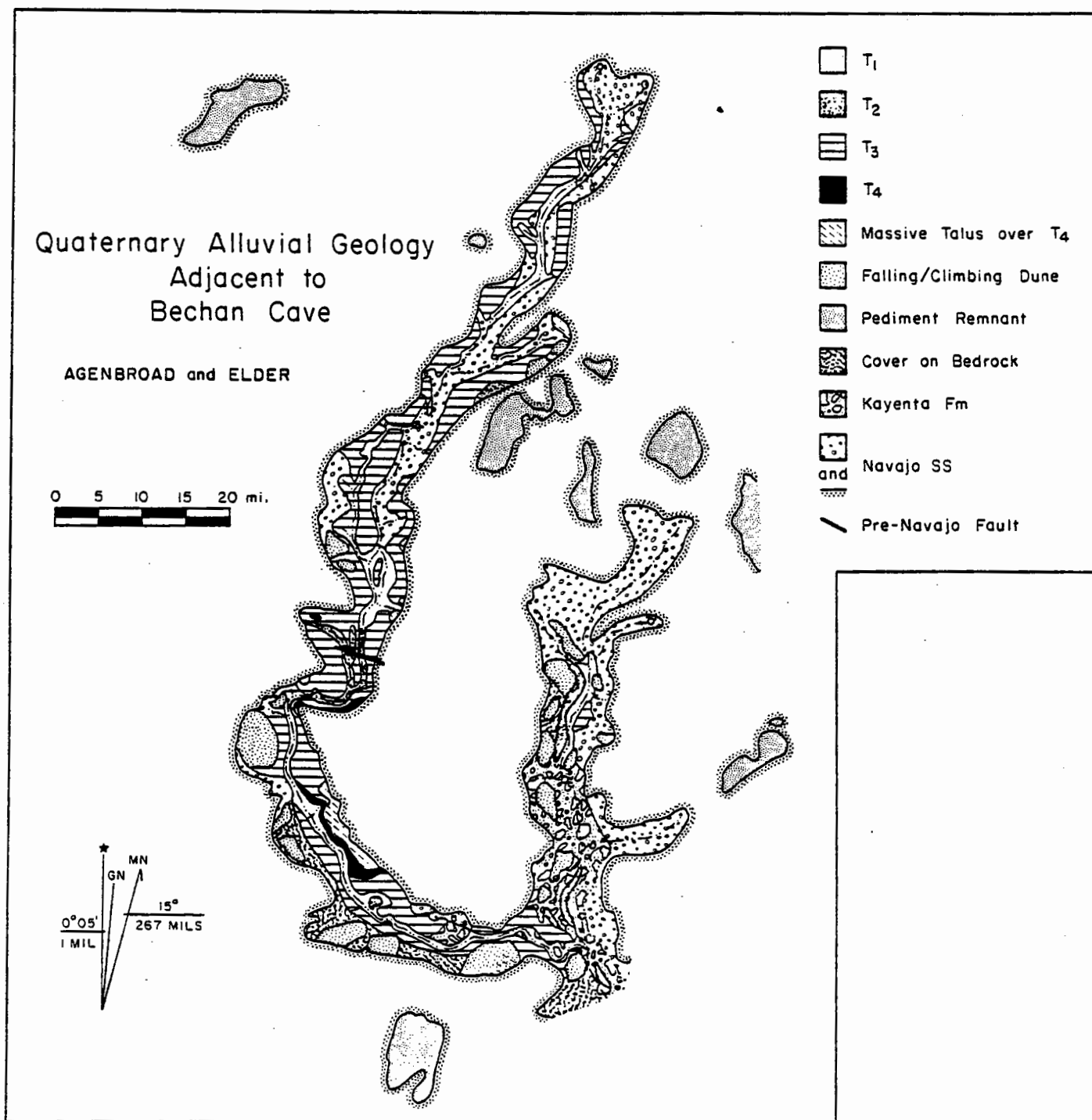


Figure 5. Geologic map of the alluvial units of Bowns and Bechan canyons.

deposition of T_2 . Terrace 2 appears to contain at least three units, T_{2a} of greater than 4,000 years antiquity, but younger than $\pm 5,500$ B.P.: 3,550 B.C. T_{2b} represents a cut and fill sequence dating less than 4,000 B.P.: 2,050 B.C., but older than 900 B.P.: A.D. 1,050. At approximately 900 B.P.: A.D. 1,050, T_{2b} was eroded, to be filled before 300 B.P.: A.D. 1,650. Based on C-14 dates available, T_2 and older units were subjected to erosion at 100-75 B.P.: A.D. 1,850-1,875, judging from the age of the oak forests that covered T_2 and T_3 surfaces prior to this time. As the erosional interval continued, the water table was lowered causing the death of valley floor forests. This erosion interval again cut to the bedrock floor of the canyon and began deposition of Terrace 1 between 100-50 B.P.: A.D. 1,850-1,900. Erosion of T_1 began at approximately 50 B.P.: A.D. 1,900 leaving low T_1 terraces and reaching the bedrock floor of the canyon, which comprises most of the stream floor at the present time.

Cultural occupation occurs in the canyon fill at 5,300 B.P.: 3,350 B.C. based on the dates submitted and returned from the laboratory at the time of compilation of this report. Dates still in process may extend the temporal range of cultural materials. Cultural dates in Bechan Cave appear at 7,795 B.P.: 5,845 B.C., indicating Archaic Culture peoples present in the canyon at dates earlier than presently reflected by alluvial dates from the canyon (Table 2).

Arguments could be forwarded that earlier cultural presence was contained in the alluvium, but was removed by subsequent cut and fill activity. It is here that the chronology of the fill of Bechan Cave becomes very important. These canyons were isolated from the Colorado River by a fall of ± 61 m from the pre-Lake Powell shoreline. The canyons are relatively small and isolated, with only one route of access (at the head of Bechan Canyon) for large animals

such as those documented in the late Pleistocene dung blanket from Bechan Cave (Davis et al. 1984; Mead et al. 1986). The impact of these statements is that the alluvial fill of the canyons immediately adjacent to the cave was pasturage for the large herbivores. Analysis of the dung (David et al. 1984) indicates a riparian forest of spruce and birch, with parklands of sagebrush and tall grasses. Dung elements also contain water plants, both bank-side and free-floating varieties that indicate standing bodies of water within the canyon, as well as marshy ground (cienega) conditions.

In considering cultural presence in the cave and canyons, an important tentative correlation can be made. Assuming Archaic people (and Formative groups) were experimenting with horticulture and became agriculture-dependent, the canyon floor would be attractive to such groups as potential garden/farm land only in periods of relative stability, i.e. quiescent, soil forming periods of time. Periods of either aggradation or degradation of the valley fill would be unsatisfactory to such subsistence techniques. Comparison of the dated events in Bechan Cave and the canyon alluvium tend to bear this out. Without the cave record, arguments could be made for prior presence having been removed by erosional episodes. With the cave record, however, the correlation of human absence from these canyons in times of aggradation and degradation is supported by the cave record.

Phase II investigations will continue in these alluvial units, allowing a refinement of the geochronology and the interpretation of this chronology and cultural activity. This tentative model appears to have some validity with the chronology of Holocene events in the Salt Creek drainage of Canyonlands National Park. Part of the objective of the Phase II field work is alluvial studies in alluvium contained in nearby and more distant canyons, as a test of this tentative correlation.

Chapter 4
SOIL ANALYSIS
Kirk Anderson

Purpose

The purpose of this chapter is threefold. It is organized primarily to provide a foundation for the understanding of the importance of soils and their usefulness in the interpretation of Quaternary alluvial deposits. Secondly, recent data concerning work done on the soils of the Bechan Canyon area will be presented. Finally, conclusions will be made concerning the types of soils found in the Bechan Canyon area and what these soils indicate with respect to the paleoenvironments in which they formed.

Introduction

The study area is located in canyonland topography in which steep bedrock cliffs enclose valleys containing alluvial terrace deposits. Preserved within these meters-thick alluvial terraces are numerous geosols. A geosol is "the fundamental and only unit in pedostratigraphic classification" and is defined as a buried soil that is mappable and laterally continuous (NASC 1983). By characterizing the nature of present soil-forming processes within the region, a "base line" of soil formation is established. Then by classifying the geosols into various soil orders, which are indicative of their climates of origin, it becomes possible to compare the different types of soils and say something about paleoenvironmental conditions of formation.

There are five soil-forming factors which are fundamental with respect to the genesis of soils. These factors are 1) climate, 2) topography, 3) parent material, 4) vegetation, and 5) time (Jenny 1983).

At present, the area receives less than 10" of rainfall per year. The mean July temperature is 85°F and the mean January temperature is 35°F (Van

Otten 1981). The topography of each terrace is nearly flat topped with a maximum slope of 2 degrees in the downstream direction.

The parent material consists of very fine- to fine-grained quartz sand inherited from the Navajo Sandstone Formation. This sand is extremely well sorted and frosted due to the fact that the Navajo Sandstone is an extensive eolian deposit of Jurassic age. Another potential source for the parent material of the older soils is the Kayenta Formation. The Kayenta Formation is a near-shore marine deposit of Jurassic age characterized by sand, silt, and clay sized particles of both marine and non-marine deposition which has been subjected to extreme subaerial weathering. The subaerial weathering gives this formation a deep red color which, when combined with the high amounts of clay, complicates the interpretation of some of the geosols in the area. That is, if the parent material cannot be identified, it becomes difficult to distinguish pedologic processes from geologic processes.

The vegetation in the area occurs in two major habitats; riparian and eolian dune. In the riparian zone, the vegetation is one of willows, cottonwoods, hemlock and other plants which need an abundance of water and therefore live at streamside. The eolian dune habitat consists of xerophytic organisms such as sage, cactus, saltbush and agave. Soils which are presently developing in these varied habitats will have diverse characteristics based upon the different types of vegetation and different moisture regimes.

By defining the present pedogenic processes on the basis of climate, topography, parent material and vegetation, it will be possible to analyze the pedologic properties of the geosols and arrive at some conclusions concerning the climates under which they formed.

Discussion

The pioneering works of Chamberlain and Leverett in the late eighteenth century laid the foundation for unraveling the glacial history of the midwestern U.S. Since that time soils have been used to subdivide the major and minor glacial events (Evenson 1976; Dreimanas 1974; Johnson 1976). Soils have also been used to estimate the climates of interglacial times (Ruhe 1974). Classical studies in the Rockies have identified various neoglacial events on the basis of the degree of soil development on different moraines (Richmond 1962; Birkeland 1984). Attempts have also been made in desert regions to define soil formation in arid and semi-arid landscapes (Gile 1966, 1970, 1977; Gile and Grossman 1968; Birkeland and Shroba 1974; Boul 1965).

Geosols are useful to the Quaternary scientist in three general ways. First, geosols can be used as relative dating horizons in which it is assumed that the better developed the geosol is (based on pedogenic properties) the longer it has been (or was) exposed to the weathering environment. One can then construct a chronosequence in which four of the five soil-forming factors are held constant and the fifth factor, time, is varied. In this way, soils can be compared with one another as to the extent of their development and placed into a relative age sequence.

The second use of geosols is in constructing a chronostratigraphic sequence in which "absolute" dates are applied to the soils within the stratigraphic complex, usually by using C-14. Once a chronostratigraphic sequence has been recognized, it can be used to correlate other sections of similar morphostratigraphic type and pedologic and/or geologic characteristics. Two geographically separate units cannot necessarily be associated solely on the basis of similar characteristics and stratigraphic position. In order to avoid any doubts concerning the ages of apparently

similar units, each stratigraphic section should be dated so that various chronostratigraphic sequences can be compared by "absolutely" dated events.

The third use of geosols is their importance as a source of proxy data for the interpretation of paleoclimates. It is assumed that soils develop under specific climatic conditions and that these conditions led to the formation of soils with uniquely characteristic properties. To make this point quite clear, one must only think of the differences between the Oxisols of the tropical regions and the Entisols of the arctic climatic zone. It becomes possible then to characterize soils on the basis of their properties and to classify them into one of the ten soil orders (Soil Survey Staff 1983). Soils can then be identified as to suborder and great group due to diagnostic horizons and climates of formation, respectively.

Important Soil Properties

A soil profile is divided into four soil units which are designated by the capital letters, O, A, B, C, R. The "O" horizon is the organic layer on the land's surface composed entirely of vegetative litter. The "A" horizon is the organic/mineral horizon which can be several centimeters thick, dark brown in color, and consist of less than 15% organic matter and more than 85% mineral matter. There may be several distinct horizons below the A horizon which will have a "B" designation and a modifying subscript depending upon mineral content and/or clay accumulation. As an example, the B_t horizon indicates a B horizon with an accumulation of transported clay. The "C" horizon is the unaltered parent material. In the case of the Bechan Canyon soils, the parent material is almost entirely very fine sandstone from the Navajo Sandstone. The "R" unit is the designation for bedrock (i.e. Navajo Sandstone).

Work completed in the field to date consists of detailed mapping of the five alluvial terraces, concentrated at the confluence of the two creeks in the vicinity of Bechan Canyon (Figure 6). The morphologically different terraces were identified and key locations were chosen that best represent the soil development and their relationship with one another within the alluvial terrace stratigraphic context. Eight vertical sections were measured and soils were characterized according to the specifications of the Soil Survey manual. The results of these measured sections are seen in Appendix I. Each characteristic of the terrace profile identifies certain features of each horizon which distinguishes one terrace unit from another. In this manner, A, B, and C horizons can be identified according to certain criteria and categorized for use as stratigraphic markers and/or environmental indicators.

Several cross sections were also sketched in order to illustrate the correlations among and between terraces of varying geographic locations within the Bechan Canyon Area (Figures 7 to 11). The cross sections provide a quick reference for the number, magnitude, and age of depositional, erosional, and soil-forming events.

Ninety-eight soil horizons were described with 80 samples collected from eight soil profiles. Samples were analyzed in the laboratory to determine: 1) particle size, 2) percent CaCO_3 , 3) percent organic matter, and 4) pH. The results of the laboratory analysis are illustrated in Appendix II.

Particle size analysis is used to interpret hydrologic regimes of the parent material during deposition. It can also be used to indicate translocation or accumulation of clays during pedogenic processes. Within the enclosed canyons of the study area, there is basically a single provenience for the parent material; the Navajo Sandstone which consists of predominantly very fine quartz sandstone. Since the Navajo Sandstone is of eolian origin, the

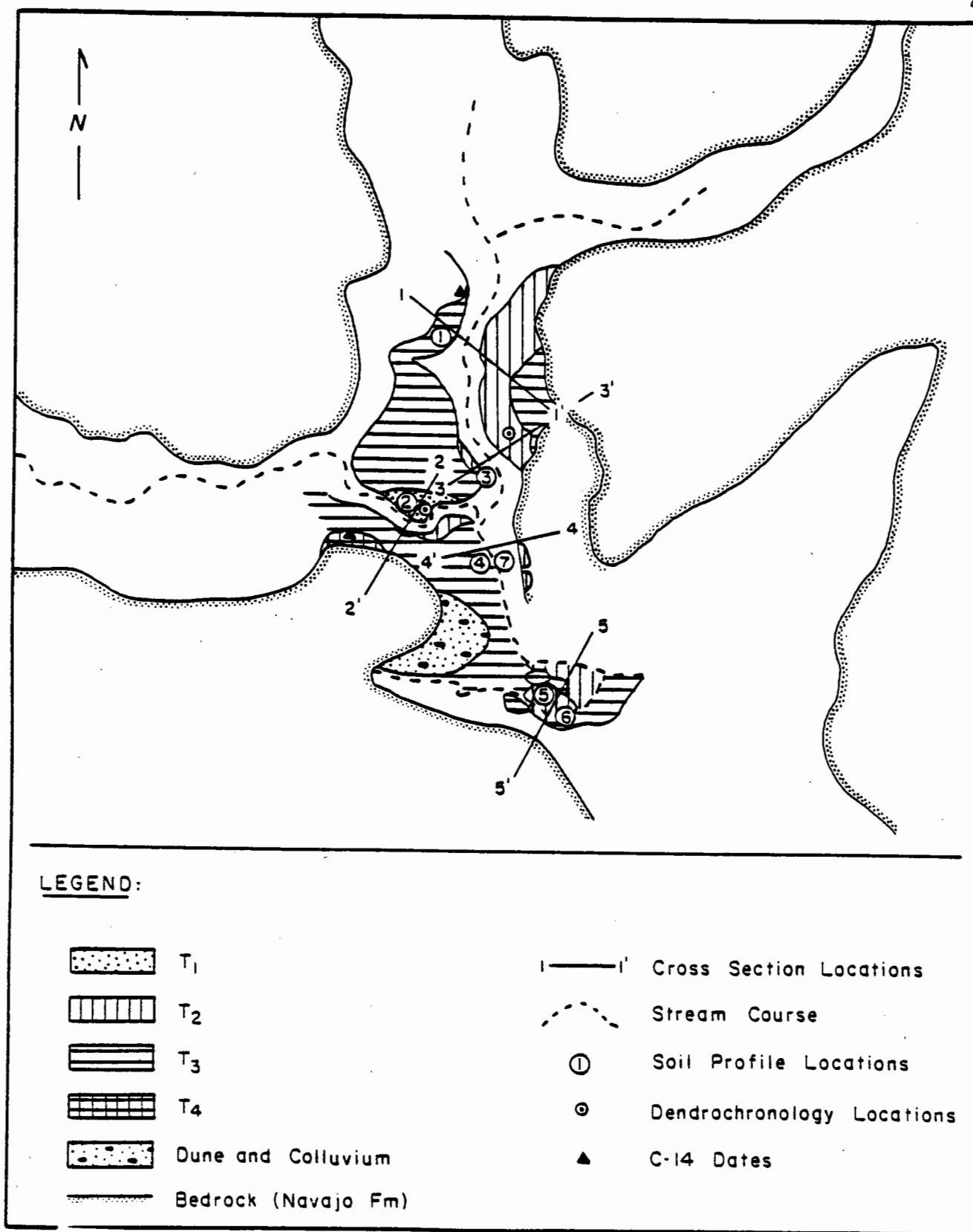


Figure 6. Location map for soil sections.

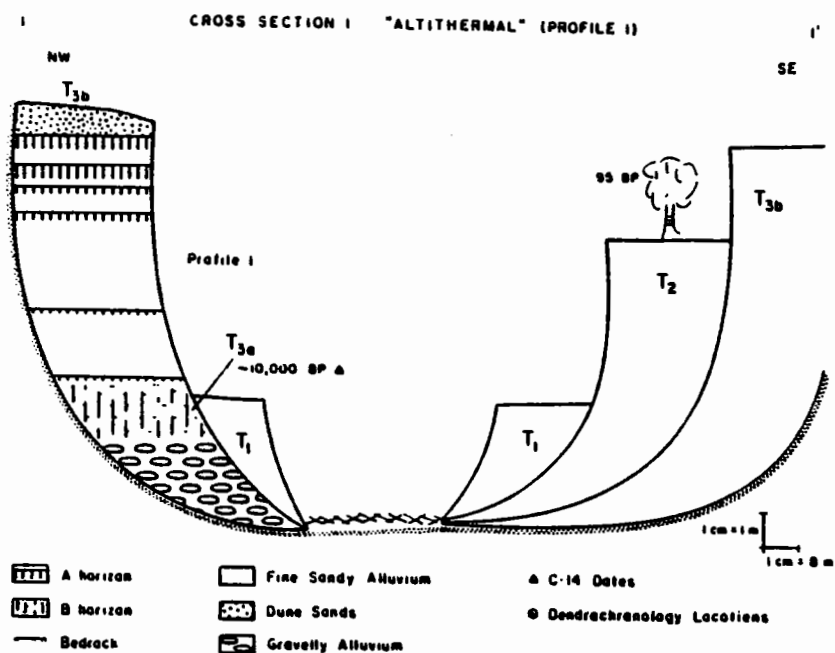


Figure 7. Soil profile 1; the B horizon possibly indicates the "Altithermal" soil.

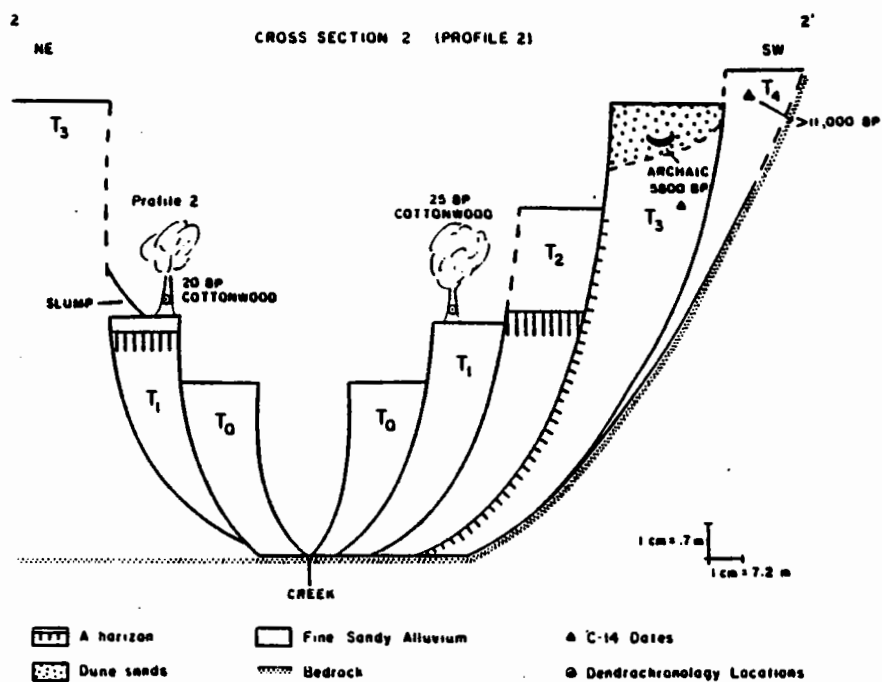


Figure 8. Soil profile 2 with dendrochronologic and carbon-14 dates.

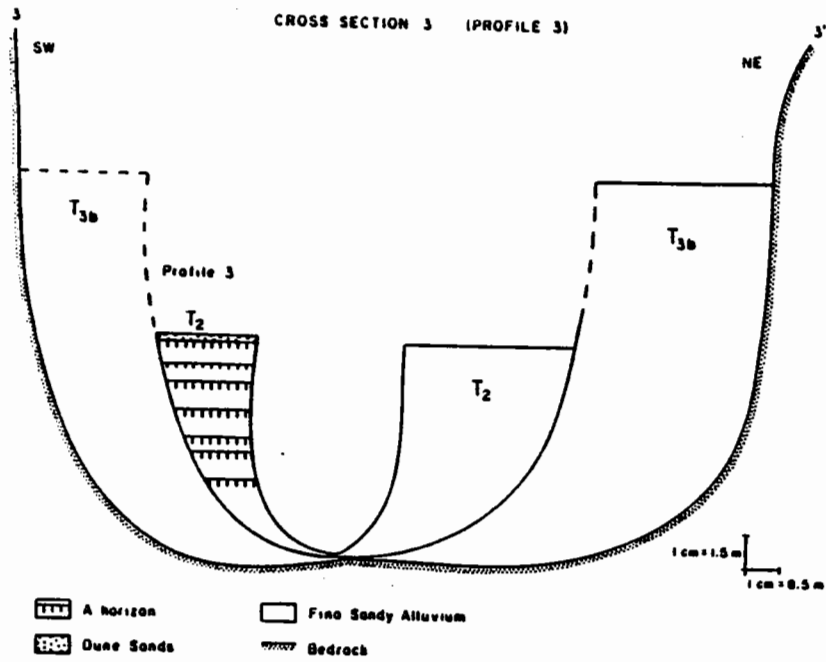


Figure 9. Soil profile 3.

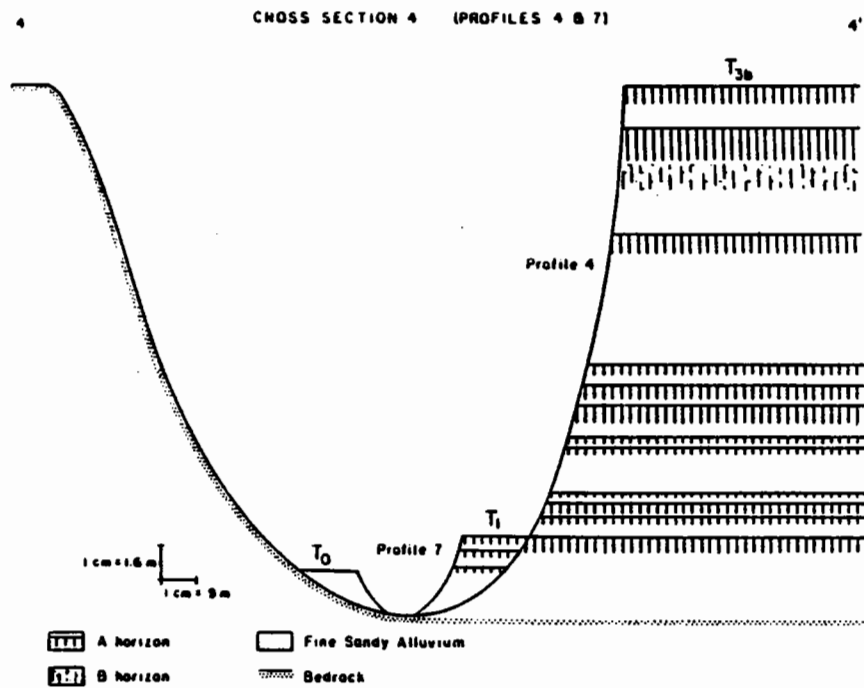


Figure 10. Soil profile 4.

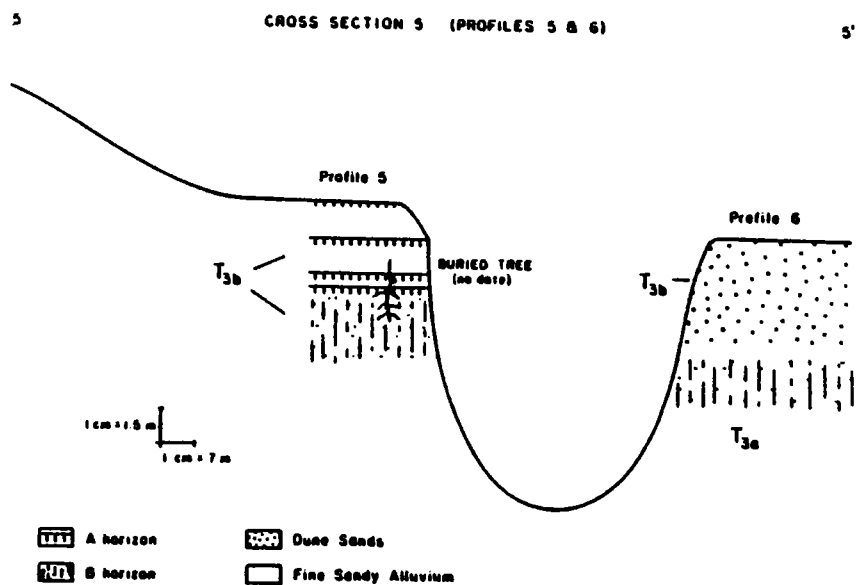


Figure 11. Soil profile 5.

sand grains are particularly well sorted and thereby provide a very uniform soil parent material. The rather high percentages of clay seen in the laboratory data may indicate the presence of wind transported clays into the depositional environment. This is the likely origin of clays in the younger geosols, whereas the older geosols containing the thicker, more highly developed horizons may contain high clay percentages derived from another source area (Kayenta Formation), or may be accumulated through pedogenic processes.

The first pedogenic process involves the translocation of clays from the surface (A) horizon into the B horizon. Once a relatively high percentage of clay accumulation in the B horizon has been reached, the second pedologic process takes place; the production of clays within the B horizon. Since it takes some time for the translocation and production of clays to occur, it is assumed that the geosols with the higher percentages of pedogenically derived clays are the oldest (Birkeland 1984). More laboratory data must be obtained in order to distinguish primary from secondary clays.

In areas more humid than the area of study, CaCO_3 percentages can be very high in the lower horizons. The process requires the continuous infiltration of water which dissolves the CaCO_3 from the upper soil horizons and deposits it in the lower horizons, where they accumulate into white bands and nodules. Desert sands, at the other end of the moisture spectrum, can form a near surface layer of cemented CaCO_3 due to the high rates of evaporation of the water within the soil. As the water travels up through the profile, it brings with it dissolved CaCO_3 which precipitates onto the surface of rocks and other soil particles upon evaporation of the water. This is how caliche is formed (Gile 1966). Neither of these processes is evident in the soils of Bechan Canyon area. What seems to be accounting for the high percentages of

CaCO_3 (4% is rather high), is the result of wind transported particles of CaCO_3 into the depositional environment. One other source for the CaCO_3 comes from the Navajo Sandstone directly. Though it is composed of 90% silica, the Navajo Sandstone still contains a large quantity of CaCO_3 as a cementing agent for the silica sands. The CaCO_3 is transported downslope by rainwater and deposited on, and incorporated into, the alluvial terraces.

The acidity or alkalinity of a soil can be important in differentiating A, B, and C horizons. In general, the pH should increase with depth in the soil profile. The A horizon has more organic matter than the lower horizons, and therefore more organic acids and a lower pH. Horizons B and C generally have no organic acids but have concentrations of clays and basic cations which tend to increase the pH. In very old soils with high concentrations of CaCO_3 , the pH will be greater than 8.3. Again, the rather high pHs of some of the horizons studied is due to primary (and secondary) deposition of CaCO_3 and probably not to the pedogenic processes.

The percentage of organic matter is a direct measurement of the amount of organic material present in the soil horizons. This is an important determinant in whether a horizon is A, B, or C, in that the definition for horizon differentiation incorporates relative amounts of organic matter as diagnostic criteria. The method used to determine percent organic matter is a direct burn method (loss on ignition) in which the weight of the pre-burned soil sample is compared with the burned weight. The difference in weights is a rough measure of the amount of organic matter in the soil. As can be seen in the laboratory data sheets, only two profiles were analyzed for organic matter present--Profiles 5 and 6. The next phase in organic matter determination is to apply another, more quantitative method and compare the results. If the results are within an order of magnitude variant, the less

costly and less time consuming loss on ignition method will be used for the rest of the samples. As yet, no conclusions have been drawn from the organic matter data. It must be noted, however, that determination of the occurrence and amounts of organic matter is critical to the interpretation of certain possibly anomalous dark horizons which are possibly due to the presence of manganese oxides and not to high percentages of organic matter. Manganese oxide is a metallic oxide which can occur in dark horizons by two methods. The first method is due to primary deposition of MnO nodules from some as yet unidentified source area. The second method relates the occurrence of MnO to a previous high water table. The process is somewhat complicated, but basically provides for the precipitation of MnO out of the groundwater into discrete bands which represent high water tables on a localized level or of the presence of springs which were previously active but are presently inactive. Analysis for metallic constituents must be performed before this problem can be resolved.

Paleoenvironmental Implications of the Bechan Area Geosols

Five alluvial terrace levels have been identified on the basis of morphostratigraphic characteristics; terrace height above stream level, inset relations, and geosols. Two soil orders are present in these canyons, each representing different climates of formation; Aridisols and Entisols. Aridisols are soils which developed or are developing in semi-arid to arid conditions. They usually have a calcareous horizon of high CaCO_3 concentration, and argillic or cambic B horizon. As it appears, the older geosols of Bechan Canyon area can be subdivided into Haplargids and Camborthids, of probable "Altithermal" age or greater.

Aridisols - Haplargids
Camborthids
Entisols - Fluvent
Luvic
subarid

aridisols → altithermal age or greater.

The altithermal is a period of time in which the climate was warmer and drier than the present. The term altithermal was proposed by Antevs to represent a period of time, about 4000 to 7500 years ago, in which worldwide warm/dry conditions occurred and are documented from northern Europe, Alaska and the southwestern U.S. If indeed the geosols of Bechan area are of altithermal age and origin, it would be possible to correlate these geosols with paleoclimatic conditions on a regional and interregional scale (Antevs 1948).

= fluvents?
Entisols are incipient soils with a simple A/C horizonation. They too generally occur in arid to semi-arid regions or along the floodplains of laterally and vertically accreting streams. The process involves the repeated burial of developing A horizons. Another factor limiting the development of Entisols in the Bechan region is the uniformity of the quartz parent material. It is very difficult to weather pure quartz into clays in order to establish a B horizon. The entisols are subdivided into Quartzic psamments and ustifluvents, two great groups which indicate amount of quartz in the parent material and moisture regime, respectively. More will be discussed concerning these great groups in later portions of this section.

The highest terrace, denoted T4, is the oldest and least known, dating greater than 10,000 years B.P. (see Figure 4; Agenbroad, personal communication). No geosols have been identified in this terrace, though the possibility exists and is quite intriguing.

The next oldest terrace, denoted T3, has been C-14 dated to be at least 4,025 years old. The terrace height is 753 cm above stream level and in some sections contains as many as seventeen distinct fluventic geosols. This T3 terrace has been subdivided into T3a and T3b due to the fact that the T3a

contains the older Haplargids and Camborthid geosols, and the younger T3b contains only fluvents. The heights of the T3a and T3b are, however, equal.

Two soils have been identified as Haplargids, Soil 1 (Figure 6) and Soil 6 (Figure 6). These two geosols are very similar with regard to data obtained from laboratory analysis and field work. Their characteristics are summarized in Table 3. A Haplargid is an Aridisol with minimum development of an argillic horizon. An argillic horizon is defined by the presence of clay skins (clay coatings on peds or grains) which indicate a high percentage of clay. While there are no clay skins present in these Haplargids, they do fit the criteria for an argillic horizon in that they contain 1 to 2 times as much clay as the unaltered parent material (Birkeland 1984). Increases in clay percentages indicate an increase in the degree of weathering and therefore an increase in age. These Aridisols formed in arid to semi-arid conditions. Due to the thick red Bt horizons, it is postulated that the Haplargids represent periods of soil formation in which the climate was significantly warmer and drier than the period of time preceding and post-dating these soils (5,000 B.P.: 3,050 B.C.).

Soil 5 (Figure 6) is a Camborthid, a true aridisol with a cambic B horizon (Bw). This Cambic B is defined by a redder hue and a stronger chroma than the underlying horizons. While it contains a higher percentage of clays than the underlying horizons, the percentages are not high enough to be called a Haplargid. The laboratory and field data for Soil 5 is summarized in Table 3 and defined in detail in the soil description section under Soil 5. It is postulated that this soil represents either a period of weathering that was not as long as that of Soils 1 and 6, or not as extreme. Again, more laboratory data is necessary to evaluate this problem properly.

The Entisols of T3b and T2 are classified into two great groups; Ustifluvents and Quartzzi-psammments (Table 3). The Ustifluvents are those soils forming in an Ustic moisture regime on an accreting floodplain. An ustic moisture regime is one that is found in semi-arid climates.

These fluventic geosols do not develop further than an Entisol due to two factors. The first is the fact that the incipient A horizons are continuously buried by flooding events. These flooding events cover the A horizons with "fresh" sediment, thereby supplying new parent material. Nonflooding events allow for vegetation to reinhabit the area, die, and provide organic matter for the development of the next A horizon. In this manner the flooding events which bury old A horizons are followed by periods of soil formation. The T3 terrace contains many geosols formed in this way. Thus, the ustifluvent is an entisol which forms in the riparian habitat in which moisture and temperature conditions are intermediate between aridic and udic (Soil Survey Staff 1980).

The second factor restricting the development of higher order soils than Entisols (i.e. Inceptisols, Alfisols, etc.) is the nature of the parent material. The parent material in this area is nearly 100% quartz sand which is very resistant to chemical weathering and will not break down to form alumino-silicate clays. This greatly restricts the possibility for the formation of a B horizon. The modern soil profile is also characterized as a Ustifluvent, though some may well be classified as Aquents, in that they are almost always moist throughout the year, as is characteristic of a perennial riparian environment.

By characterizing the geosols of T3b and T2 as ustifluvents--as well as those of the modern soil profile, a correlation is made which indicates the possibility that paleoclimatic regimes of T3b and T2 time were similar with those of today. The dark, thin, often discontinuous bands with very fine

Table 3. Summary of the soils in the Bechan Canyon Area.

Classification	ΣO.M.	Texture	Structure	PH	Σ CaCo3	Horiz.	Σ clay	Color
Haplargid (Soil 1)	-	sandy loam	Mod.SBK	7.9	6.0	Bt1;Bt2	16	reddish yellow 5YR 6/6
Haplargid (Soil 6)	1.9	f.sandy loam	ABK-Prism	7.9	4.55	Bt1;Bt2	20	red 2.5 YR 6/6
Camborthid (Soil 5)	1.2	v.f.sand	Mod.SBK	8.3	2.2	Bw1	10	reddish yellow 5 YR 6/
Quartzipsamment	-	v.f.sand	f.-m. SBK	8.1	2.8	A (24 cm.) C (36 cm.)	10	strong brown 7.5 YR 4/6
Ustifluent (geosols of T3)	-	v.f.sand	f.-m. SBK	8.2	5.65	A (23 cm.) C (50 cm.)	11	A- st. brown C-red. yellow
Ustifluents (modern soil)	-	v.f.sand	f.-m. SBK	8.0	9	3(A/C) 58 cm.	9	A- brn. 7.5 YR 5/4 C- pale brown 10 YR 6/

sandy texture and poor structure of the T3 terrace are identical with those of the youngest, modern, terrace on which soils are presently forming. So that in general, a terrace sequence of repeated A/C horizons is considered to be representative of climatic conditions not unlike those of today.

Quartzic psamments are those entisols which are forming today in the dune habitat. Deposited by fluvial processes hundreds, or thousands of years ago, the sandy parent material for these soils prevents them from developing into soil orders higher than entisols. Rather thick, dark A horizons are, however, present (see Appendix I). Further laboratory data may subdivide these into Quartzic psamments (90% quartz sand) and Torri-psamments in which the same type of sandy soil is forming in a torric regime, that is, hot and dry throughout the entire year.

Summary

Five terraces have been identified in the Bechan Canyon area and are basically differentiated by geomorphologic characteristics. The T4 terrace is the highest and oldest terrace, located greater than 10 m above stream level and dating >11,000 years B.P.: 9,050 B.C. The T3 terrace has been differentiated into two separate depositional events, T3a and T3b. The T3a contains the best developed soils; Haplargids and Camborthids. T3b terraces are 4 to 8 m above present stream level and consist of interfingering alluvial, colluvial, and eolian deposits which are interstratified with fluventic geosols. T3b is the most extensive terrace in geographic extent and may be further subdivided into a greater number of units upon completion of more detailed fieldwork. The age of the T3b terrace is somewhat obscured due to incomplete radiocarbon dating, lack of dendrochronologic dating, and a complex stratigraphic sequence. The best determination at this time indicates that the T3a unit dates younger than 11,000 years B.P.: 9,050 B.C. and the T3b

unit dates older than 3,000 B.P.: 1,050 B.C., but may be as young as 800 B.P.: A.D. 1,150.

The T2 terrace ranges from 450 cm in height to 300 cm in height above present stream level. It dates younger than 4,000 B.P.: 2,050 B.C. and consists of interfingering eolian, alluvial, and colluvial material interstratified with poorly developed A/C soil horizons of fluventic origin.

The T1 terrace has cottonwood germination dates of between AD. 1950 and 1970, providing a minimum date for the deposition of this terrace. It is generally less than 2 m above stream level but may be as high as 3 m above the present stream level.

The T0 terrace, the modern floodplain, is less than 2.5 m above stream level and dates to the late 1970s. Interestingly enough, the degree of soil development and horizon characteristics of the modern terrace are essentially the same as those of the older terraces. A quick comparison of the field description of Profile 4 (T3b) and Profile 7 (T0) will illustrate this point. The dark organic rich A horizons thin laterally and grade rather abruptly into the parent material. Laboratory data indicates comparable amounts of CaCO_3 , percent organic matter, and pH. This leads one to conclude that the climate of deposition of terraces T0 through T3b were all rather similar in their hydrologic regimes, amounts of organic matter, and length of time for soil development.

Conclusion

The geosols of the Bechan Canyon area have undergone preliminary examination in order to understand their usefulness as stratigraphic markers, point boundaries, and paleoclimatic indicators. The Haplargid geosols in Profiles 1 and 6 have been used as stratigraphic marker horizons for correlation of T3a units (see cross sections, Profile 1 and Profile 6; also

see field and laboratory data for Profile 1 and Profile 6), as indicators of relative age and relative stratigraphic position. Unfortunately, all of the fluventic geosols in each terrace unit are too similar in their characteristics to be considered as good stratigraphic markers; they simply formed and were buried too quickly for distinctive soils to develop. Their uniformity in genesis and preservation is strongly suggestive, however, that the climates of deposition were quite similar to the climate of today in which nearly identical A/C soils are forming.

The characteristics of the "altithermal" soil, on the other hand, indicate a climate of extreme oxidation and relative hydrologic stability. The high amounts of clay, thick red B horizons, and high degree of oxidation suggest an ancient soil which formed under warmer and drier conditions, sometime during early to mid-Holocene.

The usefulness of soils as point boundaries in this area has not been fully realized in that more radiocarbon dates must be acquired to create a complete chronostratigraphic assemblage. The large numbers of buried soils and the amounts of organic matter provide a unique opportunity to establish chronotoxic uniformity in dating the erosional and depositional events.

cambric soils
(Distinction not clear in text.)

Chapter 5

ALLUVIAL HOLOCENE POLLEN AND PALEOECOLOGY OF BOWNS CANYON
GLEN CANYON NATIONAL RECREATION AREA, SOUTH CENTRAL UTAH

Richard Hevly and Scott Clay-Poole

Introduction

Reconstruction of Holocene (last 12,000 years) paleovegetation and paleoclimate have traditionally employed pollen derived from lacustrine sediments. However, due to a dearth of suitable lacustrine environments, palynologists of the American Southwest have resorted to the use of pollen derived from alluvial sediments (Martin 1963; Schoenwetter and Eddy 1964; Mehringer 1967; Hall 1977).

The pollen found within the alluvium of this canyon will help to document changing vegetation of the immediate and surrounding area, yielding data useful for the understanding of correlative geological phenomena. Use of alluvial pollen may also provide data on the wild and cultivated plants exploited by the prehistoric humans and herbivores occupying this canyon at various times in the past, provided that erosion has not removed this critical record.

Description of the Study Area

Climate. Bowns Canyon is located at an elevation of 1300 m on a desert plateau. Bowns has a dry climate, receiving less than 25 cm of precipitation during an average year. Much of this falls during the warm summer months when afternoon thunderstorms form occasionally over the strongly heated desert mesas. These local storms, which obtain most of their moisture from the Gulf of Mexico, are usually accompanied by brief, heavy rain showers, often preceded by strong gusty winds and blowing sand. In some years, late summer precipitation may be increased by a dissipating tropical disturbance moving

northward from the Gulf of California and the adjacent sections of the Pacific Ocean. These rare storms produce unusually heavy rains, which may persist for more than 24 hours.

Bowns normally receives very little precipitation in the fall, winter, and spring. Only occasionally does a storm from the Pacific Ocean release enough moisture to more than dampen the surface. Most of the winter and early spring storms that affect Bowns are dry, advancing from the north or northwest. They are often accompanied by strong winds.

Bowns Canyon normally has a mild to warm summer climate. Average daily temperatures from the middle of June until the end of August are in the mid-80s to lower 90s in the afternoons. Bowns Canyon has a fairly mild winter climate. Early morning temperatures may drop into the lower 20s with a quick rise in temperature to the 40s and 50s as the sun enters the canyon.

Temperatures into the 60s are not rare (Sellers and Hill 1974).

Canyon Vegetation. Within the Bowns-Bechan Canyon system are two major habitats, each with its own distinctive plant assemblage. The canyon bottom is dominated by cottonwood and willow with scattered cat-tail and sedge. The dune-influenced eroded alluvial terraces are occupied by single-seed juniper, hackberry and Gambel oak. For a detailed list of species of the area see Table 4.

Upland Vegetation on Navajo Sandstone. The upland vegetation is extremely sparse, dominated by shrubs such as Juniperus (juniper or cedar), Cercocarpus (mountain mahogany), Artemesia spp. (sagebrush), Chrysothamnus (rabbitbrush), Atriplex (saltbush), Coleogyne (blackbush) and extremely rare individuals of Pinus edulis (pinyon pine). It has been observed that a single individual of Ponderosa pine (perhaps relictual from a previously more extensive stand) has

Table 4
 PLANT LIST FOR BOWNS CANYON
 GLEN CANYON NATIONAL RECREATION AREA
 GARFIELD COUNTY, UTAH
 (Welsch, Martin and Davis 1984)

Family	Species Name	Common Name
ANCARDIACEAE (Sumac)	<i>Rhus radicans rydbergii</i>	Poison Ivy
	<i>Rhus trilobata</i>	Squawbush Sumac
	<i>Rhus trilobata simplicifolia</i>	Squawbush Sumac
APIACEAE (Carrot)	<i>Cymopterus fendleri</i>	
APOCYNACEAE (Dogbane)	<i>Amsonia eastwoodiana</i>	
	<i>Amsonia tomentosa</i>	
ASTERACEAE (Sunflower)	<i>Artemisia begelovii</i>	Sagebrush
	<i>Artemisia ludoviciana</i>	Wormwood
	<i>Baccharis glutinosa</i>	
	<i>Brickellia atractoyloides</i>	
	<i>Brickellia longifolia</i>	
	<i>Brickellia microphylla</i>	
	<i>Chaenactis stevioides</i>	
	<i>Chrysothamnus nauseosus</i>	Rabbitbrush
	<i>Chrysothamnus viscidiflorus</i>	Rabbitbrush
	<i>Cirsium calcareum</i>	Thistle
	<i>Cirsium rydbergii</i>	Thistle
	<i>Dyssodia pentachaeta</i>	
	<i>Erigeron divergens</i>	Fleabane
	<i>Erigeron utahensis</i>	Fleabane
	<i>Gutierrezia microcephalum</i>	Snakeweed

	<i>Gutierrezia sarothrae</i>	Snakeweed
	<i>Haplopappus gracillis</i>	
	<i>Heterotheca villosa</i>	
	<i>Hymenoxys acaulis</i>	
	<i>Leucelene ericoides</i>	
	<i>Machaeranthera canescens</i>	
	<i>Solidago sparsiflora</i>	Goldenrod
	<i>Taraxacum officinale</i>	Dandelion
	<i>Townsendia incana</i>	
	<i>Xylorhiza tortifolia</i>	
BERBERIDACEAE (Barberry)	<i>Mahonia repens</i>	Oregon grape
BORAGINACEAE (Borage)	<i>Cryptantha flava</i>	Cryptantha
	<i>Cryptantha micrantha</i>	Cryptantha
	<i>Cryptantha pterocarya</i>	
	<i>Tiquilia latior</i>	
BRASSICACEAE (Mustard)	<i>Dithyria wislizenii</i>	Spectacle pod
	<i>Lepidium montanum</i>	Peppergrass
	<i>Schoenocrambe linifolia</i>	
	<i>Stephanomeria tenuifolia</i>	
	<i>Streptanthelia longirostris</i>	
CACTACEAE (Cactus)	<i>Opuntia phaeacantha</i>	
	var. <i>major</i>	Prickly pear
	<i>Sclerocactus pubespinus</i>	
CARYOPHYLLACEAE (Pink)	<i>Arenaria eastwoodiae</i>	Sandwort
	<i>Silene antirrhina</i>	Catchfly
CHENOPODIACEAE (Chenopod)	<i>Atriplex canescens</i>	Saltbush
	<i>Grayia spinosa</i>	

COMMELINACEAE (Spiderwort)	<i>Tradescantia occidentalis</i>	Tradescantia
CUPRESSACEAE (Cedar)	<i>Juniperus osteosperma</i>	Juniper
CYPERACEAE (Sedge)	<i>Carex aurea</i>	Sedge
ELAEAGNACEAE (Russian olive)	<i>Shepherdia rotundifolia</i>	Buffaloberry
EPHEDRACEAE (Ephedra)	<i>Ephedra torryana</i>	Morman tea
	<i>Ephedra viridis</i>	Morman tea
EQUISETACEAE (Horsetail)	<i>Equisetum laevigatum</i>	Scouring rush
FABACEAE (Legume)	<i>Astragalus amphioxys</i>	Locoweed
	<i>Astragalus desperatus</i>	Locoweed
	<i>Dalea fremontii</i>	Indigo bush
FAGACEAE (Beech)	<i>Quercus gambelii</i>	Oak
	<i>Quercus turbinella</i>	Oak
GENTIANACEAE (Gentian)	<i>Swertia utahensis</i>	Swertia
HYDROPHYLLACEAE (Waterleaf)	<i>Phacelia ivesiana</i>	Phacelia
JUNCACEAE (Rush)	<i>Juncus balticus</i>	Rush
	<i>Juncus ensifolius</i>	Rush
	<i>Juncus tracyi</i>	Rush
LILIACEAE (Lily)	<i>Allium macropetalum</i>	Onion
	<i>Eremocrinum albomarginatum</i>	
	<i>Smilacina steliata</i>	
	<i>Yucca standleyi</i>	Yucca
	<i>Yucca toftiae</i>	Yucca
LOASACEAE (Stickleaf)	<i>Mentzelia cronquistii</i>	Stickleaf
MALVACEAE (Mallow)	<i>Sphaeraicea grossulariaefolia</i>	Globe mallow
NYCTAGINACEAE (4 o'clock)	<i>Abronia elliptica</i>	
	<i>Mirabilis forebelii</i>	4 o'clock
OLEACEAE (Olive)	<i>Fraxinis anomala</i>	Ash

ONAGRACEAE (Evening primrose)	<i>Oenothera caespitosa</i>	Evening primrose
	<i>Oenothera coronopifolia</i>	Evening primrose
ORCHIDACEAE (Orchid)	<i>Epipactis gigantea</i>	
PINACEAE (Pine)	<i>Pinus edulis</i>	Pinyon pine
PLANTAGINACEAE (Plantain)	<i>Plantago purshii</i>	Plantain
POACEAE (Grass)	<i>Aristida purpurea</i>	3-awn
	<i>Bromus tectorum</i>	Brome
	<i>Calamagrostis scopulorum</i>	
	<i>Distichlis stricta</i>	Orchard grass
	<i>Hilaria jamesii</i>	Hilari
	<i>Muhlenbergia</i> spp.	Muhli
	<i>Oryzopsis humenoides</i>	Indian rice grass
	<i>Panicum lepidulum</i>	Panic
	<i>Phragmites communis</i>	Reed grass
	<i>Poa fendleriana</i>	Poa
	<i>Schizachryrium scoparium</i>	
	<i>Sporobolus airoides</i>	Dropseed
	<i>Sporobolus contractus</i>	Dropseed
	<i>Stipa comata</i>	Needlegrass
	<i>Stipa speciosa</i>	Needlegrass
	<i>Vulpia octoflora</i>	Six-weeks fescue
POLEMONIACEAE (Phlox)	<i>Gilia aggregata</i>	Gilia
	<i>Gilia gunnisonii</i>	Gilia
	<i>Gilia leptomeria</i>	Gilia
POLYGONACEAE (Buckwheat)	<i>Eriogonum corymbosum</i>	Wild buckwheat
	<i>Eriogonum inflatum</i>	Wild buckwheat

POLYPODIACEAE (Fern)	<i>Adiantum capillus-veneris</i>	Maidenhair fern
	<i>Cystopteris fragilis</i>	
PRIMULACEAE (Primrose)	<i>Primula specuicola</i>	Primrose
RANUNCULACEAE (Buttercup)	<i>Clematis ligusticifolia</i>	Clematis
RHAMNACEAE (Buckhorn)	<i>Rhamnus betulifolia</i>	Buckthorn
ROSACEAE (Rose)	<i>Amelanchior utahensis</i>	Serviceberry
	<i>Coleogyne ramosissima</i>	Blackbrush
	<i>Cowania mexicana</i>	Cliff rose
	<i>Petrophyton caespitosum</i>	
SALICACEAE (Willow)	<i>Populus fremontii</i>	Cottonwood
	<i>Salix exigua</i>	Willow
SCROPHULARIACEAE (Figwort)	<i>Castilleja chromosa</i>	Indian paintbrush
	<i>Castilleja linarifolia</i>	Indian paintbrush
	<i>Mimulus eastwoodi</i>	Monkeyflower
	<i>Penstemon eatonii</i>	Penstemon
SOLANACEAE (Nightshade)	<i>Datura metaloides</i>	Datura
	<i>Nicotiana trigonophylla</i>	Tobacco
TAMARICACEAE (Salt Cedar)	<i>Tamarix ramosissima</i>	Salt Cedar
TYPHACEAE (Cat-Tail)	<i>Typha domingensis</i>	Cat-Tail
ULMACEAE (Elm)	<i>Celtis reticulata</i>	Hackberry
VITACEAE (Grape)	<i>Parthenocissus vitacea</i>	Virginia creeper

been seen during a helicopter flight over the area (pers. comm., Larry Agenbroad, Geology Dept., Northern Arizona University).

Topography and Geology. Bowns Canyon drains in a southerly direction into Lake Powell (Colorado River). The canyon itself leads up from Lake Powell for two miles and then forks; the left (west) fork becomes Bowns Canyon and terminates in one and a half miles, the right (east) fork becomes Bechan Canyon and terminates in three-quarters of a mile. Bowns Canyon is surrounded by Navajo and Kayenta sandstones through which it has cut to a depth of approximately 182 m. The dissected tableland within which the Bowns Canyon drainage is situated extends for many kilometers. On the horizon may be seen Navajo Mountain 40 km to the south, the Kaparowits Plateau 16 km to the west, and the Henry Mountains 56 km to the north.

Alluvial Stratigraphy. Alluvium is sediment deposited by water. During the Holocene there has been a sequence of canyon-filling and erosion (aggrading and degrading). This aggrading and degrading has occurred at least four times. The oldest of the local aggradations (with its subsequent degradation) is referred to as Terrace 4. The sequence continues with Terrace 3, Terrace 2, Terrace 1 and Terrace 0. Terrace 0 is the youngest and its lowest degradation point is usually the bedrock bottom of the canyon. Recently obtained radiometric dating indicates that Terrace 4 is older than 10,000 years B.P.: 8,050 B.C. Terrace 3 ranges between 10,000 to 6,000 B.P.: 8,050 to 4,050 B.C. and Terrace 2 ranges from 5,400 B.P.: 4,050 B.C. to 100 B.P.: A.D. 1,850. Terraces 0, 1 and 2 have not yet been sampled for pollen, but Terraces 3 and 4 should yield pollen coeval in time with Paleoindian and early archaic occupation.

The study site where the samples were taken is approximately one mile above the left fork of the canyon (Figure 5). Sediments within these profiles

↑ need more detail

are predominantly sand with thin laminae of silt and clay (Figures 12 and 13). Hanging onto the western-facing sandstone wall are the remains of Terrace 4 where samples from Profiles E and F were taken (Figures 14 and 15). Fossil freshwater clams were recovered from profile E. Profile E was sampled to a point where there was nothing but dune material and sandstone rock (possibly indicative of a major rockfall from the canyon walls). The difference in vertical drop between the end of the E profile and the beginning of the F profile is 17.45 m. The sediment underlying profile F is sand 10 m to the canyon bedrock. In the foreground of Terrace 4 is the younger Terrace 3 where Profiles A, B, C and D had been sampled. Freshwater snails associated with some of the clay laminae (Profiles A and D) are indicative of temporary ponding units. Horizontal tracing of the more distinctive sedimentary laminae permitted the reconstruction of a composite section actually sampled by means of four profiles reachable from the upper end of slump material partially obscuring the face of this exposure.

Methods

Seventy-seven sediment samples were collected from Terraces 3 and 4. These samples were obtained by working down from the top of the terrace and sampling the facies that would have the most potential for pollen preservation. During the sampling the facies were measured as to distance from the top of the terrace and from a freshly exposed (cleaned) surface. Generally if only one sample was taken, the sample was removed from the center of that section. If two samples were taken from a section, then the first sample was taken one-third down from the beginning of the section. Some sections were actually so thin that the entire section was removed, which were scraped clean of the overlying and the underlying sections, reducing

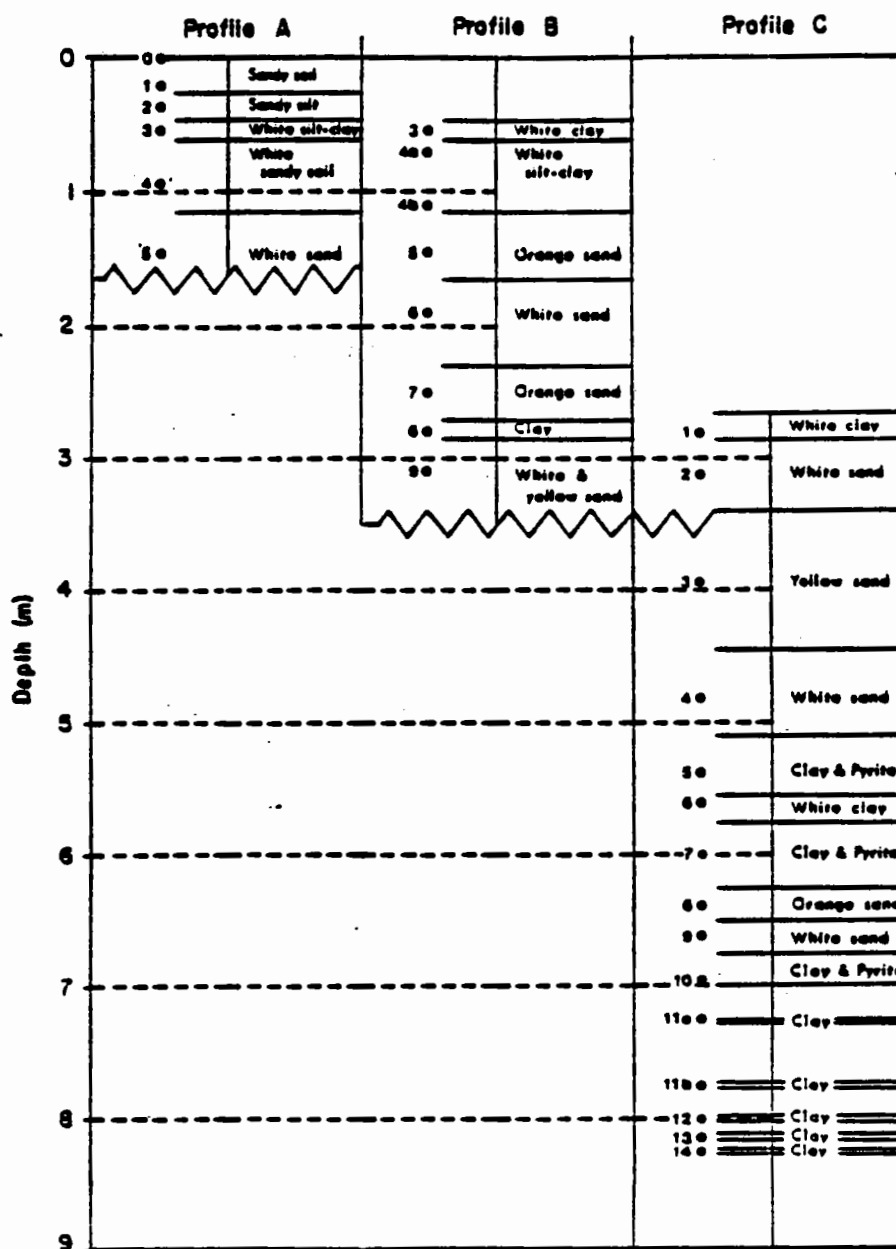


Figure 12. Profiles A, B and C of Terrace 3. The profiles are identified on the right column and the position of the appropriate sample is represented by a dot in the left column. Sampling was conducted in a vertical fashion until profile was obscured by dune material, then the sedimentary unit was traced to the right and sampling continued.

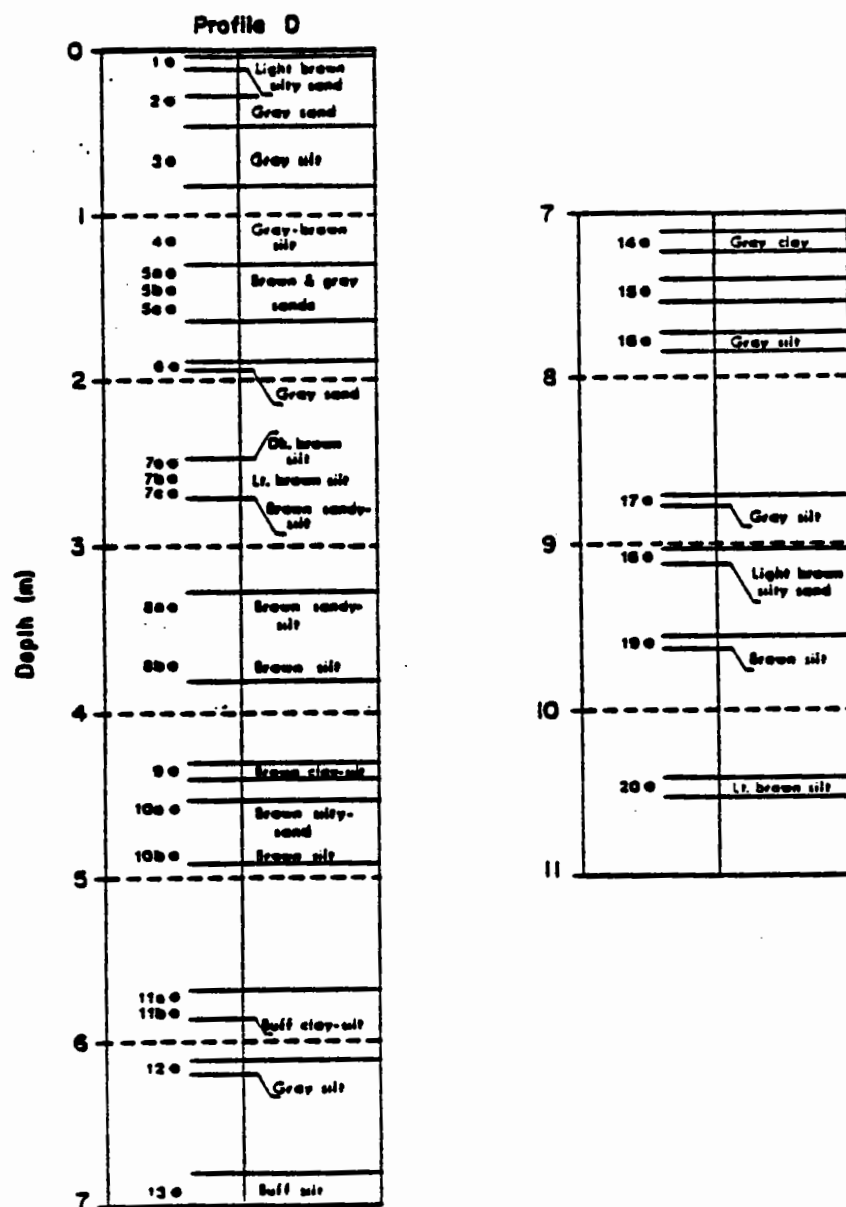


Figure 13. Profile D of Terrace 3. The profiles are identified on the right column of the profile and the position of the appropriate sample represented by a dot is located in the left column.

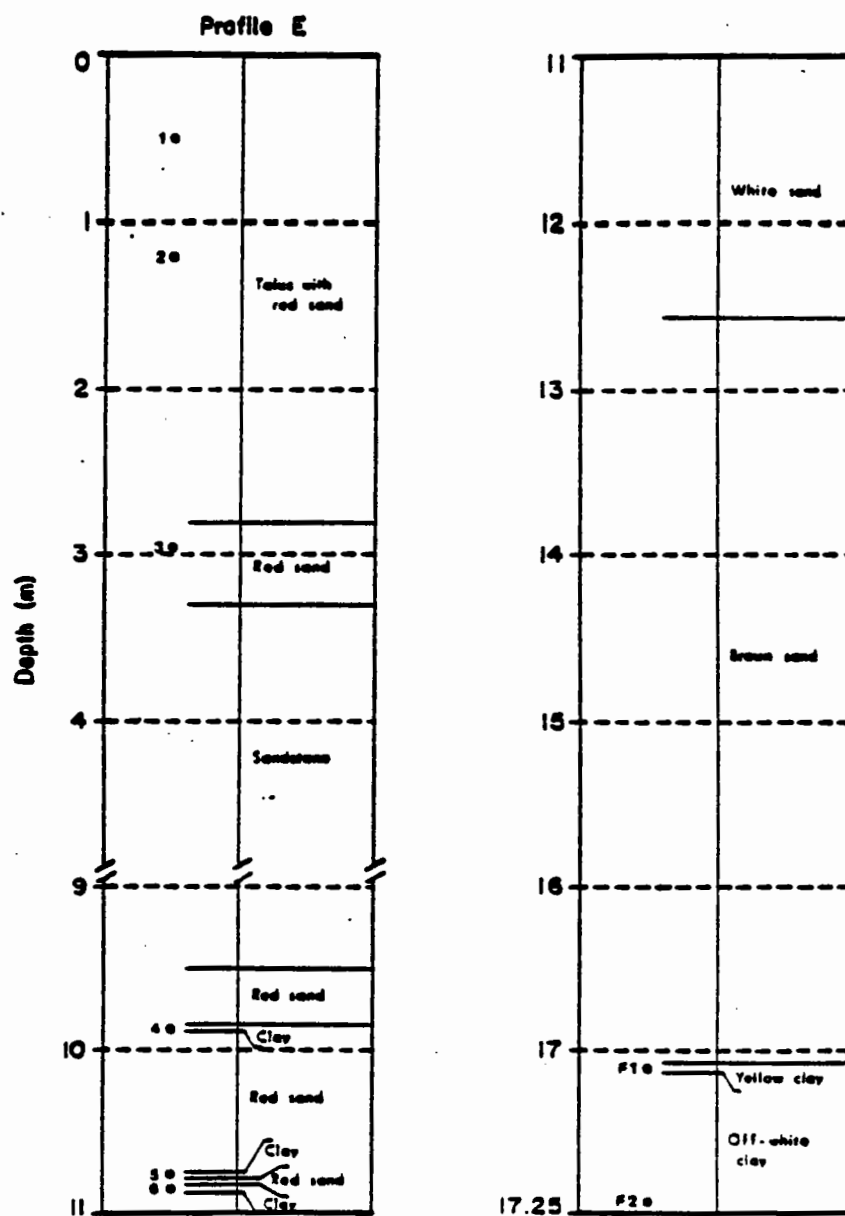


Figure 14. Profile E of Terrace 3. The profiles are identified on the right column of the profile and the position of the appropriate sample represented by a dot is located in the left column.

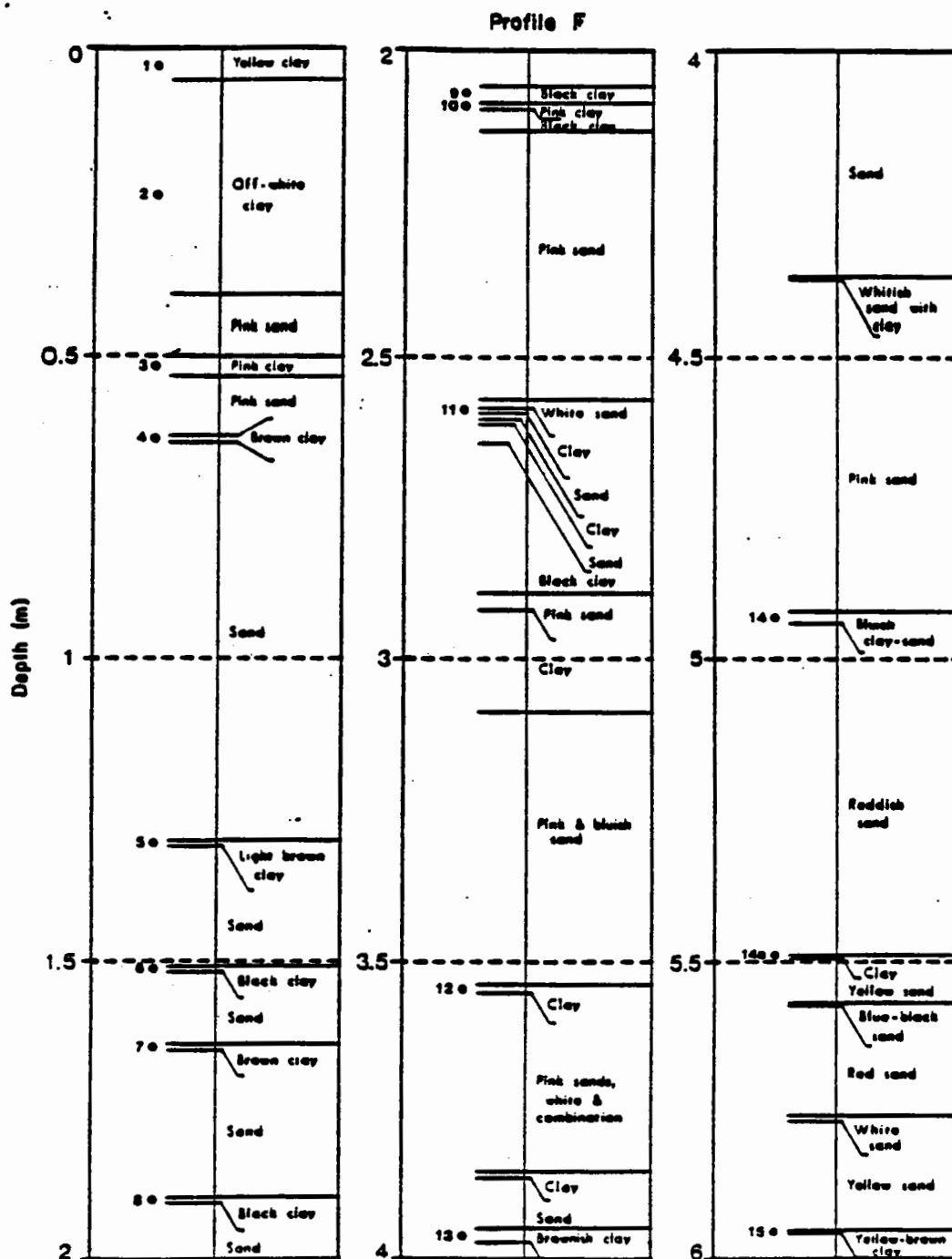


Figure 15. Profile F of Terrace 3. The profiles are identified on the right column of the profile and the position of the appropriate sample represented by a dot is located in the left column.

contamination. Figures 12 through 15 show where each of the samples were taken. Each of the samples were placed in plastic bags, identified, and recorded.

The extraction techniques developed for processing these samples were a combination of several methods. To overcome problems of highly dispersed and carbonate-bound pollen, 350 cc of sediment were mixed in 200 to 300 ml of distilled water, and concentrated hydrochloric acid was added and stirred until further reaction ceased. The acid treatment removed much of the carbonates, releasing any bound pollen (Anderson 1955). Separation of a pollen-enriched fine fraction from a coarse fraction containing mostly sand was obtained by first screening through #60 and #100 wire mesh. Then the suspension was permitted to stand 90 seconds prior to carefully decanting the aqueous fraction into four labeled, 50 ml Nalgene centrifuge tubes (Funkhauser and Evitt 1959). These four tubes were centrifuged and the concentrated sediments combined into one tube. The next step was the addition of 5% potassium hydroxide into the sample and heated in a boiling bath for 3-5 minutes for the removal of humic material. The next process was with the use of sodium pyrophosphate for compromising the ionic binding of any clay particles to the pollen (Bates, Coxon and Gibbard 1978). After water washing, silicates were removed by slowly adding and cautiously mixing 38% hydrofluoric acid with the sediments and permitting the mixture to stand overnight (Faegri and Iverson 1950). The following day the mixture was centrifuged, the acid decanted, and hot dilute hydrochloric acid used as a wash to remove any colloidal flocculate which may have formed. The next step was the use of glacial acetic acid to remove any water, thus decreasing any possibility of explosion with the acetolysis mixture. The acetolysis step (combining 9 parts acetic anhydride with 1 part concentrated sulphuric acid) removes cellulosic

materials (Faegri and Iverson 1950). Following this step is a washing with glacial acetic acid, then a final wash of water. The remaining acid resistant residue was then rinsed into labeled, 2 dram screw-top vials. A little water was added with up to 3 drops of 1% basic fuchsin included to stain the pollen. To check for possible chemical corrosion of pollen, the samples were spiked with modern exotic spores or pollen prior to extraction. No evidence of corrosion resulting from chemical treatment was observed.

Analysis. A single drop of pollen-enriched sediment was placed on a labeled microscope slide, and a drop of glycerine was added and both mixed well. The preparation was covered with a No. 0, 24 x 50 cover glass and examined with an Olympus binocular microscope having objective lenses of 10x, 43x, and 97x, and ocular lenses of 10x. The slides were scanned at 100 diameters to locate pollen, and identifications were made at 430x and 970x.

Pollen Counts. Pollen counts of at least 200 grains per sample were possible for seven of the samples in which pollen concentration and preservation allowed the preparation of countable slides. In all of the samples only 8 had counts over 100. Those samples having counts of 100 or more are listed in bold-face in the tables of Appendix III. Each identifiable whole pollen grain was identified and recorded on tabular sheets. Fragments of known pollen grain types were also included in the standard count. Broken Pinus grains, for example, were counted as one-third of a grain for each bladder and one-third for the body of the grain. At the end of each standard count all fractions were rounded off to the nearest whole number.

Pollen Types. The Asteraceae pollen in this report is divided into three major categories based upon their morphological distinction: 1) high-spine Tubuliflorae, 2) low-spine Tubuliflorae, and 3) Liguliflorae (Fenestrate). The two Tubuliflorae categories, high-spine and low-spine, are arbitrary

divisions of the subfamily Tubuliflorae. The high-spine group is generally insect or self-pollinated and their echinate pollen grains have spines greater than two microns in length (Martin 1963). The low-spine group, on the other hand, is often wind-pollinated, having spines less than two microns in length. Two representative genera of the low-spine group include ragweed (Ambrosia) and marsh-elder (Iva). Because of their scarcity, sagebrush (Artemesia) pollen was also lumped into this category. Two representative genera of the high-spine group include rabbit-brush (Chrysothamnus) and thistle (Cirsium). The Liguliflorae, having fenestrate pollen, are highly distinctive grains morphologically and are insect-pollinated. A representative genus of the Liguliflorae is dandelion (Taraxacum).

In 1963, the term "Cheno-Ams" for pollen of the chenopodiaceae, and the genus Amaranthus in the family Amaranthaceae was proposed (Martin 1963). These two taxa were combined into this single artificial group termed Cheno-Ams since their pollen grains are so morphologically similar that it is nearly impossible to distinguish one type from another.

The Ephedra pollen in the Southwest is generally divided into two groups: Ephedra torreyana and Ephedra nevadensis (Steeves and Barghoorn 1959). The Ephedra torreyana group is distinguished by its large number (ca 15) of unbranched straight furrows while the Ephedra nevadensis group tends to have fewer furrows (ca 6) with undulating ridges and a number of conspicuous hyaline strands intersecting the furrows at various points along the grain. In this report Ephedra nevadensis and Ephedra aspera are placed in the Ephedra nevadensis group.

Otherwise, identification of pollen employed standard keys and illustrations (Faegri and Iverson 1964; Kapp 1969; Moore and Webb 1978; Ogden et al. 1974; Wodehouse 1959) and personal reference slides produced from

herbarium sheets of identified specimens from the Deaver Herbarium, Department of Biological Sciences, Northern Arizona University.

Results

The quantitative recovery of the pollen from the alluvium is recorded in Figure 16. Each data point is the amount of pollen contained in two drops of acid-resistant residue from 350 cc of sediment samples.

Considering the total pollen count in Terrace 3, Profiles A and C are relatively high compared to Profile B. The same trend occurs in the D profile. The D profile is compared with profiles A, B, and C because of its identical placement in Terrace 3, but whose stratigraphy is distinct. Profile D was divided equally into three sections and named accordingly for comparative purposes (Profiles A, B and C / D_a, D_b and D_c). In Terrace 4 the general trend is a progressive reduction in total pollen from the E profile through Profile F.

Besides a stratigraphic distinction between Profiles C and D, there is a difference in the pollen quantities. Poaceae is much greater in Profile C than in D_c, and considering the Cheno-Ams, Profile C having an actual count of 511 (which is off the scale in the figure) has no comparison with the Cheno-Am count of D_c. Field observations indicated that the stratigraphy of Profiles A, B, and C is not traceable into Profile D and pollen evidence further indicates that the two are not equivalent. Radiometric dating will help resolve the stratigraphic relationship as to which of these two profiles is the younger or older.

The Terrace 4 counts have generally more pollen and the composition is more variable. There is significantly more Poaceae and Pinus ponderosa pollen with less Asteraceae and Cheno-Am pollen.

POLLEN QUANTITY

POLLEN QUANTITY

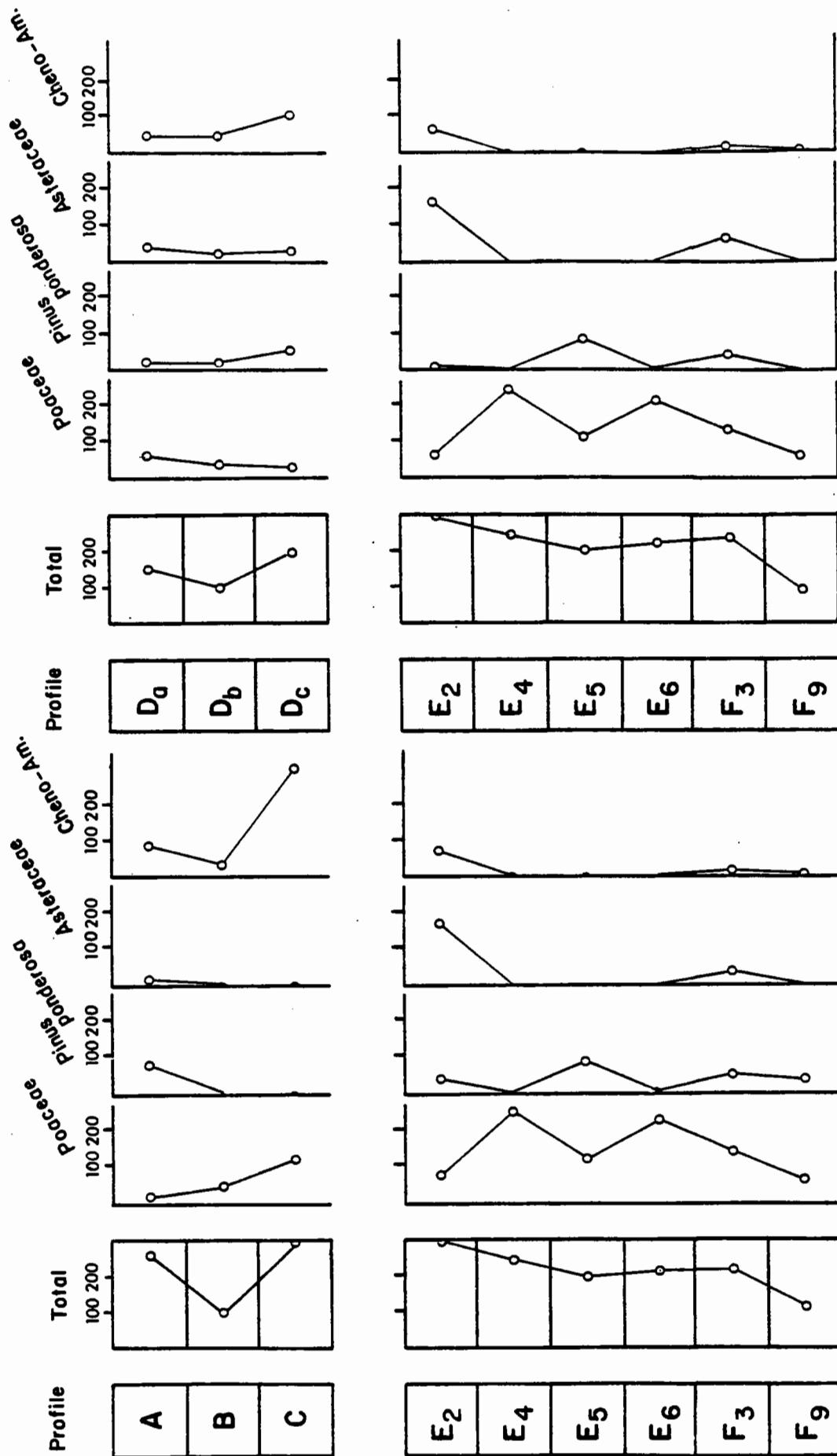


Figure 16. Amount of pollen represented in each profile. Profile D was divided into even thirds for comparative purposes to Profiles A, B and C as both are situated in the same position in Terrace 3. All of the profiles listed represent statistically relevant pollen counts that represent a continuum from either Profiles A-B-C or D or both. In this figure, the individual taxa within the *Asteraceae* have been combined forming one category, *Asteraceae*.

Discussion

Studies relating modern pollen rain with present vegetation communities are essential for the interpretation of fossil pollen assemblages. Statistical comparisons have shown vegetation percentages not to be equivalent with modern pollen percentages (Davis 1963; Janssen 1967), since taxa do not contribute equal amounts of pollen to the atmosphere and many species may be either over- or under-represented in the pollen rain. Most comparisons between pollen and vegetation rely on qualitative interpretations since the mechanisms for pollen production and deposition are not fully understood.

Studies done in the southwestern United States have compared surface pollen samples with modern vegetation data (Potter and Rowley 1960; Martin 1963; Hevly, Mehringer and Yocum 1963; Bent and Wright 1963; Maher 1963; Adam 1967; Mehringer 1967; and Hevly 1968). Surface soil samples have been commonly used as modern analogs for interpreting fossil alluvial pollen sequences (Martin 1963; Mehringer 1967). The comparison of modern surface soil samples and modern alluvial samples with the vegetation of Bowns Canyon demonstrates that there are differences in the pollen percentages represented by the modern alluvium and the modern soil samples.

Previous studies have shown that each of the major plant communities can be palynologically characterized. Bowns Canyon pollen has, as of yet, no reliable surface samples available. Surface samples contain much arboreal pollen, not reflective of modern vegetation and can be interpreted as ancient sediments exposed by erosion, or a reflection of long distance transported pollen (assuming dominance due to locally poor pollen production). The pollen of the arboreal plants that are currently present (oak, cottonwood, hackberry, willow and juniper) are simply not represented on the top of Terrace 3 where

one might expect them to be. None of the emergent aquatic species, e.g. Typha (cat-tail), Scirpus (rush), Carex (sedge), Eleocharis (spike-rush) and Juncus (rush) are represented at all by pollen, anywhere, yet are locally abundant today.

Sources of Pollen. The focus of alluvial studies has been to reconstruct the past vegetation and derive inferences of paleoclimates, but some concern has been expressed as to how the pollen got into the various deposition environments studied. Most pollen entering depositional environments of the American Southwest was initially dispersed from the producing plants by wind (Martin 1963) but some question still remains, particularly in alluvial sediments, as to whether such pollen is predominantly produced by local plants or was secondarily transported from upstream habitats to the downstream depositional site by water (Fell 1981; Solomon et al. 1982). Due to the limited topographic relief (elevation gradient is less than 305 m in all directions for several kilometers) and short length of the canyon, pollen should have been derived from local sources predominantly. There is no large headwater transport of sediments or pollen flowing into Bowns Canyon. Bowns Canyon is a box canyon with water percolating through the Navajo Sandstone and flowing out from the interface above the impervious Kayenta Sandstone into the canyon.

Several studies now demonstrate the idea that water transportation of pollen is responsible for the better part of its deposition in water-controlled environments. Cross et al. (1966) found, in a study in marine sediments in the Gulf of California, that water was a better dispersal agent than the wind; the highest pollen concentrations were found in the silty clays. Another study also showed that the more buoyant the pollen grain the further in distance it can be transported, there being a selective transport mechanism that kept the pollen in suspension until the water turbulence was

pour off

from upper area?

question?

low. Deposition occurred (there is a strong association that with the finer grained sediments settle the lighter, more buoyant pollen grains) (Traverse and Ginsburg 1966).

Brush and Brush (1972) did work on transport of pollen grains in water and established that the heavier, or more dense the pollen grain, the more quickly it settled. The water transport of pollen and its subsequent deposition in sediments has distinguished itself in the three types of sediment in our profiles: sand, silt and clay. Sand, silt and clay represent a progression in the velocity of water from relatively fast for sand to a virtual standstill situation for clay. Considering the rapid movement of water, lighter, more buoyant pollen grains will be carried further downstream, hindering deposition. Furthermore, the rapid movement of water, representing sand deposition, contributes to an abrading effect obliterating the grains. In all of the samples taken from sand units there were few to no pollen grains preserved. As water velocity slackens the deposition of pollen increases. For the most part this is true, but in many of the clay units there was little pollen. Some of these clay units were only millimeters in thickness, indicating a short depositional duration and perhaps the particular time the clay unit was being created did not synchronize with the time of airborne pollen-type plants being in flower. Some of the clay units were around for some period of time, yet with no pollen deposition, demonstrated by the fact that Pediastrum (a green alga indicative of still water) proliferated.

Radiometric dating of sediment, snails, charcoal, etc. bracketing Terrace 3 indicate that this unit dates between 11,000-6,000 B.P.: 9,050-4,050 B.C. Pollen dominated by NAP (non-arboreal pollen) as is characteristic of other pollen records (Hall 1977; Hevly and Karlstrom 1975; Maher 1972; Van Devender and Spaulding 1979; Wright et al. 1973) is not so here at this time period

just prior to or at the beginning of the mid post-Pleistocene Altithermal. Radiometric dating indicates Terrace 4 is older than 10,000 B.P.: 8,050 B.C. and is dominated by extraordinarily high proportions of grass pollen. This valley is known to have been occupied by herbivores, such as mammoth, during the late Pleistocene and the dung preserved in Bechan Cave is primarily composed of grass (Davis et al. 1984). The occurrence of the macroscopic plant remains of the mammoth and the pollen from Terrace 4 indicate a more mesic environment than today.

Conclusion

Deposition of T_4 occurred prior to 10,000 B.P.: 8,050 B.C. according to available C-14 dates. Clay units are common and contain much pollen, particularly pine. The highest pine proportions are plotted to conform with late Pleistocene high proportions of PAP (Picea - spruce, Abies - fir and Pseudotsuga - Douglas fir) at higher elevations elsewhere on the Plateau. The alluvium of T_4 is the sediment on which mammoth and other herbivores, recovered from Bechan Cave, could have walked. The environment which they occupied was one whose pollen record is dominated by pollen of the Poaceae (grass), Chenopodiaceae (goosefoot), Asteraceae (sunflower) and Pinaceae (pine) families. These types were also predominant in mammoth dung levels of Bechan Cave (Davis et al. 1984).

Abrupt changes of pollen composition (increased NAP) near the top of T_4 were quickly followed by erosion which in turn was followed by deposition of T_3 alluvium. Initial T_3 deposition began about 11,000 B.P.: 10,090 B.C. and consisted primarily of pollen-poor sands. This deposition was interrupted on more than one occasion by erosion, as observed in the Bowns Canyon profile, Figure 12. A T_3 unit believed to predate 6,000 B.P.: 4,050 B.C. was sampled intensively due to the presence of dark bands (initially believed to represent

organic matter) and also the occurrences of silts, a few of which contained snails. This terrace was divided into four sections: A, B, C, and D. Samples within each section contained very little pollen. Pollen in each section was pooled to approximate a statistically reliable 200 pollen grain count. The pooled samples of Section D contained adequate pollen for subsequent division into upper and lower subsections. Following calculation of pollen proportions of the pooled data, the data were diagrammed to correspond to general trends shown by previous studies elsewhere on the Plateau--for the period 8,000-6,000 B.P.: 6,050-4,050 B.C. and pre-10,000 B.P.: 8,050 B.C. The environment which occurred in the upper Bowns Canyon during the deposition of T_3 was one in which tree pollen was generally much less prevalent than in T_4 and non-arboreal pollen was much more abundant suggesting a more open and more xeric environment than found in T_4 . However, the silty members, where snails also occurred, contain a pollen record with more abundant AP suggesting brief periods of amelioration.

Trends of Bowns Canyon pollen data (both T_3 and T_4 sections) suggest a general temporal parallelism or synchronicity to other Colorado Plateau records (due to curve fitting), regardless of individual area's elevation, but must await further radiometric dating control (Figure 17). Explanation of the episodic high pine proportions must await studies of local modern pollen rain but may be indicative of relative local pollen production versus wash-in of long distance transport pollen . . . but local persistence of relictual population of pine in this well-watered canyon cannot be overlooked.

Lack of adequate C-14 control prevents any direct correlation of specific prehistoric occupation and paleoenvironmental trend, but in general the deposition of the portion of T_3 thus far samples is coeval in time with early Archaic occupations known from other nearby areas of the Colorado Plateau.

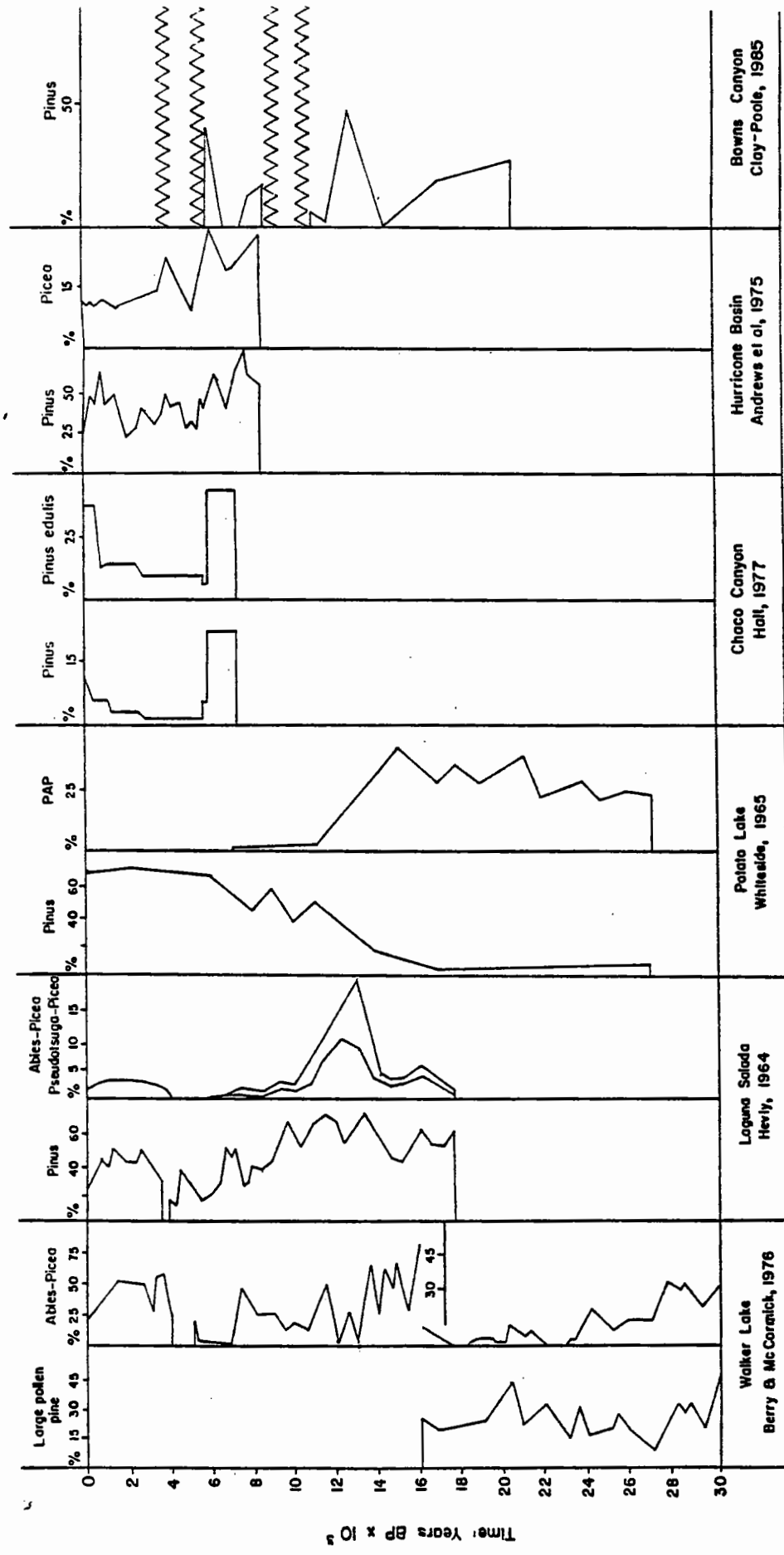


Figure 17. Comparison of the pollen percentages of the six studies (assuming a uniform sedimentation rate). Pinus is species ponderosa unless otherwise stated. The area between the sawtooth borders represents time periods of erosion and therefore no pollen deposition.

While pollen of cultivated plants would not be anticipated in this record, it is certainly possible that the pollen of native, non-cultivated plants may reflect the biotic resources which made the Bowns-Bechan Canyon system an attractive place to live. The increased pollen of Chenopods were a common dietary and/or medicinal item among early Archaic peoples (Reinhard et al. 1985).

Chapter 6

PALEONTOLOGY

L. Agenbroad, J. Mead, A. Phillips III, L. Middleton

Introduction

The end of the Wisconsin glacial ($\pm 11,000$ B.P.: 9,050 B.C.) was also the period of extinction of major Pleistocene megafauna (+45 kg body weight) such as mammoth, horse, three genera of sloths, two genera of musk oxen, several species of camel and a number of carnivores including sabre-tooth cats, dire wolves and giant short-faced bears. The cause of the extinction has been interpreted as being due to one of two major causes. The first model is a climatic model (sometimes referred to as "overchill") in which the rather abrupt climatic (and resulting environmental) change at the end of a glacial epoch destroyed the habitat for the Pleistocene fauna. A second model utilizes the entry of Paleoindian hunters in the southern latitudes of the New World as the cause of extinction of major species of game animals (sometimes referred to as the "overkill" hypothesis).

The Colorado Plateau is poorly understood with respect to Pleistocene megafauna. It is even less well understood with respect to Paleoindian utilization of the natural resources. November 1984 provided the first documented site for both Clovis mammoth hunters (Davis in press) and Folsom bison hunters (Davis 1985). Recovery of broken Paleoindian projectile points in the Phase I Northern Arizona University archaeological survey supports the premise that the Pleistocene fauna and the hunters of that fauna were present in what is now Canyonlands National Park, Glen Canyon National Recreation Area, and Natural Bridges National Monument.

The 1983 investigation at Bechan Cave provided direct evidence of a number of extinct Pleistocene animals. Dung and hair plus some teeth and bone

recovery reveal at least fourteen species of animals (most of which are extinct) were present in the Bechan Cave local area as recently as 11,000 years ago (Davis et al. 1984; Agenbroad et al. 1984).

Other than Bechan Cave, Pleistocene fossils are relatively rare on the Plateau; Cowboy Cave (Jennings 1980) is a notable example. The fossil fauna, correlated to the absolute chronology of the alluvial sequence, the episodes of climatic change and resulting environmental change evidenced by pollen studies, soil studies and cycles of erosion and filling help provide an interpretation of change through time which is independent of archaeology. In fact it is that model to which archaeological information can and must be tied, and which, in turn provides data to help explain human presence or absence at a location, through time.

Phase I Paleontological Study

This report represents one chapter detailing results of one year of field work for the contract. It is not meant to be a summary, definitive work on the paleontology of the Colorado Plateau, nor should it be evaluated as such. It presents the paleontological data from one field season. A season in which the discovery of extinct mountain goat remains in Natural Bridges National Monument and accompanying marmot remains were the dominant paleontological discoveries. Marmot remains were also recovered from Bowns Canyon and a site near Bluff, Utah.

The first year of contract has produced valuable data on the first occurrence of the extinct mountain goat (Oreamnos harringtoni) for the state of Utah. A manuscript prepared for a professional journal is included, as the current status of analysis of paleontological remains recovered from Phase I field research.

A second fossil vertebrate of importance in late Quaternary - early Holocene research of the Canyonland of southern Utah is the presence of marmot (Marmota flaviventris) recovered from T4 in Bowns Canyon; White Canyon in Natural Bridges National Monument; and a rock shelter near Bluff, Utah. Our studies of these remains are too preliminary for description at this time. The importance of these animals as paleoenvironmental indicators (due to their modern timberline, high altitude habitat) is reinforced by the fact that prior to our field research in Phase I, only two fossil marmot localities were known from Utah. Figure 18 illustrates the known distribution of fossil marmots in the Southwest.

In addition to the vertebrate fauna mentioned, packrat middens, currently in the process of being analyzed in the laboratory, are expected to provide faunal remains in addition to botanical information. The Bare Ladder Ruin in Natural Bridges National Monument serves as one example where mountain goat and marmot remains were collected from the packrat middens.

Invertebrate fossils are also present in the alluvial deposits of the canyons. The small bivalve, Pisidium, is known from T4 in Bowns Canyon. Spiral coiled snails such as Succinea are relatively common in the alluvium. The study of invertebrate remains is just beginning, as part of the total research effort. It is expected to become a major area of investigation during Phase II field and laboratory work.

Harrington's Mountain Goat

Harrington's mountain goat (Oreamnos harringtoni Stock) has been one of the least understood of the extinct North American mammals of the Rancholabrean land mammal age. And it is one of the megafauna that became extinct at approximately 11,000 B.P.: 9,050 B.C., presumably due to the predation of early human hunters (Martin 1984). Although described from

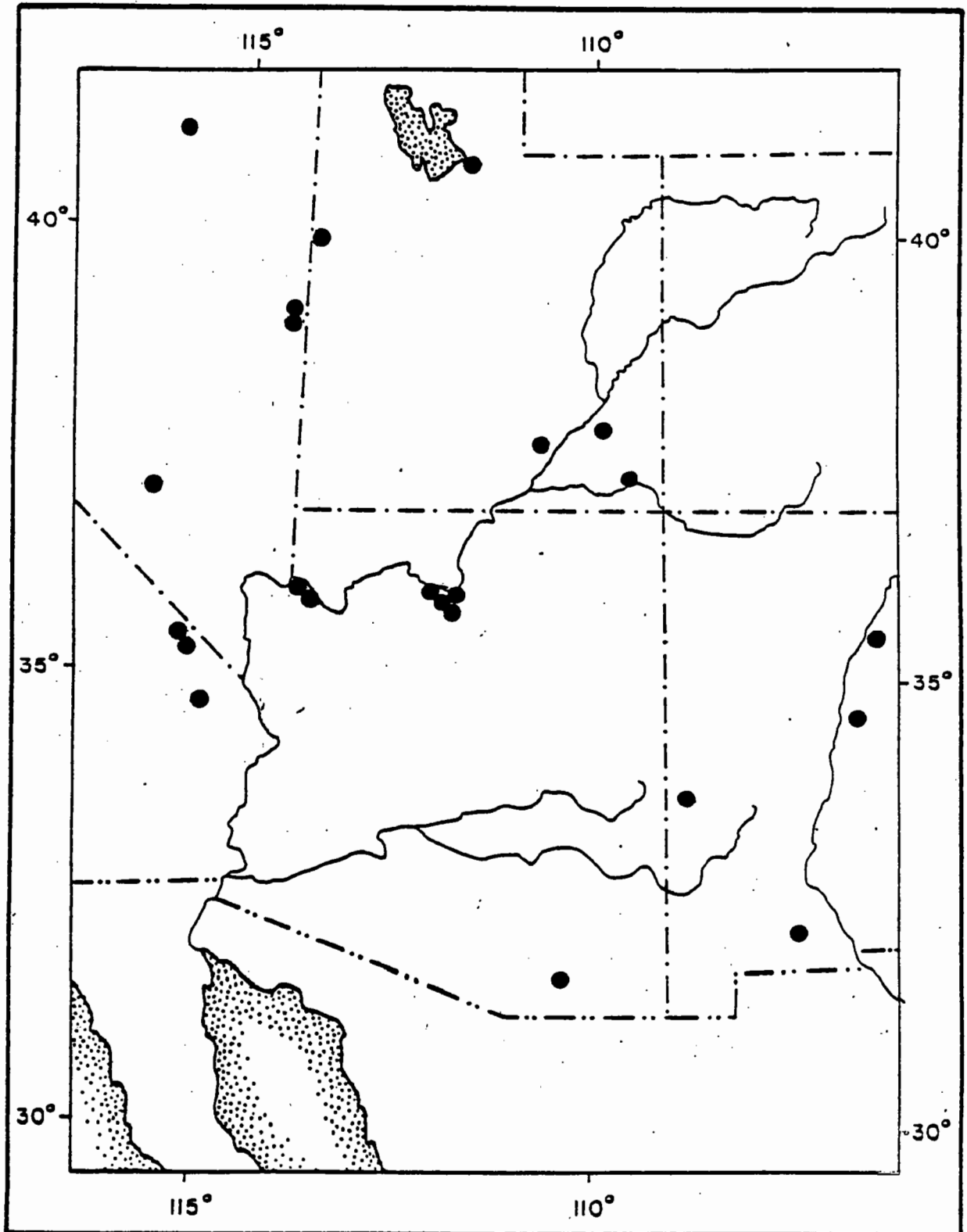


Figure 18. Location map of reported marmot distribution in the Southwest.

skeletal remains recovered from a cave in east-central Nevada (Stock 1936), the rupicaprid is known predominantly from the dry caves of the Grand Canyon, Arizona (Figure 19; Mead et al. in press). Remains of this extinct species were not known to occur on the Colorado Plateau outside of the Grand Canyon. Field work in conjunction with the National Park Service at Natural Bridges National Monument, central Colorado Plateau, southeastern Utah, produced the first evidence of this extinct animal in Utah (Figure 20; Madsen and Miller 1979; Kurten and Anderson 1980; Mead 1983; Harris 1985).

The purpose of this study is to describe the late Pleistocene remains of Oreamnos harringtoni from a single stratified site in a dry rock shelter in Natural Bridges National Monument, Utah, and to document the environmental conditions that existed in the area. These data are then used to discuss the geographical and chronological distribution and the possible migratory route taken by the extinct mountain goat.

Pleistocene Locality

The large, flat-floored shelter in the Cedar Mesa Sandstone is 10 m above the present alluvial terrace (1,820 m elevation) and contains a moderately overhung entrance platform. Remnants of a higher alluvial terrace along with an equally high patina stain on the wall (line in Figure 21) beneath the south-facing shelter entrance indicate that at one time (presumably during the late Pleistocene) a terrace was within approximately 3 m of the shelter floor. However, this remaining distance is vertical, permitting only the best and most ardent climbers access into the shelter.

Examination of the various deposits in the shelter indicates numerous indurated (cemented) packrat (Neotoma spp.) middens, many with multiple layers, containing boreal and mesic plant taxa presently not found in the immediate vicinity of the shelter, or that are only rarely located in north-

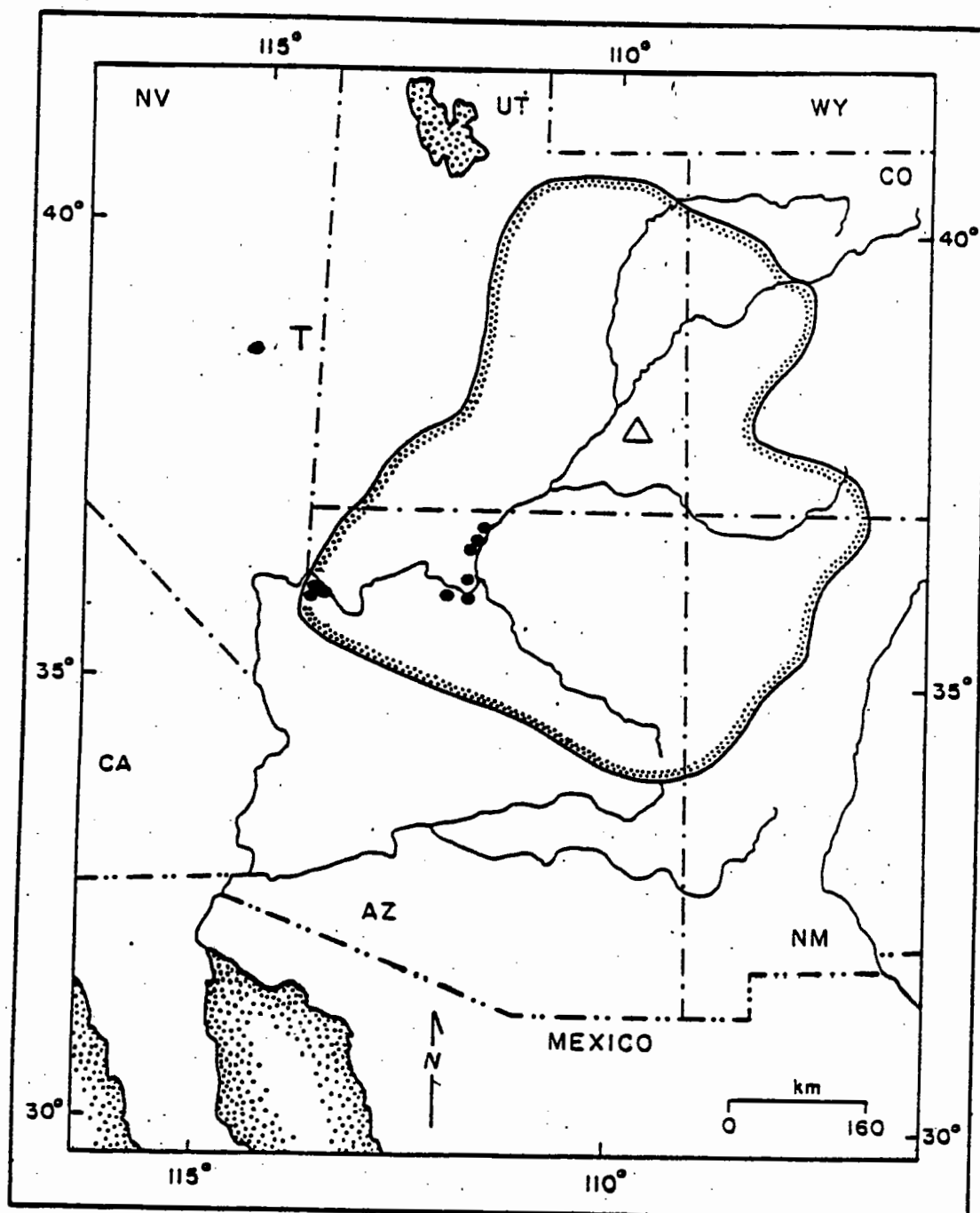


Figure 19. Map of the Colorado Plateau and adjacent areas showing the locations of late Pleistocene age Harrington's mountain goat, Oreamnos harringtoni. T = the type site for the species, Smith Creek Cave. Black dot = localities of the mountain goat in the Grand Canyon and a new, unstudied locality in the Great Basin (Steve Emslie pers. comm.). Open triangle = Natural Bridges National Monument.

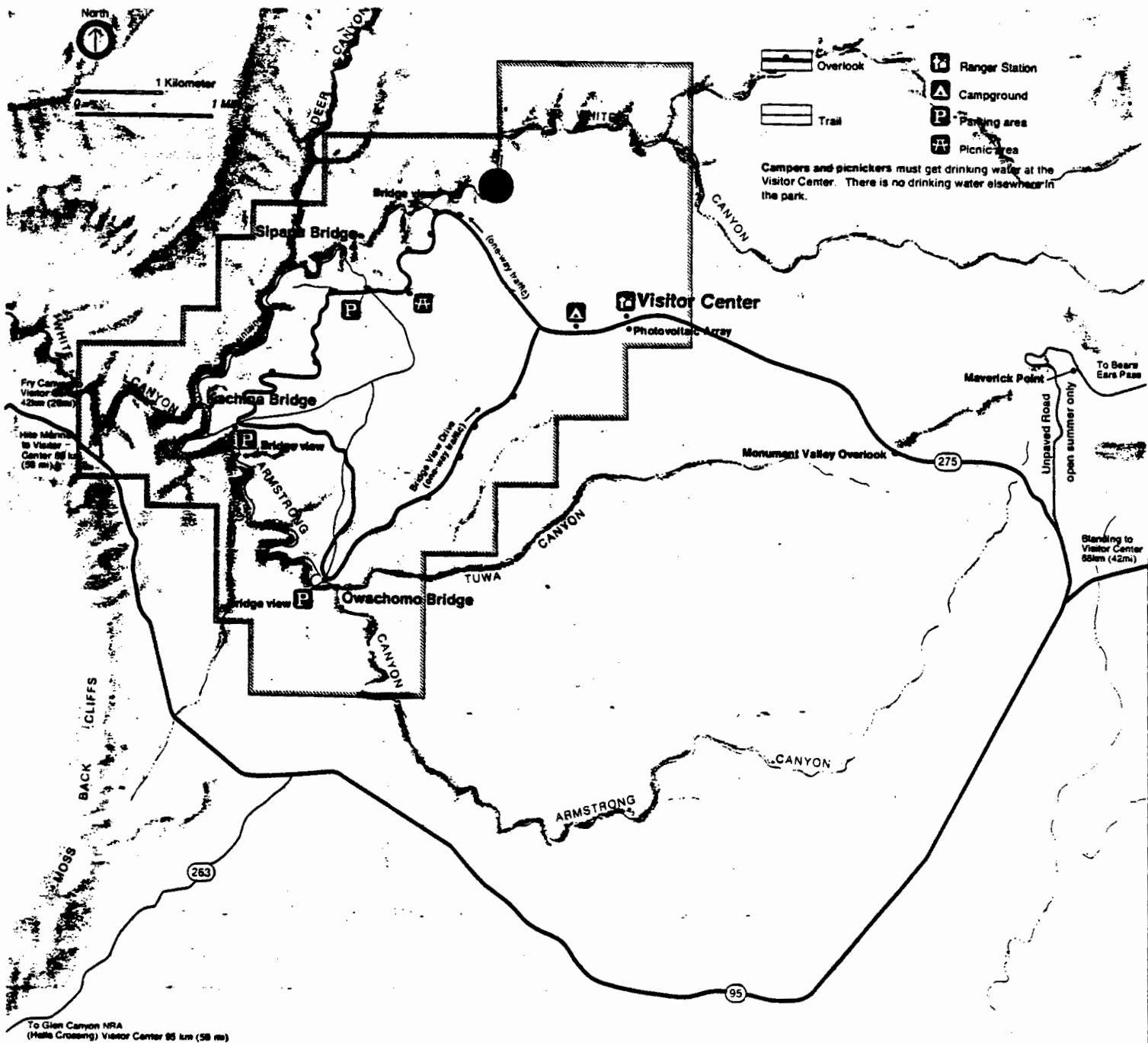


Figure 20. *Oreamnos harringtoni* remains from Natural Bridges National Monument. ●

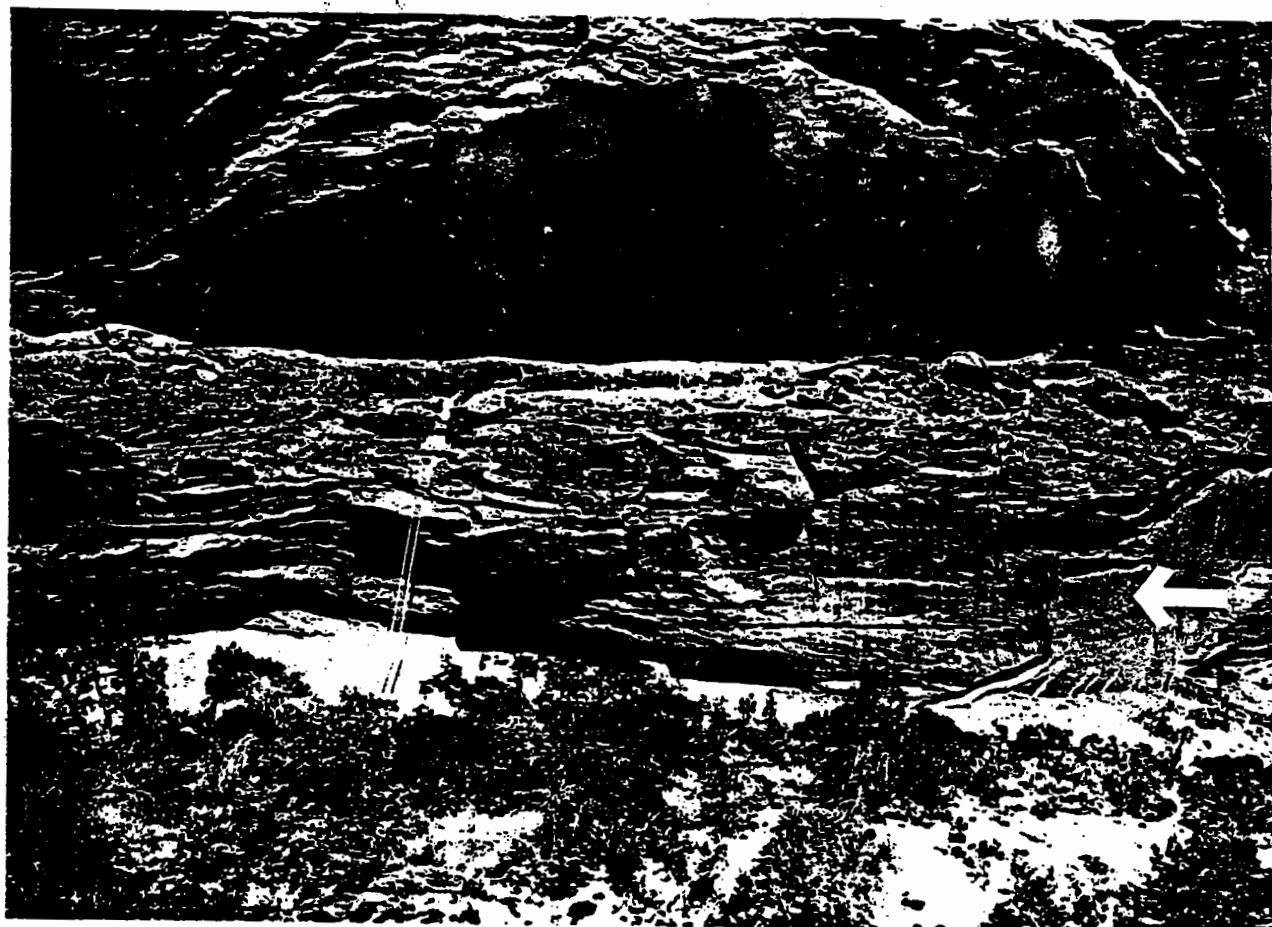


Figure 21. View of the alcove containing the goat remains. The alluvium was at the height indicated by the arrow at the time of the animals' presence.

facing protected areas. Two metapodials, identified as Oreamnos harringtoni, were recovered on the surface of the shelter floor along with large, sub-rectangular dung pellets. Two areas of the shelter contain multiple-layered floor deposits, containing both remains of extinct mountain goat and unindurated packrat middens.

Present Topography and Environments

Natural Bridges National Monument is within the White Canyon drainage system with its headwaters beginning on Elk Ridge, where the Bear's Ears, a topographic high, reach an elevation of 2,735 m. Approximately 12 km west of the Bear's Ears, the stream incises Harmony Flat at 1,945 m elevation. White River has incised a narrow canyon through the Permian Cedar Mesa Sandstone. Over 300 species of plants presently live within the boundaries of the monument. The Harmony Flat rim area bordering the narrow canyon is predominantly a pinyon (Pinus edulis Engelm.) and juniper (Juniperus osteosperma [Torr.] Little) woodland, along with sagebrush (a number of species including Artemisia tridentata Nutt.) and oak (Quercus gambelii Nutt. and Q. undulata Torr.). Ponderosa pine (P. ponderosa Lawson), Douglas fir (Pseudotsuga menziesii [Mirb.] Frano), and Rocky Mountain juniper (J. scopulorum Sarg.) occur in protected localities within the narrow canyon, especially on north-facing slopes. In wetter areas, including along the stream bottom, the following can be found: boxelder (Acer negundo L.), squawbush (Thaus trilobata Nutt.), snowberry (Symphoricarpos longiflorus Gray and S. oreophilus Gray), dogwood (Cornus stolonifera Michx.), manzanita (Arctostaphylos patula Greene), rose (Rosa woodsii and R. manca Greene), and single-leaf ash (Fraxinus anomala Torr.), to name the more apparent.

Stratigraphy

Figure 22 illustrates a vertical profile of approximately 100 cm of floor deposits (arrow in Figure 21). The basal layer is 9 cm of complete and broken-compacted sub-rectangular dung pellets. A 34 cm thick unindurated packrat midden (layer 1) containing an upper sandy subunit (1b) sharply overlies 0. Layer 2 is 7 cm thick and sharply overlies layer 1b and consists of compacted dung pellets. Layer 3 is another unindurated packrat midden, approximately 20 cm thick. Layer 4 is composed of laminated silt and mud, and acts as a capping unit for all the lower unindurated layers. Above layer 4 is a urine-cemented packrat midden (layer 5) which as it was built, sealed the top of the profile against a sandstone shelf, thus prohibiting any further deposition.

Sediments in layer 4 were analyzed in an effort to determine the mode of deposition. Routine size analyses were performed on the sediments as was an x-ray diffraction to determine the clay mineralogy. The unit is composed of unequal amounts of sand-size grains (45.8%) and silt (47.8%), as well as clay-sized (6.5%) material. The average grain size is in the medium silt range. The unit is moderately sorted and the sand-sized grains are subangular to well rounded whereas the silt-sized clasts are subangular.

Clays were examined using x-ray diffractometry to determine if any volcanically derived clays (smectite or mixed-layer illite-smectite) were present. If these were present then the possibility of an airborne source of the fine fraction would have to be considered. X-ray analysis of an untreated (less than 2 micron sample) indicates the presence of illite, kaolinite, and possibly smectite. A second x-ray trace was performed after saturation with ethylene glycol vapor for 48 hours. This indicated that no smectite was present in the sediment sample.

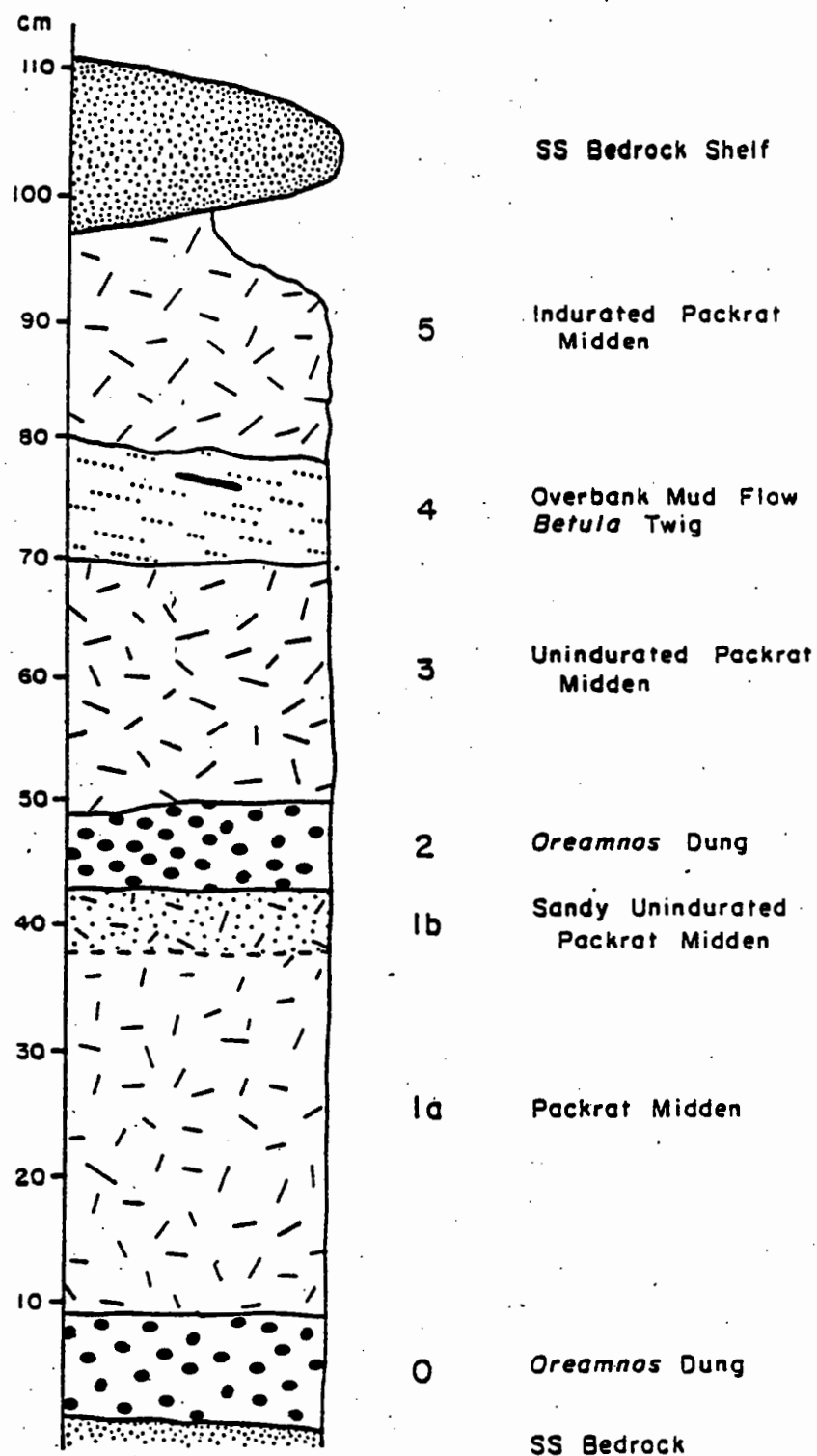


Figure 22. Generalized cross section of the stratigraphic profile of one area containing floor deposits at the fossil locality in Natural Bridges National Monument, Utah.

Although it is impossible to state unequivocally that this layer was deposited by fluvial processes (i.e., overbank flooding), the textural characteristics are consistent with a fluvial origin. The implications of this are that the stream course was at a higher topographic level than it presently occupies. Since deposition of this layer the stream has been downcutting through its own alluvium as evidenced by terrace deposits and patinas on the sides of the canyon.

CHRONOLOGY

Twenty of the largest dung pellets from layers 0 and 2 were measured and identified (see later). Each pellet was then halved along the length, one half of each pellet to be combined to form a radiocarbon sample from that layer. The other halves from the two layers were saved as separate samples for future pollen and microhistological analyses.

Dung pellets from layer 0 radiocarbon dated >39,000 B.P.: 37,050 B.C. (GX-11312) and those from layer 2 dated 23,350±1740-1430 B.P.: 21,400 B.C. (GX-11313) (Figure 22). The delicate nature of the dung samples did not permit NaOH treatments; however, both dates were corrected for ^{13}C (-25.2% and -26.0% respectively). Single dung pellets from layer 0 will be reanalyzed for radiocarbon age using the TAMS (tandem accelerator mass spectrometer) technique, with the hope of refining the time of the earliest occupation in the shelter by the mountain goat.

Neotoma dung pellets from the unindurated packrat midden of layer 3 dated to 21,330±240 B.P.: 19,380 b.C. (B-14418). A stick of water birch (Betula occidentalis Hook.) was recovered in the upper third of the overbank sediments of layer 4 and radiocarbon dated at 26,470±740-680 B.P.: 24,520 B.C. (GX-

11584). Neotoma dung pellets from the indurated packrat midden of layer 5 were dated at $9,660 \pm 160$ B.P.: 7,710 B.C. (B-14419) (Figure 22).

It was assumed that the birch stick date might determine the time of the actual flooding. Given the age and its relation to the rest of the stratigraphy, it appears that the flood waters had detached the stick from either ancient floor deposits or a packrat midden, and does not represent the time of deposition. If the laminated silt and mud sediments of layer 4 represent the beginning of downcutting in White Canyon, then this event happened sometime prior to approximately 10,000 years ago based on the age of layer 5.

FOSSIL REMAINS

Harrington's Mountain Goat

Two metapodials, a right metacarpal and a left metatarsal, both adult (fused epiphyses), were found loose as surface remains. The bones are easily identifiable as to genus, as no other late Pleistocene or recent artiodactyl has such short (total length from proximal to distal end) metapodials in comparison to their greatest width (either proximal or distal). Only the bighorn sheep (Ovis canadensis) have metapodial widths in near-comparison to Oreamnos harringtoni, however, their length is greater than twice that of Harrington's mountain goat and decidedly larger than the extant species of mountain goat, Oreamnos americanus.

Figure 23 illustrates the length in comparison to the ratio of the widths of the proximal and distal ends of both the recovered metapodials from the Utah locality. For comparison, metapodials of the extant mountain goat (adult and juvenile) are used to indicate the maximum size for the genus. Other remains include the metapodials of the extinct mountain goat recovered from

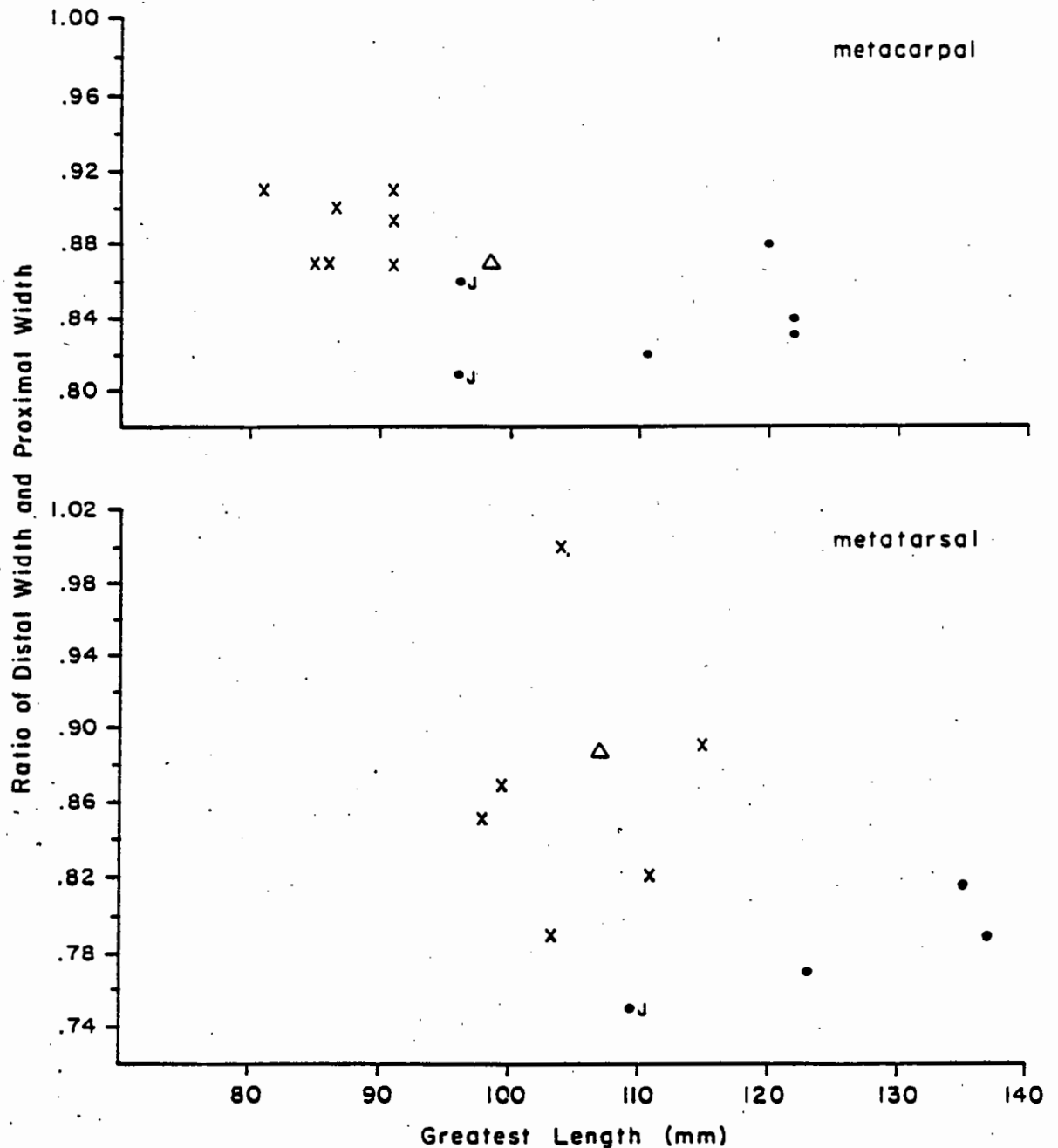


Figure 23. Measurement of the greatest length versus the ratio of the widths of the proximal and distal ends of the metatarsals and metacarpals of the extinct Oreamnos harringtoni and the extant O. americanus. X = extinct species from Rampart, Stanton's Tse'an Bida, and Tse'an Kaetan caves, Grand Canyon and the type site, Smith Creek Cave, Nevada. Open triangle = the remains from Natural Bridges National Monument, Utah. Black dot = extant species; J = juvenile element of extant species. Data from Mead (1983).

the type-site in Nevada, Smith Creek Cave (Stock 1936; remeasured for Mead 1983), and the Grand Canyon cave sites of: Rampart, Stanton's, Tse'an Bida, and Tse'an Kaetan. The metatarsal from Utah is in the same size range as that from other large adult Harrington's mountain goat, about the size of a juvenile modern mountain goat. In contrast, the metacarpal from the Utah locality is decidedly larger than any of the seven known complete Harrington's mountain goat metacarpals, which are consistently smaller than the juvenile of the extant species. The Utah specimen is somewhat larger, approaching the size of a small O. americanus.

Dung Pellets

Dung in the form of pellets are produced by almost all ruminant artiodactyls, however, identification of a particular dung pellet to genus and species can be difficult. Dung pellets of Oreamnos harringtoni, within a certain size-weight range, are known to be distinct (Mead et al. in press). For unequivocal adult dung of Harrington's mountain goat from the Grand Canyon (all were consistently found in either direct or indirect association with identifiable skeletal remains [hachured area in Figure 19; Mead et al. in press]), the pellets are large cuboid to sub-rectangular in shape (width:length ratios greater than 0.9) and weighing in excess of 0.5 g. Dung pellets recovered from the Utah locality show the same general range in size and weight as those from the Grand Canyon (although they do not attain the extreme cuboid shape as those from Rampart Cave), indicating that the large specimens most reasonably belong to O. harringtoni (Figure 24). As with the Grand Canyon cave sites, the Utah locality containing large sub-rectangular shaped dung pellets also contains skeletal remains of Harrington's mountain goat. As yet, there is no osteological indication that any other artiodactyl frequented the shelter.

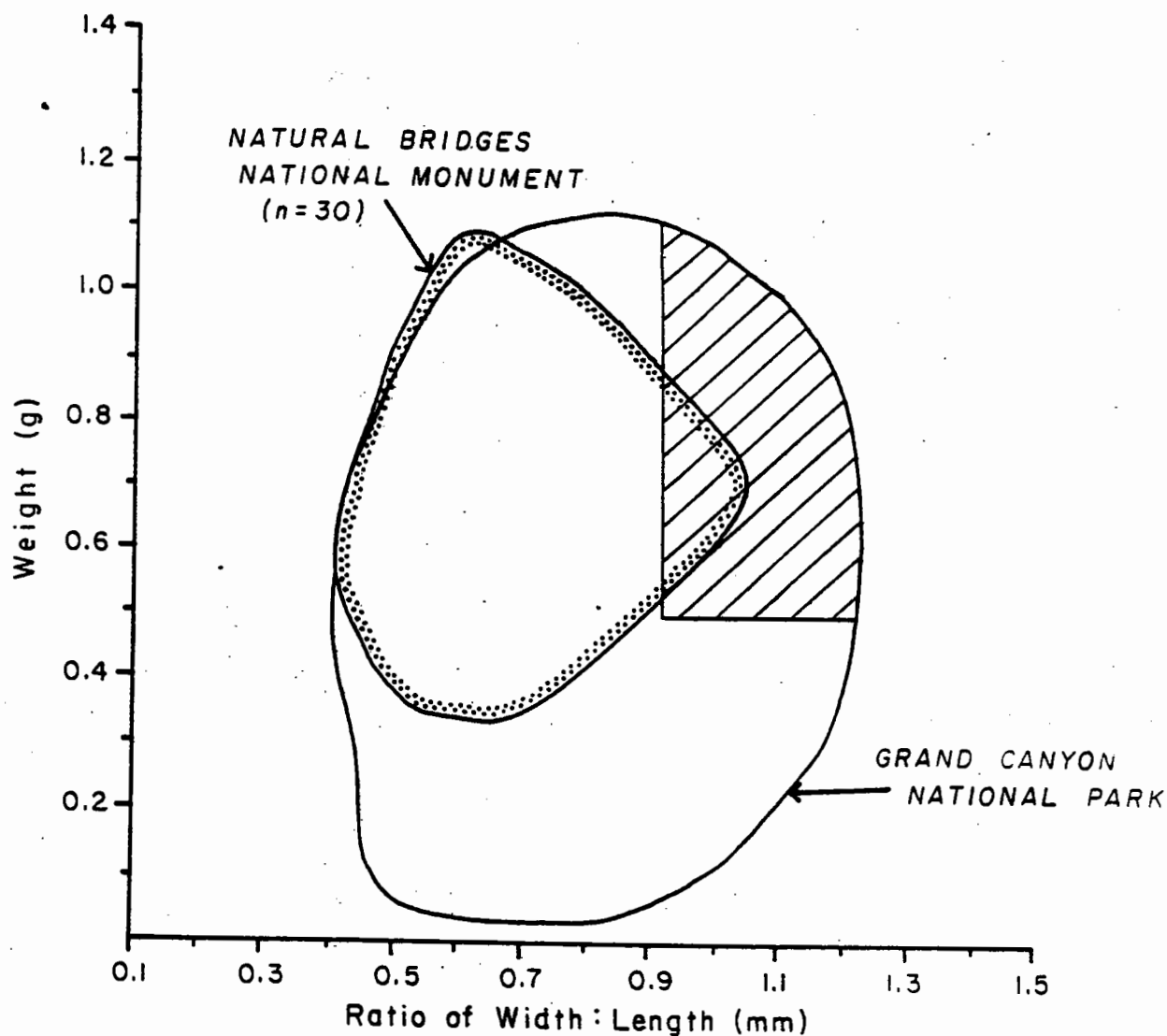


Figure 24. Weight (g) measurements and comparison to the ratio of the width:length of dung pellets of Oreamnos harringtoni from the Grand Canyon National Park, Arizona, and Natural Bridges National Monument, Utah. Hatchured area represents pellets of adult members of the species from Arizona, and shows no measurement overlap with other known artiodactyls (Mead, O'Rourke and Foppe in press).

Packrat Middens

Macro-remains of plant materials, useful for determining the vegetation in the immediate vicinity of the site, were recovered from packrat middens in layers 1, 3, and 5. Plant remains were not recovered from Oreamnos dung layers (0 and 2) or from the mudflow deposit (layer 4) except for the single Betula twig noted before. Similarly, the packrat midden did not contain mountain goat dung or bones except at the contact between stratigraphic units containing dung and midden material.

The dominant plants recovered from the midden are shown in table 1. Three of these (Piceae engelmannii, Pinus flexilis, and Juniperus communis) are high-elevation conifers found today near the Bear's Ears (higher in elevation and approximately 12 km east). One, Celtis reticulata, is often found in riparian communities or large spring and seeps over a wide elevation range, but has not been observed in the immediate area.

All three packrat midden levels contained extralocal plant species remains, although there is apparently a trend toward greater abundance of extant species and a reduction of extralocal species toward the top of the profile (Table 5).

DISCUSSION AND CONCLUSIONS

The skeletal description, associated environment, chronology, evolutionary history, and paleozoogeography of Oreamnos harringtoni were incompletely understood when the extinct animal was described in 1936 from a few incomplete remains from Smith Creek Cave, Nevada (recently additional skeletal remains have been recovered in undated context from a nearby cave; Emslie, S. personal communication 1985). Since 1936, undated skeletal remains

Table 5: Major plant species recovered from the packrat midden units illustrated in Figure 22 . Present distribution is either L0, local; or EX, extralocal. Rating is based on their relative percentage within each layer: 1 = <4%; 2 = 5-10%; 3 = 11-50%; 4 = 51-79%; 5 = 80%. L, layer within profile.

	Pres. Dist.	L1	L3	L5
<i>Acer negundo</i>	L0	-	-	3
<i>Artemisia</i> sp.	L0	-	-	2
<i>Celtis reticulata</i>	EX	-	-	1
<i>Juniperus communis</i>	EX	-	1	2
<i>Juniperus scopulorum</i>	L0	-	2	2
<i>Picea engelmannii</i>	EX	3	3	1
<i>Pinus flexilis</i>	EX	4	3	1
<i>Pseudotsuga menziesii</i>	L0	3	3	4
<i>Rosa</i> cf. <i>woodsii</i>	L0	3	3	1

were recovered in San Josecito Cave, Nuevo Leon, Mexico (work in the 1930s, Harrington 1971) and from the dry caves in the Grand Canyon (work in the late 1930s, Wilson 1942; excavations in 1969 and 1970, Euler 1984; Harrington 1984; Robbins et al. 1984); still, little was understood about the animal.

Excavations and paleoecological work in the Grand Canyon during the 1970s provided the needed late Pleistocene material to begin a reconstruction of Harrington's mountain goat. Although this information is just now being published (O'Rourke and Mead 1986; Mead et al. in press; Mead et al. 1986), the information is from only the Grand Canyon region.

The recovery of bones and dung of O. harringtoni being found isolated and in stratigraphic position in with packrat middens (along with other packrat middens temporally associated) from a new locality (Natural Bridges National Monument, Utah) permits a new and needed approach to understanding the extinct rupicaprid. The metatarsal and metacarpal from Utah are not only adults, but indicate that at least one is decidedly large for the extinct species. The metacarpal is the largest known for O. harringtoni, and is slightly larger than a juvenile modern mountain goat. Stock (1936) in his original description felt that the extinct mountain goat, as a species, was consistently one-third smaller in body stature than the extant species. The Grand Canyon data seemed to indicate that certainly the female of the extinct species was smaller than the modern species, but some of the larger males might approach the size of modern female mountain goats (Mead 1983). The metacarpal from the Utah locality adds support to this hypothesis.

The radiocarbon dates, obtained from the dung pellets of the extinct species from the Utah locality, are some of the earliest for the extinct species, and in the case of the date from layer 0, indicate that the mountain goat lived in parts of the Colorado Plateau prior to 39,800 (the oldest

radiocarbon age directly on the extinct species). A simplistic implication from this preliminary data is that Harrington's mountain goat may have entered the Grand Canyon via the upper Colorado Plateau. Mead (1983) stated that O. harringtoni probably evolved from O. americanus sometime during the last 100,000 years. Migration southward into the arid Intermountain Region, a completely new ecological and physiographic environment for the ancestral form, apparently forced a change in osteological proportions. At this time we do not know if this reduction in size is just a response to Bergman's rule.

The occurrence at Smith Creek Cave indicates that Harrington's mountain goat lived in the Great Basin, but probably only to the extent of the distribution of the boreal forests that were connected by sagebrush and juniper valleys (see review in Thompson and Mead 1982; Thompson 1984). Such an environmental restriction would have allowed easy migration onto, or probably from (as implied by the older Utah radiocarbon date) the central Colorado Plateau. The maze of drainages of the upper Colorado River and Green River would have permitted the expansion of the mountain goat over the entire central Colorado Plateau, with southward migration being down the Colorado River and into the Grand Canyon (Figure 25). Oreamnos has not been found in fossil localities in the western Great Basin, the lower Colorado River Valley, and the southern Basin and Range region (those areas of low elevations and more arid and xeric environments even during the late Pleistocene [Van Devender and Spaulding 1979]) (Kurten and Anderson 1980; Harris 1985).

It is hypothesized that Harrington's mountain goat traveled south from the Colorado Plateau along the high mountainous country of what is now the border of Arizona and New Mexico. With the wealth of late Pleistocene material now being recovered in the Guadalupe Mountain region of southern New Mexico and west Texas, we suggest that the mountain goat will be found in the

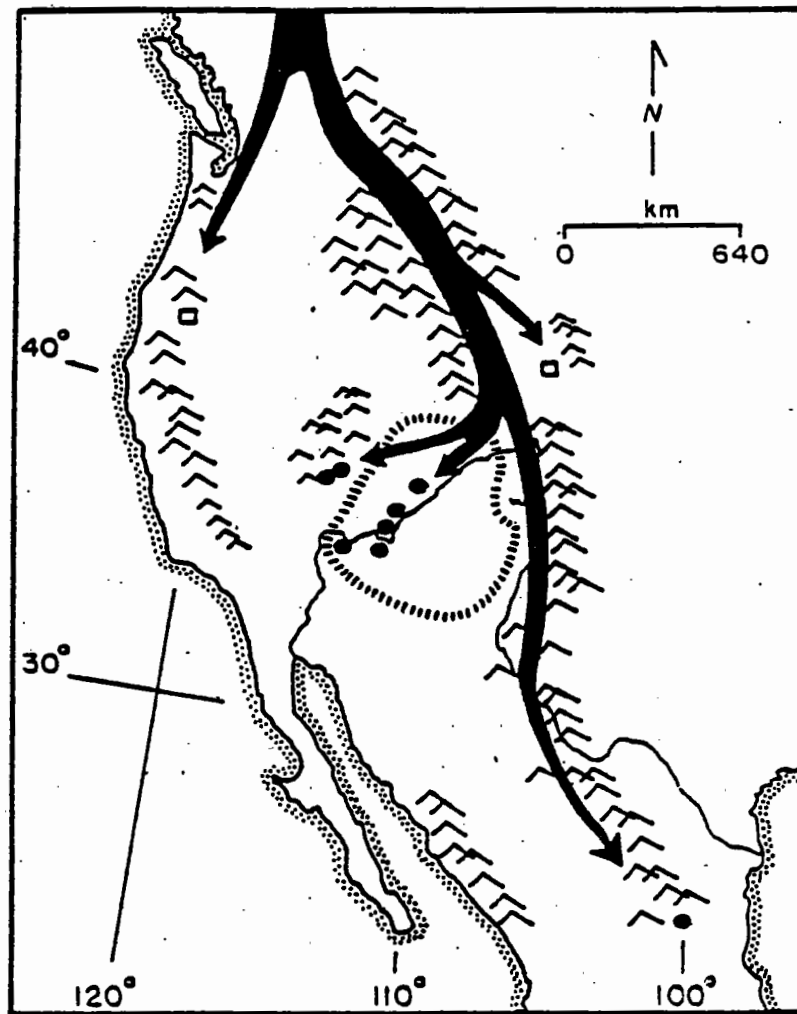


Figure 25. Proposed migration route of Oreamnos. Ancestral form entering from Canadian Rocky Mountains; Oreamnos cf. americanus remains (open square) in California and Wyoming (see Mead 1983). Dots represent the locations of the extinct Harrington's mountain goat. Extent of Colorado Plateau shown.

higher mountainous caves. Although O. harrington has yet to be found in this region, a new rupicaprid, similar to Oreamnos, is being described (Logan, L. personal communication 1982). From this region, the rupicaprid would have had easy access to the Sierra Madre Oriental, Mexico, and thereby entering the area of San Josecito Cave. It is predicted that O. harringtoni will be found in Wisconsin age deposits along the higher elevations of the Chihuahuan Desert region.

The environmental data from the Grand Canyon and the Smith Creek Cave regions indicate that Harrington's mountain goat lived in habitats ranging from near glacial ice and pluvial lakes with nearby open boreal forest (Thompson and Mead 1982), to arid, open juniper-single leaf ash woodlands incorporating desert elements (Phillips 1984; Mead et al. in press). The Utah data described here indicate that the extinct mountain goat lived within narrow, steep canyons, probably with spruce, Douglas fir, and limber pine as the major tree species.

It is not known when Harrington's mountain goat became extinct in the central Colorado Plateau. The youngest radiocarbon age, directly on remains of the mountain goat, from the Utah locality is approximately 23,000 B.P.: 21,050 B.C., some 12,000 before the mountain goat became extinct in the Grand Canyon (Mead et al. 1986). Surface dung pellets and osteological remains of the mountain goat from the Utah locality have yet to be radiocarbon dated.

The macrofossil record of montane conifers on the Colorado Plateau is inadequately known. The association of Pleistocene age spruce with Douglas fir was first noted on the central Colorado Plateau at Cowboy Cave (1710 m elevation), Utah, radiocarbon dating $11,020 \pm 180$ and $13,040 \pm 440$ B.P.: 9,070 and 11,090 B.C. (Spaulding and Van Devender 1977, 1980; Jennings 1980). Since then, Betancourt (1984) recovered the association from a packrat midden in

Fishmouth Cave (1585 m elevation), Utah, dating $12,770 \pm 140$ B.P.: 10,820 B.C.

The Natural Bridges National Monument fossil assemblages (located approximately 100 m higher in elevation than Cowboy Caves) supports the previous contention of the spruce and Douglas fir association during the Pleistocene. In addition, the Natural Bridges National Monument fossils discussed here provide the oldest Quaternary paleoenvironmental reconstructions so far presented for the central Colorado Plateau.

This study has documented that not only did Harrington's mountain goat live in the central Colorado Plateau during the late Pleistocene, but that the locality may hold a key to understanding the chronological and migrational evolution of the extinct species. Further work is needed at the complex locality in Natural Bridges National Monument. Two additional stratigraphic profiles need to be completely analyzed. The shelter contains a wealth of indurated, late Pleistocene-appearing packrat middens (many containing skeletal remains). The late Pleistocene remains will permit not only a valuable data set for an extinct species, but will now allow for a reconstruction of the plant and animal communities that occurred on the central Colorado Plateau. It is hoped that dietary analyses on the dung will permit independent tests and evaluations on what cause(s) may have forced Harrington's mountain goat into extinction.

Chapter 7

PRELIMINARY REPORT ON PACKRAT MIDDEN STUDIES IN
LONG CANYON AND OTHER SITES IN SOUTHEAST UTAH

Julio L. Betancourt

Introduction

Until quite recently, paleoenvironmental research on the Colorado Plateaus had focused primarily on pre-Quaternary deposits. We are more familiar with facies changes in Cretaceous sediments than in Holocene fill. We are more sure of the turnover from dinosaurs to mammals, thanks to rich deposits straddling either side of the Cretaceous-Tertiary boundary in New Mexico's San Juan Basin, than of the faunal changes wrought by the end of the last ice age. This is in contrast to our neighbors in the Great Basin, who have been lured to the Quaternary by lakes and tephras culminating in the recent filling of the Great Salt Lake and the great eruption of Mount St. Helens, the last of its 19 tephra eruptions in 4,500 years (Mehringer in press). Aside from tree rings (Douglass 1935) and alluvial stratigraphy (Bryan 1954; Hack 1942), which were pioneered on the Plateau, our understanding of recent paleoenvironments and their relation to culture history is rather meager.

The Colorado Plateau is now attracting more attention because it is a relatively unspoiled frontier in an increasingly competitive field. The Quaternary sciences have also played a recent supporting role in evaluation of potential sites for nuclear waste repositories, in this case, the Paradox Basin (Christenson et al. 1985). Canyon fills along the Colorado River and its numerous tributaries offer limitless opportunities to study dynamic stream behavior through time. New research in this area implies that periods of degradation and aggradation are characteristically out of phase, not only for

different streams but also for different segments along a single drainage (Boison and Patton 1985; Webb 1985). Chronostratigraphic correlation within the region can no longer be assumed, but must be carefully demonstrated with radiocarbon data. At one sigma, the radiocarbon method may be unable to resolve disparate and unrelated events that are closely spaced in time (e.g. a century apart). Archaeological dating of geological events, be they channel filling or dune formation, may also be fraught with error due to the persistence and reworking of charcoal over time (e.g. Bloug and Gillespie 1978). Apparently vigorous eolian activity between 4,000 and 2,000 years ago could be just an artifact of vast amounts of anthropogenic charcoal contributed by concentrated late Archaic-Basketmaker II occupation of dune areas.

As already pointed out by Agenbroad (this volume), one of the more productive settings for the Quaternary scientist is the canyon environment, with dry caves overlooking alluvial fills that are conveniently profiled by historic arroyo cutting. This also happens to be the setting for a major part of the region's prehistory. Cooperative efforts between archaeologists and geologists focusing on cave sediments in the Glen Canyon area include Cowboy Cave (Jennings 1980) and Bechan Cave (Davis et al. 1984). Both localities proved rich in plant macrofossils preserved in association with Pleistocene fauna (e.g. Mammuthus), and in higher strata, with human occupation spanning most of the Holocene.

Though fossil packrat middens have been used for the past 25 years to reconstruct paleovegetation in the western U.S., not until the 1980s were the first midden results published for the Plateau (Cole 1982, 1985; Mead and Cole 1981; Betancourt and Van Devender 1981; Betancourt and Davis 1984; Betancourt 1984). These middens are accumulations of plant parts, pollen, insects,

bones, and fecal pellets embedded in crystallized packrat urine and preserved in dry caves for thousands of years. Their paleoecological significance stems from the taxonomic resolution afforded by excellent preservation of plant remains, the origin of identified plants within the packrat's small foraging range (within a 50 m radius), and the suitability of the material for radiocarbon dating. Packrat middens have three general weaknesses: 1) Midden floras are subject to the collecting biases of different species of packrats. To date, there has been little work relating plant community structure and composition to the contents of modern middens; 2) The midden record is stratigraphically or temporally discontinuous. Trends between samples of different age are inferred rather than demonstrated; 3) Middens exclusively census plant communities in rocky environments and have little bearing on vegetation away from outcrops. On the other hand, an unjust criticism is that packrat middens record only the local vegetation and are thus irrelevant to regional reconstructions. Midden analyses pinpoint the exact elevation, latitude, and longitude of individual species at a given time. A network of such sites permits detailed mapping of elevational and geographic ranges through time. Middens may not, however, reflect changes in productivity that are manifested solely in the density and not in the kinds of plants present at a given site.

Archaeological projects have only seldom been the pretext for packrat midden studies. Notable exceptions include Gatecliff Shelter in central Nevada (Thompson and Hattori 1983), the Brantley Reservoir Project in eastern New Mexico (Van Devender 1980), the Tularosa Basin of southern New Mexico (Van Devender et al. 1984; Van Devender and Toolin 1984), and Chaco Canyon (Betancourt and Van Devender 1981; Betancourt et al. 1983). Midden research has contributed the botanical setting for Paleoindian-megafauna interactions

in the West and will continue to see action as primary evidence in the controversy over Pleistocene extinctions (Thompson et al. 1980; Phillips 1984; Cole 1985; Martin in press; Mead 1983). In the central Great Basin, human subsistence on pinyon nuts was delayed until ca. 6,000 B.P.: 4,050 B.C. when middens first record the successful dispersal of one-needle pinyon (Pinus monophylla) into the area by corvids or by man himself (Thompson and Hattori 1983). At Chaco Canyon, the midden record demonstrated a significant reduction in pinyon-juniper woodland between $1,230 \pm 60$ and 520 ± 60 B.P.: AD. 720 and 1,430, a period neatly encompassing peak human activity in the canyon (Betancourt and Van Devender 1981; Betancourt et al. 1983). The hypothesis that this resulted from fuel harvesting could easily be extended to other parts of the region, with the Hopi Mesas as an historical example.

Development of a packrat midden sequence from Long Canyon is my contribution to the study of late Quaternary geology and paleoenvironments relative to aboriginal occupation of Glen Canyon and Canyonlands. The Long Canyon sequence is also part of a network of sites to be used in reconstructing late Quaternary plant zonation and climates of the region.

Studies at sites other than Long Canyon were funded by the U.S. Department of Energy, the National Science Foundation and the U.S. Geological Survey. The sequences at Allen Canyon and Fishmouth Caves in San Juan County have been publicized (Betancourt 1984; Betancourt and Biggar 1985).

This report will integrate preliminary findings at Long Canyon within the larger data set and point to further progress that can be made through packrat midden analyses in the area. General statements about packrat midden research on the Colorado Plateaus will preface brief discussion of each site, from highest to lowest elevation, and a chronological summary of vegetation change in the region. Though some of the sites discussed here are outside park

boundaries, the uniformity of substrate and site type (cavate alcoves) suggests that the existing data should be predictive of vegetation change at given elevations throughout southeast Utah.

MIDDEN SEQUENCES FROM THE EASTERN COLORADO PLATEAUS

As late as 1976, the only interest in packrat middens from the Glen Canyon or Canyonlands area was as a source of nitrogen for algal mat growth on the submerged cliff faces of Lake Powell. Only months after flooding, scuba divers found brilliantly pigmented carpets of algae growing on indurated middens along sloping rock surfaces. Potter and Pattison (1976) showed the nitrogen content of this unusual substrate to be four times that of the surrounding benthic material. Naturally, the fossil midden record below 1130 m was lost when the lake filled. This makes it difficult to determine, for example, the Pleistocene eastern limit of Utah juniper (Juniperus osteosperma), which could have occupied the altitudinal wedge now submerged by Lake Powell.

By the late 1970s, midden research had progressed from Rampart Cave (Phillips 1977; Van Devender and Mead 1976) upstream to the eastern Grand Canyon (Cole 1982; Mead 1983), from 450 m to 2130 m in elevation, from the Mojave Desert of the inner gorge to the mixed conifer stands on the breaks of the Kaibab Plateau. This expansion continued in the recent work on the eastern Colorado Plateau, closes the gap between the extensive midden record of desert elevations near the delta and lacustrine pollen stratigraphies at the river's source in the Rockies. Including the eastern Grand Canyon, a total of 151 radiocarbon dates have been used to age midden material from the plateaus (Figure 26). This represents 13.6 percent of all the dates from packrat middens in the western U.S. As elsewhere in the West (Webb 1986),

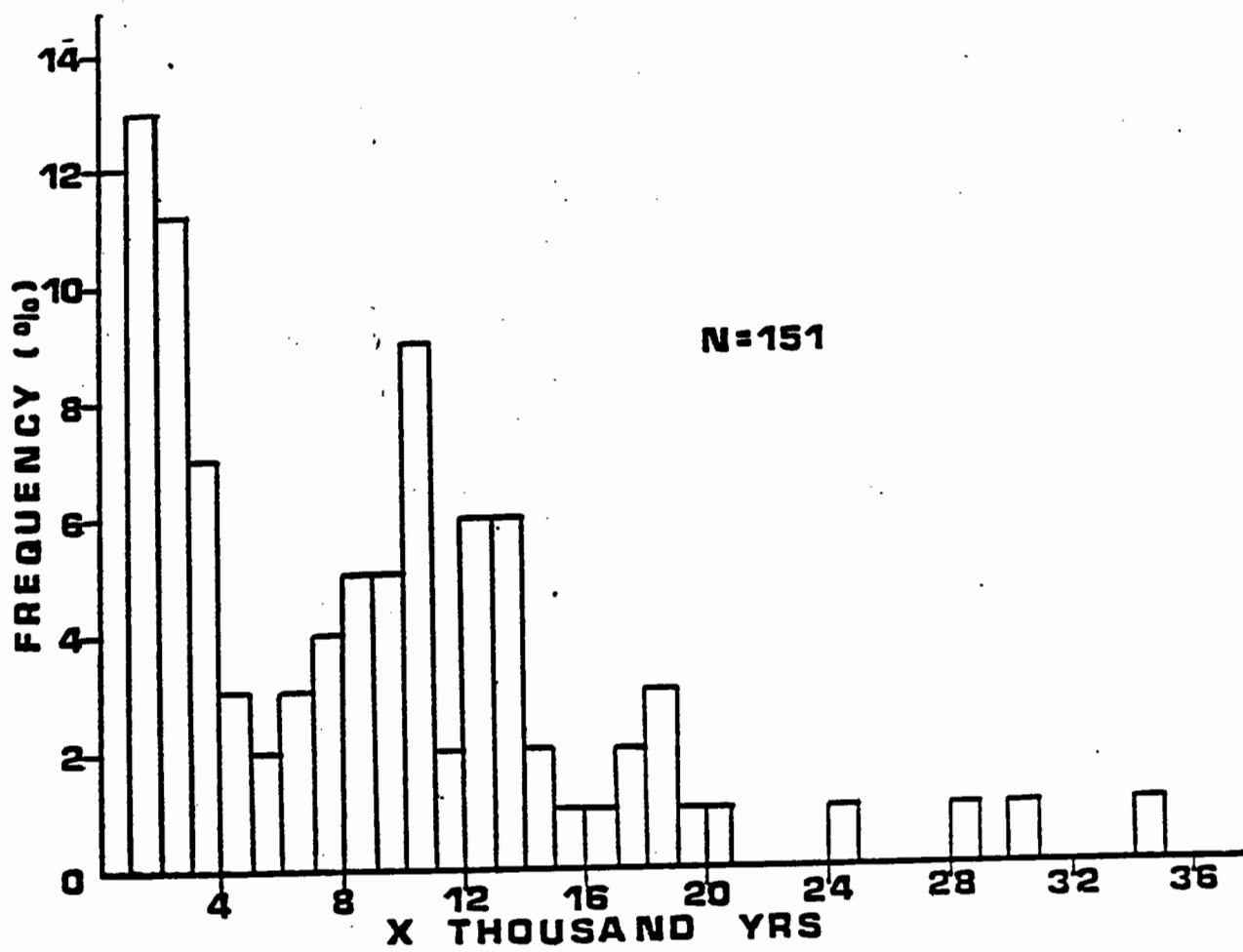


Figure 26. Histogram of radiocarbon dates from fossil packrat middens on the Colorado Plateaus.

histograms of midden ages show a sampling bias for older middens and a gap in the middle Holocene (8,000-4,000 B.P.: 6,050-2,050 B.C.), a period of particular interest to archaeologists.

Midden studies in southeast Utah record long-term vegetation change across elevation and aspect. Gradient analyses are enhanced in this region, because at least some of the variables affecting plant distribution can be held constant. Except for sporadic shale or limestone outcrops at low elevations and exposed batholithic granites in the uplands, sandstone is the predominant substrate east of the Grand Canyon. This homogeneity in substrate accounts for the uniformity in plant zonation across 3 degrees in latitude and longitude, from Page to Farmington, from Moab to Chinle. Midden floras from a given elevation near Moab will probably resemble contemporaneous ones from the same elevation near Page.

In my own research, I have tried to hold the site constant for the purpose of chronology building. I have searched for and found single shelters that contain enough middens of different age to trace evolution of local plant communities from the Pleistocene to the present. Six to 10 middens from each shelter are usually sufficient to highlight the principal events in the history of local vegetation. An elevational transect of such sites can be used to detect changes in plant zonation through time. Figure 27 shows the location of midden sites from 1390 m to 2200 m, essentially from the upper part of the desert scrub zone to the lower elevations of mixed conifer communities. Before describing the various chronosequences, I might note that the packrat midden record from the area is generally biased toward the more mesic sites in the canyon country. Most of the large rock shelters represent the upstream termini of cavate alcoves along vertical cliff faces. Plants at these localities not only grow shaded during parts of the day in different

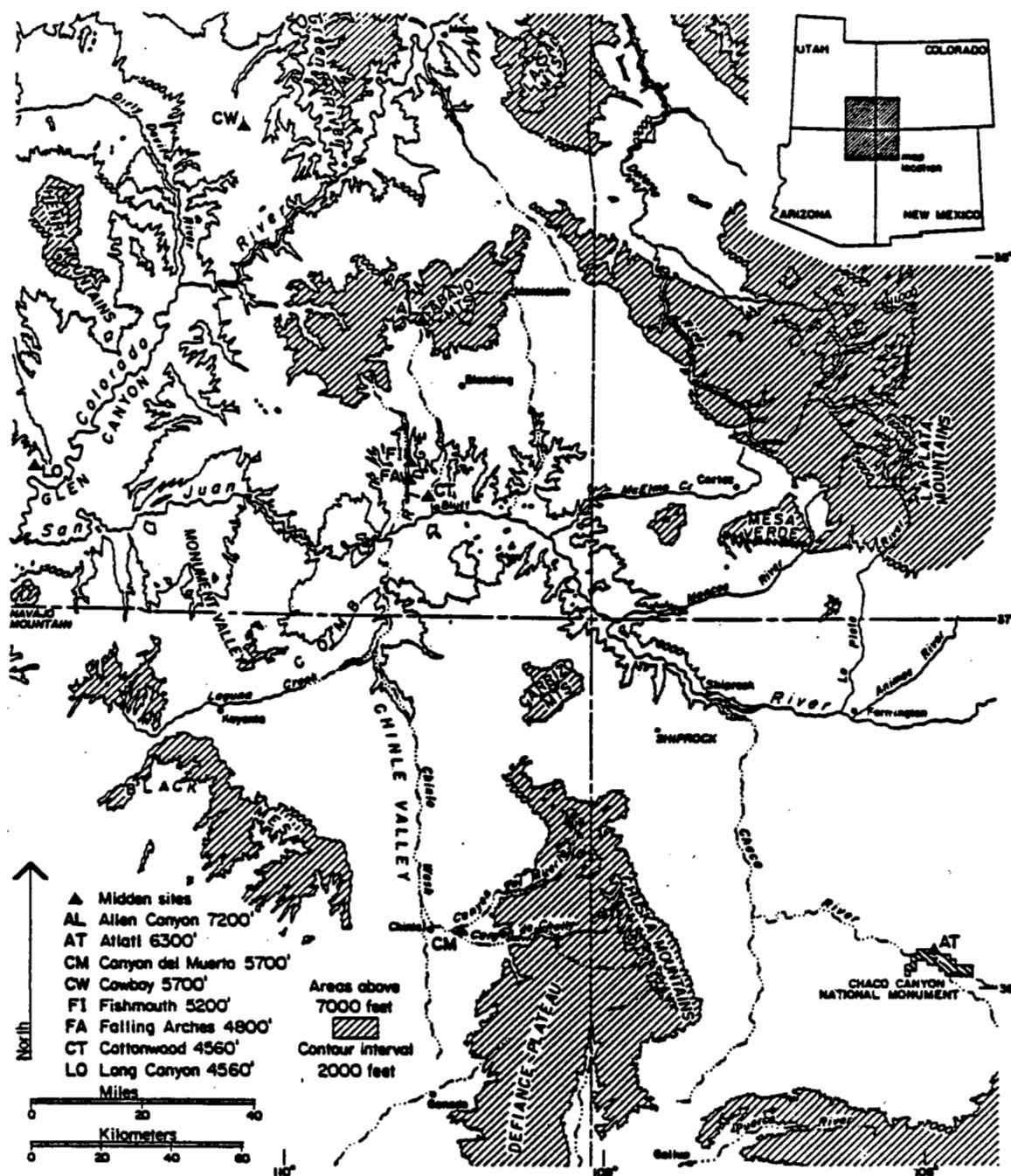


Figure 27. Map of midden localities in the eastern portion of the Colorado Plateau. Areas above 2130 m elevation are hatched to approximate the modern extent of mixed conifer communities. Prior to 10,000 B.P.: 8,050 B.C., these communities occurred at each of the midden sites.

seasons, but are also watered by springs, seeps, and periodic runoff collecting at the base of cliffs. Anyone who has hiked in the canyonlands is familiar with the marshy understory of deciduous, woody groves characteristic of alcoves. Hence, an important caveat is that the chronosequences discussed below pertain to small islands favorable to plant growth and cannot be extended to the area as a whole which is generally xeric. Nonetheless, the environmental blinders imposed by the fossil record can be turned to advantage, since habitat uniformity facilitates comparisons between midden floras of different elevation or age.

Allen Canyon Cave

This north-facing cave is at 2200 m elevation on the south slope of the Abajo Mountains, along a tributary of Allen Canyon. This untrenched tributary courses through Cliff Dwellers' Pasture, a relatively pristine and well-watered parcel now under consideration for Natural Research or Botanical Area status by the Forest Service. Pinyon-juniper woodland covers the exposed ridge above the cave, contrasting with the vegetation of the alcove, which includes Douglas fir (Pseudotsuga menziesii), ponderosa pine (Pinus ponderosa), maple (Acer), aspen (Populus tremuloides), and water birch (Betula occidentalis). This setting is duplicated at similar elevations on the north side of the Abajos, notably at the southern end of Canyonlands only 20.8 km north of Allen Canyon.

The Allen Canyon sequence spans the last 11,300 years (Betancourt 1984). Engelmann spruce (Picea engelmannii) and alpine fir (Abies lasiocarpa), limber pine (Pinus flexilis), common juniper (Juniperus communis), and russet buffaloberry (Shepherdia canadensis) dominate the 11,300 B.P.: 9,350 B.C. assemblage (Figure 27). Patches of spruce-fir forest occur only sporadically on the south side of the Abajo Mountains today, even though

elevations may exceed 3360 m. More extensive stands of spruce-fir occur on the north side of the mountains down to 2900 m. By 10,000 B.P.: 8,050 B.C., blue spruce (Picea pungens) had replaced Engelmann spruce, Douglas fir and limber pine were the dominants, and ponderosa pine and Gambel oak first arrived at the site. At 7,200 B.P.: 5,250 B.C., ponderosa pine was at least 20 times more abundant than at any other time in the sequence, suggesting codominance with Douglas fir. Utah juniper and Rocky Mountain juniper (Juniperus scopulorum) are first recorded in this midden, which surprisingly lacked pinyon (Pinus edulis). Pinyon was the dominant pine in samples dated at 3,400, 3,00, and 1,820 B.P.: 1,450, 1,050, B.C. and A.D. 130, which also contained the first records of the xerophytes Plains prickly pear (Opuntia polyacantha) and narrowleaf yucca (Yucca angustissima).

Atlatl Cave

This midden sequence is from 1910 m at the western end of Chaco Canyon Culture National Historical Park (Figure 27). Local vegetation is Great Basin desert scrub with a few scattered junipers. Directly in front of the shelter is a dense stand of chokecherry (Prunus virginiana). This locality receives only marginal rainfall compared to equivalent elevations near Canyonlands. Blanding (1868 m) and Natural Bridges (1981 m) receive about 300 mm compared to about 220 mm at Chaco. The difference is due to topographic setting and accompanying orographic effects. The mountain mass nearest Chaco is about 75 km away, while Blanding and Natural Bridges are both located along the piedmont of the Abajos. Nevertheless, the sequence from Atlatl Cave, which extends back to 10,600 B.P.: 8,650 B.C. (Betancourt et al. 1983), mirrors results from elsewhere on the Plateaus. Macrofossils and pollen associated with extinct horse and peccary from a cave at the opposite end of the park (Simmons 1984) suggests that spruce, limber pine, and Douglas fir were the

major trees on the canyon slopes during the late Wisconsin. By 10,000 B.P.: 8,050 B.C., blue spruce occurred in trace amounts in Atlatl Cave middens, with Douglas fir, limber pine, and Rocky Mountain juniper as the dominants. By 8,300 B.P.: 6,350 B.C., limber pine and spruce were replaced by pinyon, ponderosa pine, and one-seed juniper (Juniperus monosperma). Middens dated 5,550 and 2,780 B.P.: 3,600 and 830 B.C. lack Rocky Mountain juniper, but contain Douglas fir, ponderosa pine, and pinyon. Douglas fir and ponderosa pine drop out of the sequence between 2,780 and 1,970 B.P.: 830 B.P. and A.D. 20, and today the only conifer left at the site is one-seed juniper, which is only sparsely represented.

Fifty additional middens from elsewhere in Chaco Canyon support the findings at Atlatl Cave, including more widespread ponderosa pine and Douglas fir in the middle Holocene and a reduction of pinyon-juniper woodland coincident with Anasazi occupation. Two of the Chaco middens, dated at 2,000 and 3,000 B.P.: 50 and 1,050 B.C., contain seeds of Cucurbita pepo, and these relatively early dates for cultigens were later verified by direct dating of seeds with the tandem accelerator mass spectrometer at the University of Arizona (Simmons 1984). In canyon country, one can generally guess where the best agricultural fields might have been, but the accuracy of such speculation, however well founded, can seldom be tested. Packrats would have certainly raided crops for food; pollen from cultigens could have also been trapped in middens nearby. While it may sound a bit farfetched, this strategy paid off in what seemed a probable field area near Bat Cave of early corn fame. A midden wedged in a narrow crevice along the cliff face yielded both corn kernels and pollen. A direct date of $2,470 \pm 170$ B.P.: 520 B.C. on one of the kernels suggests contemporaneity with most of the corn excavated from cave fill only a few hundred yards away.

Canyon del Muerto

Two packrat middens dated at 11,900 and 3,120 B.P.: 9,950 and 1,170 B.C. were collected from a north-facing shelter at 1770 m elevation (Betancourt and Davis 1984). The shelter is near the canyon bottom not far from the confluence with Canyon de Chelley. Isolated pinyon and juniper trees grow above the shelter, but desert scrub is the dominant vegetation directly below. By contrast, the Pleistocene midden is dominated by Douglas fir and blue spruce, with lesser amounts of common and Rocky Mountain juniper, limber pine, maple (Acer glabrum), red osier dogwood (Cornus stolonifer), rose (Rosa), wild raspberry (Rubus), and elderberry (Sambucus). Almost 40 percent of the pollen counted from this midden was of Artemisia. While an interpretation of expanded sagebrush steppe at low elevations is consistent with the pollen record from the nearby Chuska Mountains, Wright et al. (1973) misjudged the downward displacement of montane conifers onto the lowlands. Their inference was that a slight depression of 500 m for lower tree line precluded expansion of ponderosa into elevations now in desert scrub, which were invaded instead by pinyon. As it turns out, neither ponderosa nor pinyon macrofossils have been recovered from Pleistocene contexts on the Colorado Plateaus. The midden record demonstrates that the higher conifers expanded down into what is now Great Basin desert scrub, displacing the intervening ponderosa forests and pinyon-juniper woodlands to the south. Both pinyon and ponderosa arrived in Canyon del Muerto at least by 6,210 B.P.: 4,260 B.C., when both are recorded in a midden on Wide Rock Butte (2100 m) in Canyon de Chelley (Schmutz et al. 1976). The younger midden (3,120 B.P.: 1,170 B.C.) in Canyon del Muerto contains only traces of pinyon and juniper and closely reflects present desert scrub vegetation at the site. The presence of corn and high percentages of Cleome, a common disturbance plant in agricultural

fields, in the pollen from this midden suggests an early date for cultivation in the canyon, where evidence of late Archaic occupation is surprisingly meager.

Fishmouth Cave

Fishmouth Cave is a large shelter along Comb Ridge, overlooking the monoclinal valley of Butler Wash (Figure 27). Like Allen Canyon, it is located in the Navajo Sandstone which is also the predominant substrate throughout the Glen Canyon area. The inscription, "Hyde Exploring Expedition, R.W., 1894," on the back wall refers to a visit from Richard Wetherill. A brief description of the cave appears in Prudden (1903), and a photograph of it is in Gregory's (1938, Plate 23A) treatise on the geology of southeastern Utah.

The vegetation of Comb Ridge at this elevation is juniper grassland. The lower edge of the pinyon-juniper woodland is but a few miles north along the ridge and barely 50 m higher in elevation. A few riparian pinyons occur within a few hundred yards, but not directly in front of the cave. Eight middens were studied to develop the local chronosequence. All but one of these (13,800 B.P.: 11,850 B.C.) were published in Betancourt (1984). The two Pleistocene middens (13,800 and 12,770 B.P.: 11,850 and 10,820 B.C.) resemble the older midden at Canyon del Muerto. Limber pine, Douglas fir, common and Rocky Mountain juniper dominate these assemblages, with lesser amounts of blue spruce, red osier dogwood, and rose. Both of these middens contain plains prickly pear, narrow leaf yucca, and Mormon tea (Ephedra), xerophytes that are not commonly associated with subalpine conifers today, but apparently were in the Pleistocene. A midden dated at 10,360 B.P.: 8,410 B.C. records the persistence of limber pine, Douglas fir, Rocky Mountain juniper, the disappearance of blue spruce and common juniper, and the first appearance of Gambel oak

(Quercus gambelii). By 9,700 B.P.: 7,750 B.C., limber pine and Rocky Mountain juniper drops out, and Utah juniper and little leaf mountain mahogany (Cercocarpus intricatus) arrive at the site. The persistence of significant levels of Douglas fir in the 9,700 and 6,100 B.P.: 7,750 and 4,150 B.C. samples, provided this is not contamination from older material, suggests that moisture was sufficient to support Pleistocene relicts. A midden dated at 3,740 B.P.: 1,790 B.C. contains the only pinyon records and the greatest abundance of Utah juniper (by a factor of two) in the sequence. As might be expected, a midden dated at 2,260 B.P.: 310 B.C. contains corn pollen (Owen Davis pers. comm.).

Falling Arches

This shelter at 1463 m is along Comb Ridge, just a few miles south of Fishmouth Cave. Results from midden studies at this cave are yet unpublished. This locality is unusually depauperate compared to the other midden sites described in this report because of the southerly exposure and the lack of seeps in the immediate area of the shelter. Consequently, vegetation on the slickrock in front of the shelter is sparse and dominated by blackbrush (Coleogyne ramossissima). Utah junipers and single leaf ash (Fraxinus anomala) are sparsely represented above the shelter and about 30-50 m below in the bottom of a small canyon, along with Gambel oak and cottonwood. Though 10 middens were collected, only six have been dated and analyzed. Two of the middens are of Pleistocene age. One of these is dominated by Rocky Mountain juniper, with lesser amounts of limber pine, Douglas fir, and the ubiquitous red osier dogwood and rose. The other is dominated by limber pine, with lesser amounts of Rocky Mountain juniper, Douglas fir, and red osier dogwood. There is no blue spruce in either assemblage. The four remaining middens, dominated by Utah juniper, date to

9,200; 5,770; 3,770; and 2,440 B.P.: 7,250; 3,820; 1,820 and 490 B.C.

Blackbrush appears in the youngest middens, which contain prehistoric twine and abundant charcoal.

Cottonwood

This south-facing shelter at 1390 m is in a small alcove tributary of Cottonwood Wash just a couple of miles upstream from Bluff. Fishmouth Cave, Falling Arches, and Cottonwood all occur within 40 km of the eastern boundary of Glen Canyon and Natural Bridges. No junipers occur at the Cottonwood site, although a stand of carrizo (Phragmites communis) marks the shelter's dripline and fairly dense vegetation is fed by an active spring in the small alcove. Dominant shrubs and trees include sagebrush (Artemisia tridentata), buffalo berry (Shepherdia canadensis), wolfberry (Lycium pallida), hackberry (Celtis reticulata), skunk bush (Rhus trilobata), Gambel oak (Quercus gambelii), greasewood (Sarcobatus vermiculatus), and New Mexican olive (Forstiera neomexicana). A total of five middens were collected from the shelter; results are yet unpublished. Four of the middens are of Pleistocene age (12,060, 12,600, 12,690, and 15,600 B.P.: 10,110, 10,650, 10,740, and 13,650 B.C.). The remaining midden was dated at 6,030 B.P.: 4,080 B.C. The full glacial midden (15,600 B.P.: 13,650 B.C.) was dominated by blue spruce, with only trace amounts of Douglas fir and limber pine; there was no plains prickly pear. Other assemblages from this site are indistinguishable from Pleistocene middens at Fishmouth Cave. Two of these Pleistocene middens are dominated by limber pine, Douglas fir, raspberry, red osier dogwood, and Rocky Mountain juniper, with only traces of blue spruce. Another midden lacks blue spruce and contains less prickly pear, the dominants being Rocky Mountain juniper and limber pine. This sample also contains tickseed (Corispermum), a summer annual previously thought to have been introduced, but recently shown to be

native to North American (Betancourt et al. 1984). The youngest sample contains abundant hackberry, oak, skunk bush, box elder, Indian rice grass, and four-wing salt bush (Atriplex canescens).

Long Canyon

This locality is on the east side of Long Canyon, the stream that drains the southwestern end of the Waterpocket Fold in Glen Canyon. This canyon contrasts markedly with Bowns Canyon, only a few kilometers to the west. Long Canyon has few meanders with no appreciable amounts of alluvium for most of its length, and has carved a course well below the Navajo Sandstone into the Kayenta Formation. The midden sequence comes from a southwest facing shelter at 1390 m elevation. The ceiling opens into a partial arch, which results in a secondary dripline and vegetation growing well inside the shelter.

Vegetation at the site includes scrub oak (Quercus turbinella), wavyleaf oak (Q. undulata), singleleaf ash, Utah juniper, a few young pinyons, serviceberry, buffaloberry, Plains prickly pear, snakeweed (Gutierrezia), brickellbush (Brickellia californica), Mormon tea (Ephedra nevadensis and E. torreyana), and rabbitbrush (Chrysothamnus viscidifloris). Indian rice grass is common on sand dune ridges flanking the cave.

The middens were located in vertical fractures on opposite sides of the shelter. Table 6 lists radiocarbon dates and weights of various fractions in the middens. The oldest midden (17,430 B.P.: 15,480 B.C.) is the only Pleistocene midden above 1000 m elevation in western North America without conifer macrofossils. The most common item in this sample is the distinctive cambium of Artemisia, which presumably was used by the rats for nesting material. Though no diagnostic leaves were found, this material is probably referable to big sagebrush (Artemisia tridentata). Other common items in this

Table 6. Fossil packrat middens from Long Canyon (L0) shelter, Kane Co., Utah (37°24'N, 110°50'30"W; 1390 m elevation). Weights from various fractions (in grams) and radiocarbon ages. All middens dated on packrat fecal pellets.

Midden	Indurated weight (i)	Washed weight (w)	w/i	Weight pellets (p)	Weight of		Radiocarbon age	Laboratory Number
					plant matrix (w - p)			
L04	495.5	52.6	0.106	24.3	28.3		2540 ± 140	GX-11195
L05	735.5	53.3	0.073	20.3	33.0		5240 ± 190	GX-11196
L02	875.4	69.6	0.080	16.1	53.5		6640 ± 190	GX 11193
L03	384.0	38.0	0.099	18.3	19.7		7635 ± 290	GX-11194
L07	896.3	59.5	0.067	4.4	45.1		9545 ± 370	GX-11198
L01	914.5	170.8	0.186	37.1	133.7		14,860 ± 460	GX-11192
*L06	632.0	110.6	0.175	13.8	96.8		17,430 ± 770	GX-11197

*Sample was heavily carbonated.

midden are rose, Indian rice grass, plains prickly pear, red osier dogwood, and snowberry (Symphoricarpus).

The Pleistocene midden (14,860 B.P.: 12,910 B.C.) contains abundant blue spruce and birch in addition to plants found in the glacial assemblage. The early Holocene midden (9,545 B.P.: 7595 B.C.) is dominated by Utah juniper, oak, and plains prickly pear, with lesser amounts of winterfat (Ceratoides lanata), Indian rice grass, skunkbush, and traces of Artemisia cambium, which is missing from younger middens. Utah juniper macrofossils are progressively reduced in the samples dated 7,635, 6,640 and 5,240 B.P.: 5,685, 4,690 and 3,290 B.C., and this trend is reversed in the 2540 B.P.: 590 B.C. midden which contains several grams of juniper twigs and seeds. Common taxa in the Holocene middens include oak (both Q. undulata and Q. turbinella), hackberry, four-wing saltbush, rabbitbrush, plains prickly pear, Mormon tea, narrow leaf yucca, Indian rice grass, skunkbush, singleleaf ash, and serviceberry. Pinyon needles were not found in any of the samples even though they are common litter on the shelter floor today. This suggests that the few pinyons at the site today have only recently colonized the site.

DISCUSSION AND SUMMARY

Seven midden chronosequences describe the course of local vegetation change since full glacial times in cavate alcoves between 2200 m and 1390 m elevation. Due to the relatively high base level of the lowlands and limited extent of the highlands, this elevational range represents over half the area of the eastern Colorado Plateau (Figure 27). The predominant substrate is sandstone, which ensures homogeneity in plant zonation across broad areas both today and in the past. Contemporaneous midden floras from a given elevation should be quite similar, regardless of the horizontal distance between

sites. Hence, one might have predicted red osier dogwood and roses in the understory of subalpine trees during the Pleistocene from the shores of Lake Powell to de Chelly.

Since the midden record is generally restricted to alcoves, where water emerges from aquiferous sandstones, it is a better measure of lower than upper limits of plants. Growing season temperature is the key climatic parameter affecting plant growth in these alcoves. Lower temperatures reduce transpirational stress in summer, increase effective moisture, and lengthen the season of flow for local seeps and springs, which in turn irrigate the natural gardens in alcoves. Greater precipitation as snow, the latter's initiation earlier in the fall, or its persistence later in the spring increase water storage in local aquifers and will augment flow from seeps and springs. Consequently, a few alcoves that today support seasonal springs failed to support perennial ones in the Pleistocene, if only because of significantly cooler, summer temperatures.

Only three middens mark the Wisconsin full glacial (20,000-15,000 B.P.: 18,050-13,050 B.C.) at three of the seven sites: Long Canyon, Cottonwood, and Falling Arches. At the first two sites, the full glacial assemblages are quite different than those of the late glacial (15,000-11,000 B.P.: 13,050-9,050 B.C.). At Long Canyon, the lack of conifers in the full glacial and dominance of blue spruce in late glacial will please proponents of a pluvial on the heels of a cold, dry period (Brakenridge 1978; Galloway 1983). A colder full glacial might explain high levels of blue spruce and low levels of other conifers, such as limber pine, Douglas fir, and Rocky Mountain juniper at the Cottonwood site. The reversal of this in the late glacial may mean higher temperatures in the growing season. At Falling Arches there is no spruce in the sequence and the full glacial midden is a close facsimile for

the late glacial floras both there and at Fishmouth Cave, where limber pine, Douglas fir, and Rocky Mountain juniper were dominant. A reasonable reconstruction of late glacial (15,000-11,000 B.P.: 13,050-9,050 B.C.) vegetation in the areas of Glen Canyon and Canyonlands might go as follows: Alcoves with perennial springs from 2130 m to 1310 m; (the elevation of Bechan Cave) supported stands of blue spruce, Douglas fir, limber pine, Rocky Mountain juniper, occasionally common juniper, red osier dogwood, raspberry, and roses. The vegetation of less favorable sites, such as mesatops and colluvial slopes, probably included forest patches of limber pine, Douglas fir, and Rocky Mountain juniper surrounded by sagebrush steppe. Above 2130 m were subalpine meadows and Engelmann spruce-alpine fir forest. Judging from periglacial and pollen evidence from the central and southern Rockies, upper treeline was between 3050 m and 2750 m and probably in the lower part of that range in the full glacial. The biomes that characterize the Plateaus today, the blackbrush desert, the pinyon-juniper woodlands, and ponderosa pine forests were displaced hundreds of miles to the south. Contrary to pollen records (Wright et al. 1973; Clay-Poole this report), neither ponderosa nor pinyon has been recorded as Pleistocene macrofossils north of the Mogollon Rim, and it is likely that their ranges were fully pre-empted by other montane and subalpine elements.

Opposite traditional constructs, the Rocky Mountains were not the source area for the diverse conifer floras of the southwestern mountains and plateaus, at least not in the Quaternary. With a base level of 2130 m, most of the Rockies would have been in spruce-fir forest, tundra and steppe, or ice. The Pleistocene refugia for most of the western conifers and a good deal of our montane flora and fauna were the eastern Colorado Plateaus and the subMogollon highlands. Consequently, species such as white fir (Abies

concolor), ponderosa pine, Douglas fir, blue spruce, and Rocky Mountain juniper have migrated east and north into the Rockies during brief interglacials and were restricted to the lowlands and southerly latitudes during the longer glacial periods. Clovis cultures experienced the vegetation of western North America as it was over nine-tenths of the last two million years. Folsom witnessed the swing from glacial to interglacial conditions. Archaic peoples adapted to developing vegetation patterns pursuant to increasing aridity, and the Anasazi probably were primary agents of vegetation change through fuelwood harvesting and floodplain farming.

The period between 11,000 and 10,000 B.P.: 9,050 and 8,050 B.C. was really intermediate between the Pleistocene and the Holocene. At Allen Canyon, middens record the upslope retreat of blue spruce, which is no longer at the site and did not occur there a thousand years earlier. Ponderosa and gambel oak expanded into the area at this time. At Atlatl Cave, limber pine and spruce lingered on, and limber pine was also an important plant at Fishmouth Cave by 9,500 B.P.: 7,550 B.C. Cole (1982) records pinyon as early as 10,000 B.P.: 9,050 B.C. in the eastern Grand Canyon, but the earliest record further east is at Chaco Canyon at 8300 B.P.: 6,350 B.C. when it is accompanied by ponderosa pine and one-seed juniper.

The middle Holocene (8,000-4,000 B.P.: 6,050-2,050 B.C.) on the Plateaus remains enigmatic. As in the Rockies (Nichols 1982), the hot, dry Altithermal of Antevs (1955) has met with some opposition. Part of the problem is that upper treeline appears to go up while lower treeline goes down. Most would agree that warmer summers would raise upper treeline and an increase in summer rainfall might depress the lower limits of some conifers. One possible explanation might involve increased cloud cover in summer due to enhanced monsoonal circulation with a steeper equator-polar thermal gradient. At upper

treeline, cloudy summer nights would increase counter radiation, raising minimum daily temperature. At lower treeline, the higher albedo of cumuliform clouds in the afternoon would reduce incident solar radiation and would effectively lower maximum temperatures. Under this model, upper and lower treeline diverge with increased cloud cover. With clear skies, they should diverge, holding all else constant. While upper treeline was going up in the Rockies, it appears that at least some of the alcoves discussed in this report were wet enough to support trees like Douglas fir and ponderosa pine below their present lower limits. The evidence, however, is not conclusive.

As might be expected, the youngest midden in each chronosequence most closely resembles the modern flora at each site. Utah juniper appears to increase in density at Fishmouth Cave and at Long Canyon in the late Holocene, and pinyon briefly makes an appearance there at 3,700 B.P.: 1,750 B.C. and within the last 2,000 years, respectively. In the late Holocene, the most dramatic vegetation change on the Plateaus has probably been due to human impact, as seen in the prehistoric conversion of woodland to desert scrub at Chaco and elsewhere, and in the historic and present reduction of grass cover by overstocking of ranges.

Chapter 8

ABSOLUTE CHRONOLOGY

L. Agenbroad

Establishing an absolute chronology of the late Pleistocene and Holocene is a major objective of the research. This chronology allows a sequence of events, natural and cultural, to be determined for the areas specified and for the region as a whole. Using C-14 control of the alluvial record allows the paleoenvironmental sequence to be established and interpreted as evidenced by the geologic/hydrologic/biologic events.

Figure 28 is a documentation plot of the majority of C-14 samples taken in Phase I research. Bowns Canyon and the Bechan Cave area were selected as a control area, whose absolute chronology would be studied in detail, to allow correlation of less completely dated materials from other areas within the research coverage. Six cultural units in the alluvial deposits were sampled to provide control on geologic processes such as rate of deposition, cut and fill event timing, date for stable alluvial surfaces, and chronology of formation of sand dune deposits. Figures 29 through 31 document four of these dates with cultural context. One sample contained insufficient charcoal for dating.

Three of the cultural dates (B.C. 13, 15, 17) taken for stratigraphic information reflect Basketmaker visitation or occupation of both canyons during the 1290-1525 B.P.: A.D. 425-660 interval. The two additional cultural dates (B.C. 12, 16) indicate Archaic presence in the canyons at 5,300 and 3,000 B.P.: 3,350-1,050 B.C. The Basketmaker dates match well with the TAMS (tandem accelerator mass spectrometer) dates of corn, beans, and squash from Bechan Cave. The 3,000 B.P.: 1,050 B.C. Archaic date is close to the dates from an Archaic horizon in the cave fill. The 5,300 B.P.: 3,350 B.C. date is

DOCUMENTATION PLOT
Bowns/Bechan Cave Area

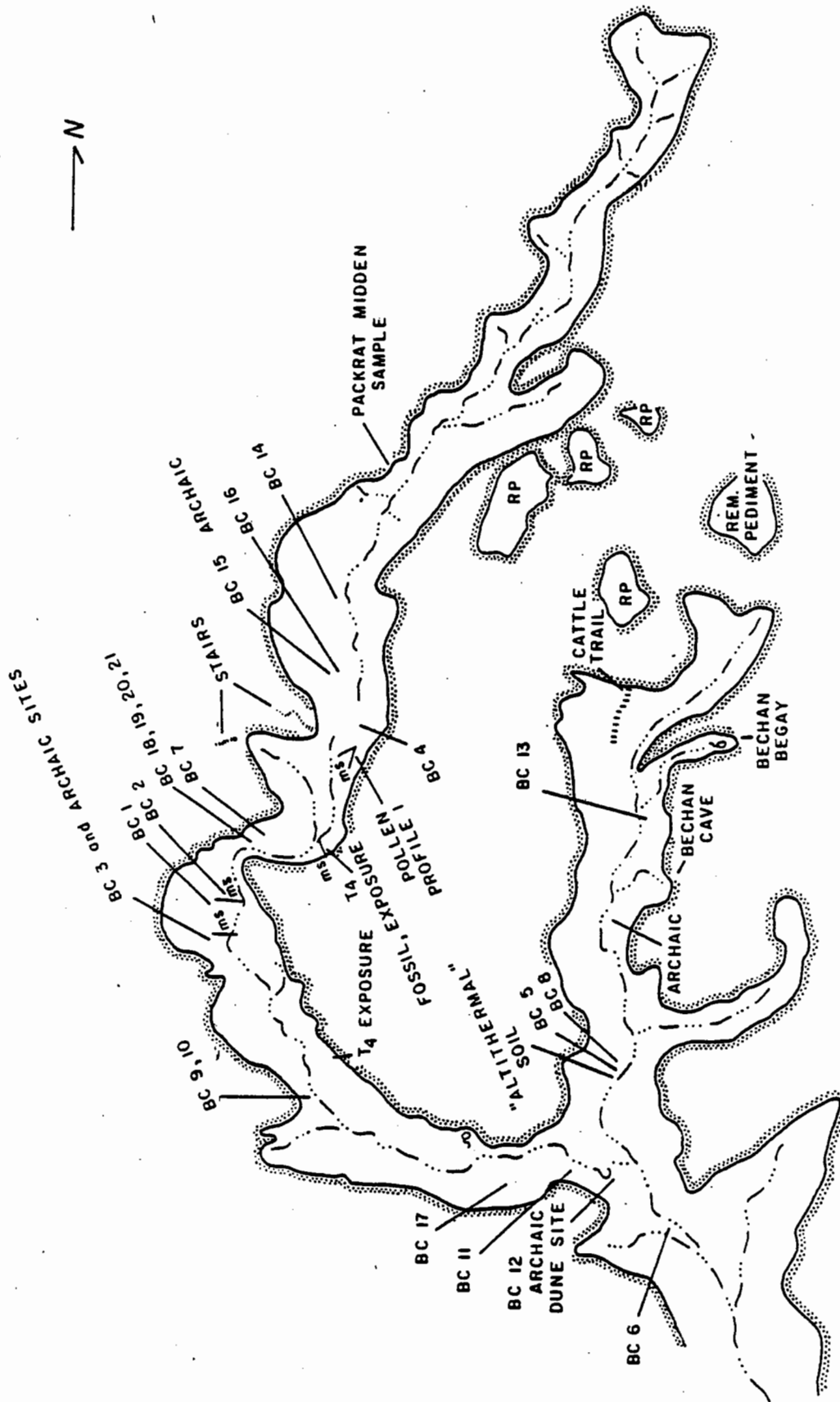


Figure 28. Documentation plot of alluvial C-14 dates from Browns and Bechan Canyons.

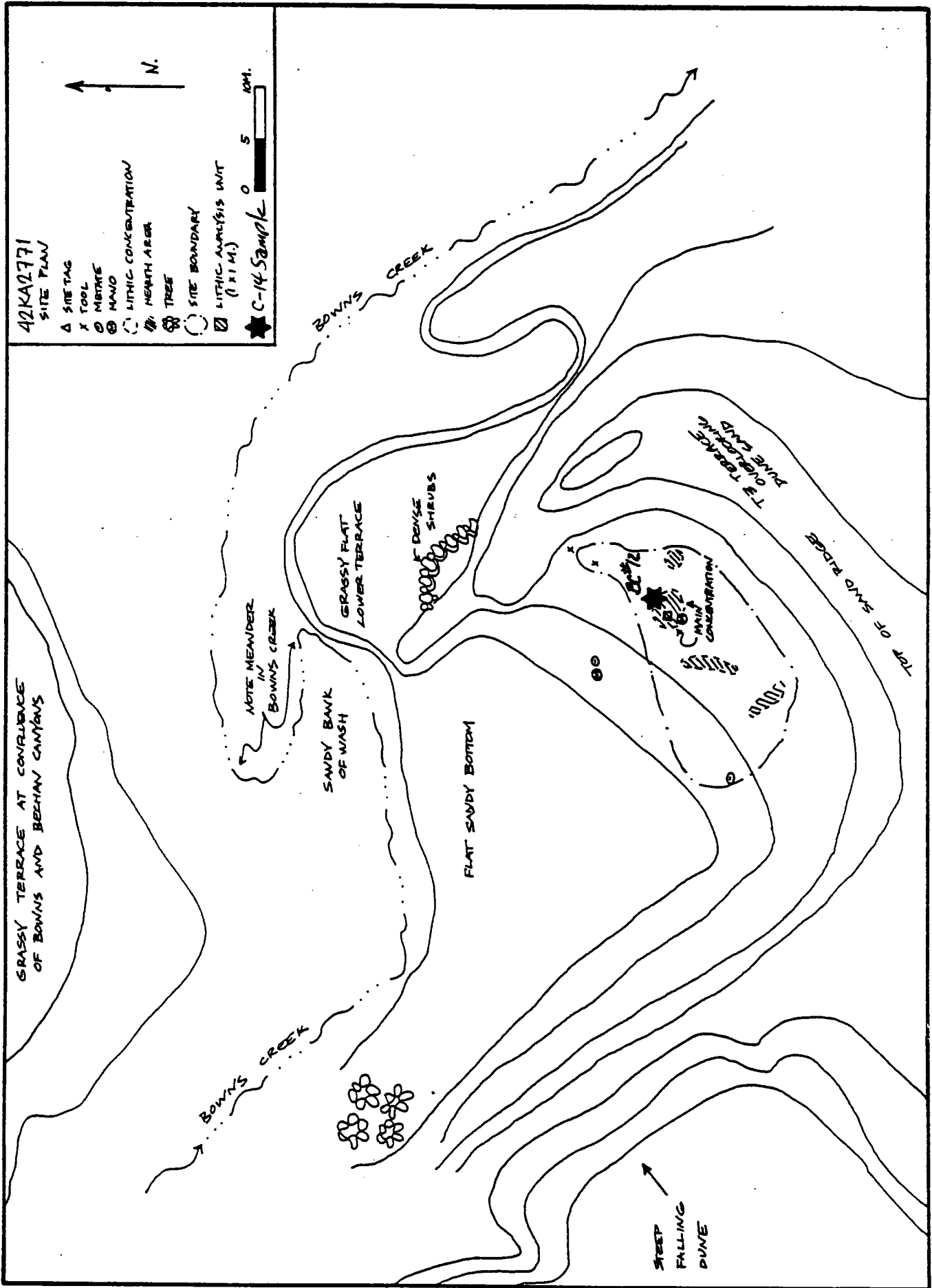


Figure 29. Site 42KA2771 with C-14 sample.

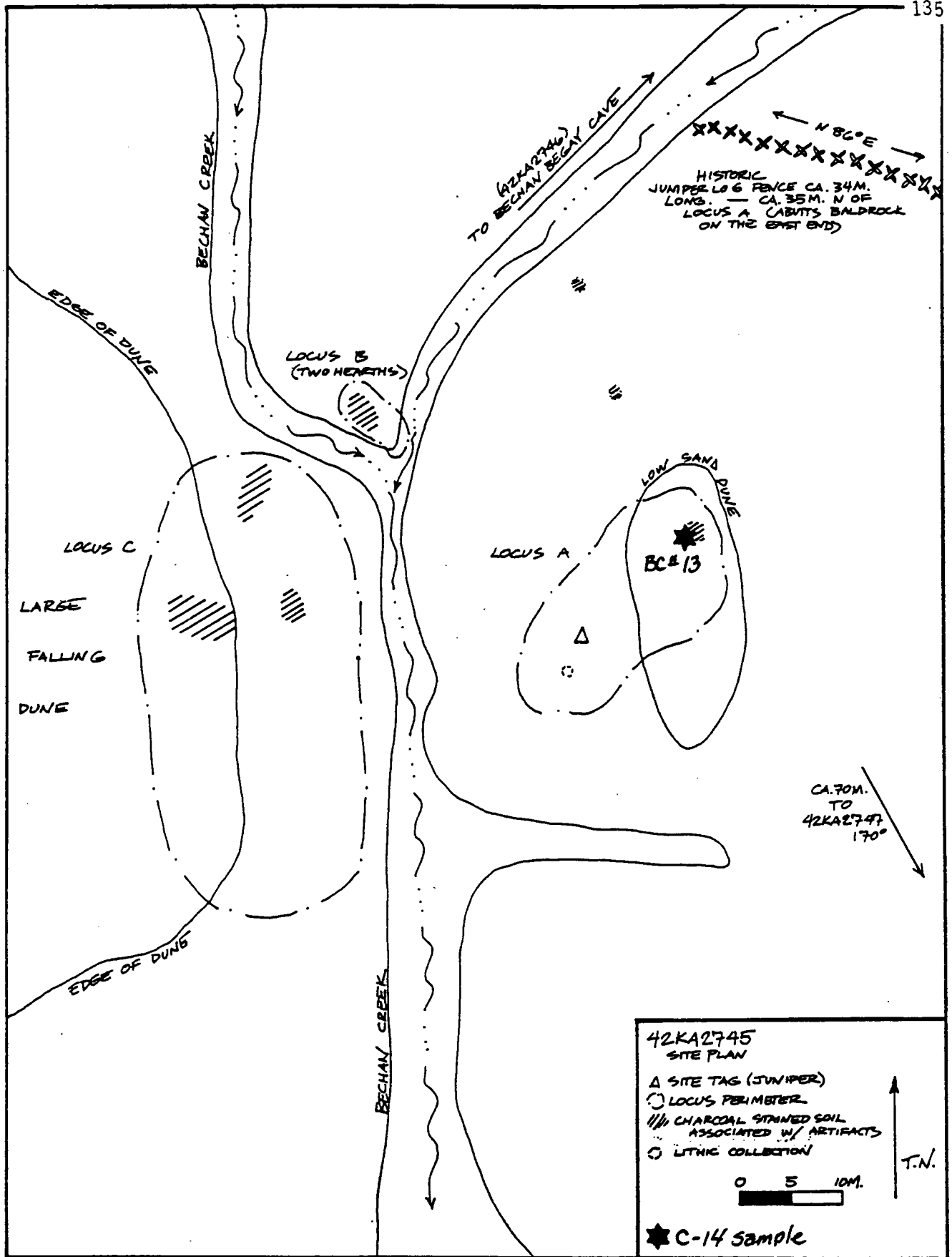


Figure 30. Site 42KA2745 with C-14 sample.

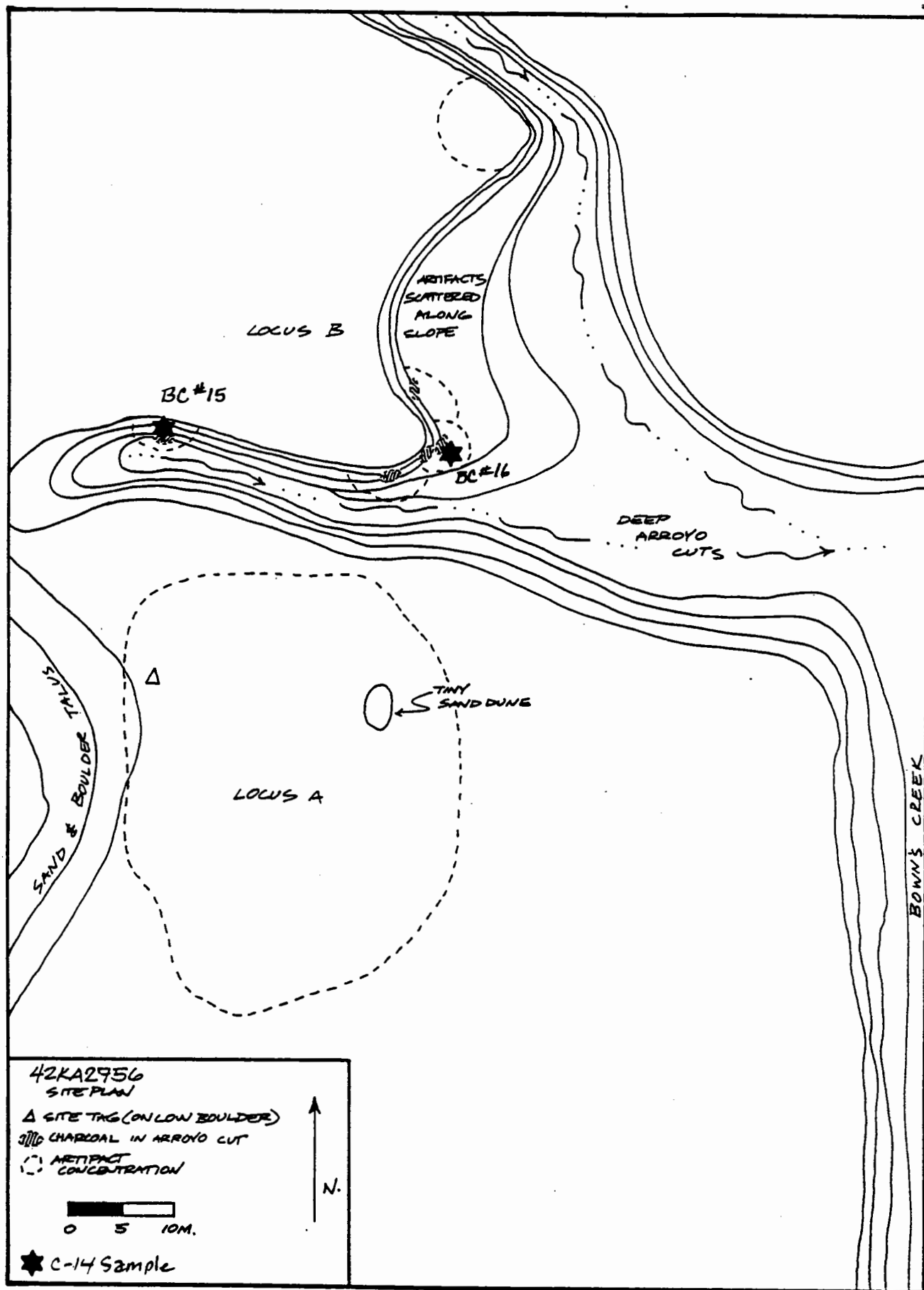


Figure 31. Site 42KA2756 with C-14 sample.

virtually identical with a second Archaic horizon from the cave, if one considers the statistical error at one standard deviation.

Archaic and Basketmaker cultural levels in the alluvium appear to indicate occupation prior to eolian deposition intervals at $\pm 5,000$ B.P.: 3,350 B.C. and 1,250 B.P.: A.D. 700. The cultural dates seem to support the preliminary cut and fill sequence model shown in Figure 4; Table 2. The evidence of human utilization of Bowns and Bechan Canyons seems to correlate with periods of alluvial stability and to indicate human absence in intervals of degradation or aggradation. The alluvial record is substantiated by the evidence of human occupation in Bechan Cave.

Radiocarbon dates from the sequence of pack rat middens from Long Canyon document vegetational change for the past 17,000 years. The dung bed in Bechan Cave gives striking evidence of botanical change since 11,670 B.P.: 9,720 B.C. Pack rat midden data help to refine these changes by both faunal and floral information. Middens from Bowns Canyon and other localities are currently in analysis.

The midden information and faunal material from Bare Ladder Ruin in Natural Bridges National Monument provide the oldest paleoenvironmental data for the Colorado Plateau. The radiocarbon dates from Oreamnos harringtoni (extinct mountain goat) are the oldest dates for this species in this hemisphere and allowed for extension, and testing, of the model generated from the Bechan-Bowns study. Dating conducted by the studies of Woodward-Clyde Consultants near Canyonlands was incorporated into the C-14 data base, as were dates generated from packrat midden analyses in Long Canyon. More dates will be generated from material collected during Phase I which is currently undergoing laboratory analysis. Additional sampling in areas needing more temporal control, or refinement will be undertaken in Phase II field efforts,

as well as those of ensuing years. Appendix IV presents the C-14 sample data and radiometric ages of the samples. Table 2 presents these data by area and antiquity, as well as cultural vs. geological vs. dung bed dates. Figure 1 presents the dated horizons of Bechan Cave which can be correlated to the chronology of the alluvium in Figure 4. These figures and the table provide the model of geologic processes and biologic and cultural changes in these canyons, and the cave. It even appears that a preliminary correlation to the Salt Creek Drainage in Canyonlands National Park is possible. The discovery of the ancient goat remains in Natural Bridges National Monument provides valuable new insights to the origin and dispersion of this species. The lower level of goat dung dates greater than 39,800 B.P.: 37,850 B.C.; the upper level dates 23,350 B.P.: 21,400 B.C. One birch twig (Betula) has been dated at 26,000 B.P.: 24,050 B.C. from the rat midden. Other botanical samples are currently being dated.

As additional data are compiled from alluvial, palynological, pedological, botanical, and chronological sampling, a more refined model will be constructed.

Chapter 9
NATURAL RESOURCES AVAILABLE TO, AND UTILIZED BY, PREHISTORIC
CULTURAL GROUPS IN THE GLEN CANYON NATIONAL RECREATION
AREA AND CANYONLANDS NATIONAL PARK
Larry Agenbroad and Richard Hevly

Geologic Resources

Geologic resources available to prehistoric people were varied in space, time, and use potential. Lithic resources appear to have been the primary entity sought in all cultural phases, primarily for tool manufacture or modification. In earlier cultural groups, the emphasis was on silicic materials for the production of projectile points and butchering tools. From the data available in and near the study areas the use of high grade chert, jasper, obsidian, and chalcedony characterizes the Paleoindian occupation. Some of the material recovered at the Montgomery Site (Davis 1985) on the Green River seems to reflect lithic sources as far away as Wyoming (Davis personal communication), whereas local jasper outcrops were also quarried, from the Morrison Formation. Paleoindian hunting groups are thought to be more nomadic due to game migration, particularly of bison and mammoth, than the later semi-sedentary to sedentary Archaic and Formative groups. Such a nomadic lifestyle would promote the introduction of non-local lithic material into the region, as well as some dependence on local resources.

As the Archaic lifestyle became dominant, manufacture of projectile points and butchering tools was still of primary importance, but the production and utilization of processing tools such as metates and manos, from a different category of lithic materials, became increasingly important. With the loss of the Pleistocene fauna game base, the hunting tools changed in style, preferred material, and shape. An increase in poorer quality, more

local raw material is evidenced in the tool inventories, with local jaspers, quartzites, and chalcedonies comprising the bulk of the lithic resources for hunting and butchering tools. Local sandstones, fine-grained conglomerates and basalts became the primary lithic types used for processing tools. This trend carried from the semi-sedentary gathering groups to the horticultural groups, to the sedentary groups.

As semi-sedentary and sedentary lifestyles became common, a third class of geologic resource came into importance - the ceramic clays (and their tempers) and the use of clay mortar in construction of pueblo walls and for plastering of internal walls.

Horticulture and incipient agriculture also created the need for alluvial terraces and dune fields as agricultural land, creating a fourth type of geologic resource utilized by the prehistoric populations of the Colorado Plateau.

Of minor importance was the utilization of specific geologic units and/or minerals for artwork, or pigmentation for painting, decoration, and ornamentation. Pictographs throughout the canyonlands display varied colors, usually of mineral pigments held by some organic binder. Sheltered exposures of desert varnish became "art galleries" of another type - petroglyphs such as displayed in numerous canyons within the study area.

Hydrologic Resources

Under the present climatic conditions, water availability is a controlling factor for the movement and settlement of humans. There is evidence this was the condition in the last $\pm 8,000$ years of human history on the Colorado Plateau. Perennial river systems became avenues of migration, or settlement, except where access was limited by the steep-walled canyons that

are characteristic of the Glen Canyon and Canyonlands sections of the Colorado Plateau.

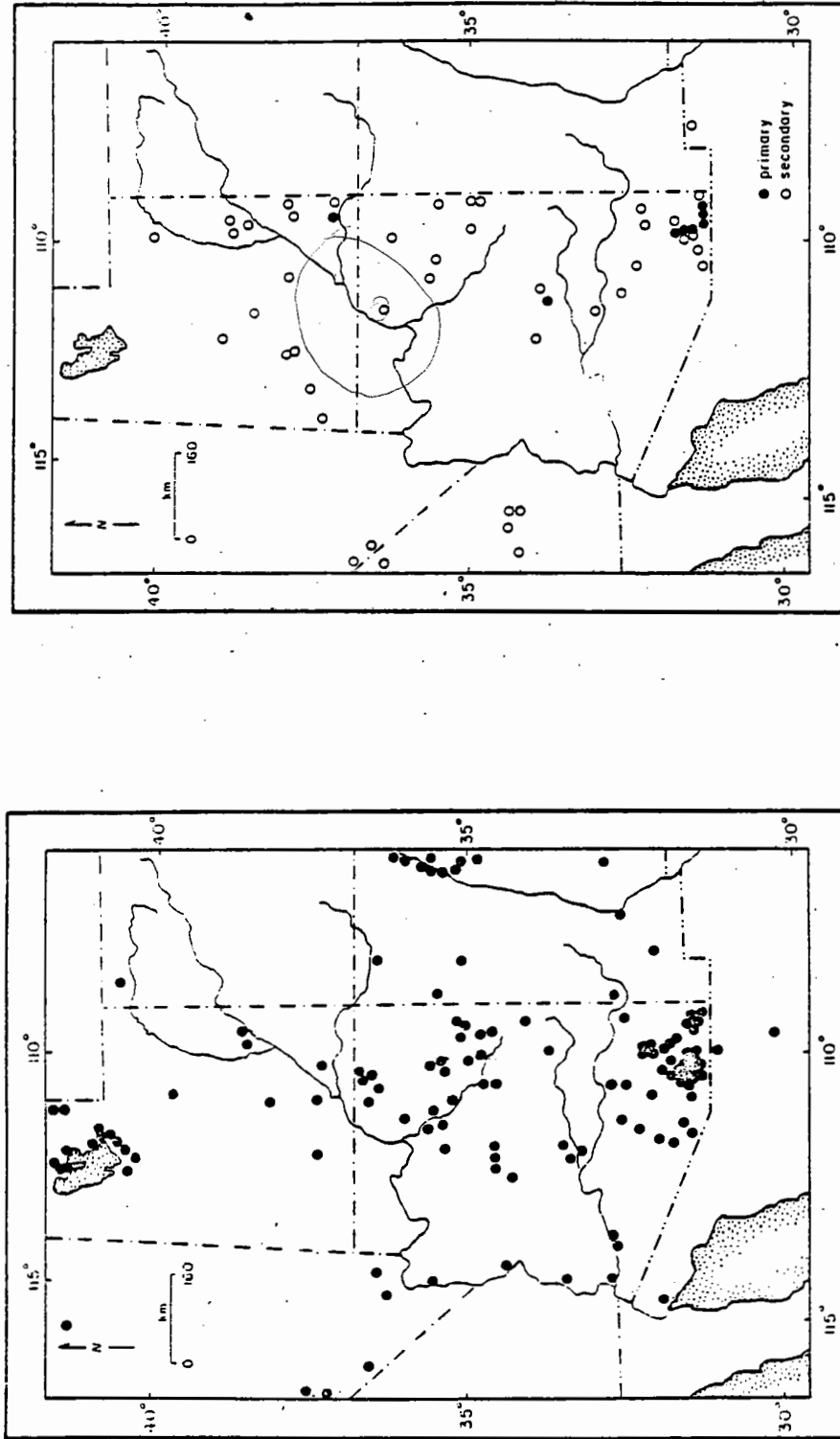
The surficial outcrops of Navajo Sandstone provide seasonal and perennial water holes as is indicated by the abundance of pothole water supplies, many of which are perennial, that give areas such as the Waterpocket Fold its name. Numerous springs are available at the Navajo Sandstone-Kayenta Formation contact, the sandstone serving as the collector and transmission material whereas the less porous and permeable Kayenta Formation impedes vertical percolation, forcing lateral movement of groundwater, to emerge as springs in the canyons.

Drainages such as the San Juan River, Green River, Colorado River, and Escalante River may have been too "flashy" for successful long-term agricultural efforts. The paleoflood record, as well as the historic records, indicate a flood cycle that is unpredictable. Agricultural activity was, in all likelihood, more successful in the smaller, tributary drainages containing alluvial fill and perennial water supplies. These side drainages have a smaller catchnet and their alluvial deposits are less likely to be affected by flash flooding.

Vegetation and Plant Resources

Vegetation of the wind- and sand-sculptured land forms of the Glen Canyon National Recreation Area and Canyonlands National Monument appears to be sparse and largely dominated by low-growing shrubs, grasses, and forbs. However, more than 200 species are known to occur in these harsh environments below 1,371 m. When these environments are well watered, as are Bowns and Bechan Canyons, the diversity of the flora is enhanced not only by riparian taxa including trees, but also by species more typically found in higher elevation in more mesic habitats.

Taxa	Common name	Use: Part Used		
		Food	Medicinal	Technological
Polemoniaceae	Phlox			
<u>Gilia</u> spp.		leaves		
Polygonaceae	Dock			
(<u>Rumex hymenosepalis</u>)		leaves	root	
Rhamnaceae	Buckthorn			
<u>Rhamnus betulifolia</u>			bark	stems
Rosaceae				
* <u>Amelanchior utahensis</u>	Serviceberry	fruit		stems
<u>Cowania mexicana</u>	Cliff rose		leaves	stems
* <u>Rosa arizonica</u>	Rose	fruit		
<u>Rubus</u> sp.		fruit	—	
Salicaceae				
<u>Populus fremontii</u>	Cottonwood		leaves/bark	stems
<u>Salix exigua</u>	Willow		leaves/bark	stems
Saxifragaceae	Gooseberry			
* <u>Ribes</u> sp.		fruit		
Solanaceae				
<u>Datura metaloidss</u>	Datura		seeds	
(<u>Lycium pallidum</u>)	Wolfberry	fruit		
Typhaceae				
<u>Typha domingensis</u>	Cat-tail	stem		leaves
Ulmaceae				
<u>Celtis reticulata</u>	Hackberry	seed		
Verbenaceae	Verbena			
(<u>Verbena</u> spp.)			leaves	



MAMMOTH

CLOVIS

Figure 32. Distribution of reported mammoth remains and the occurrence of Clovis Culture fluted points (open circles = isolate Clovis point; closed circle = Clovis site).

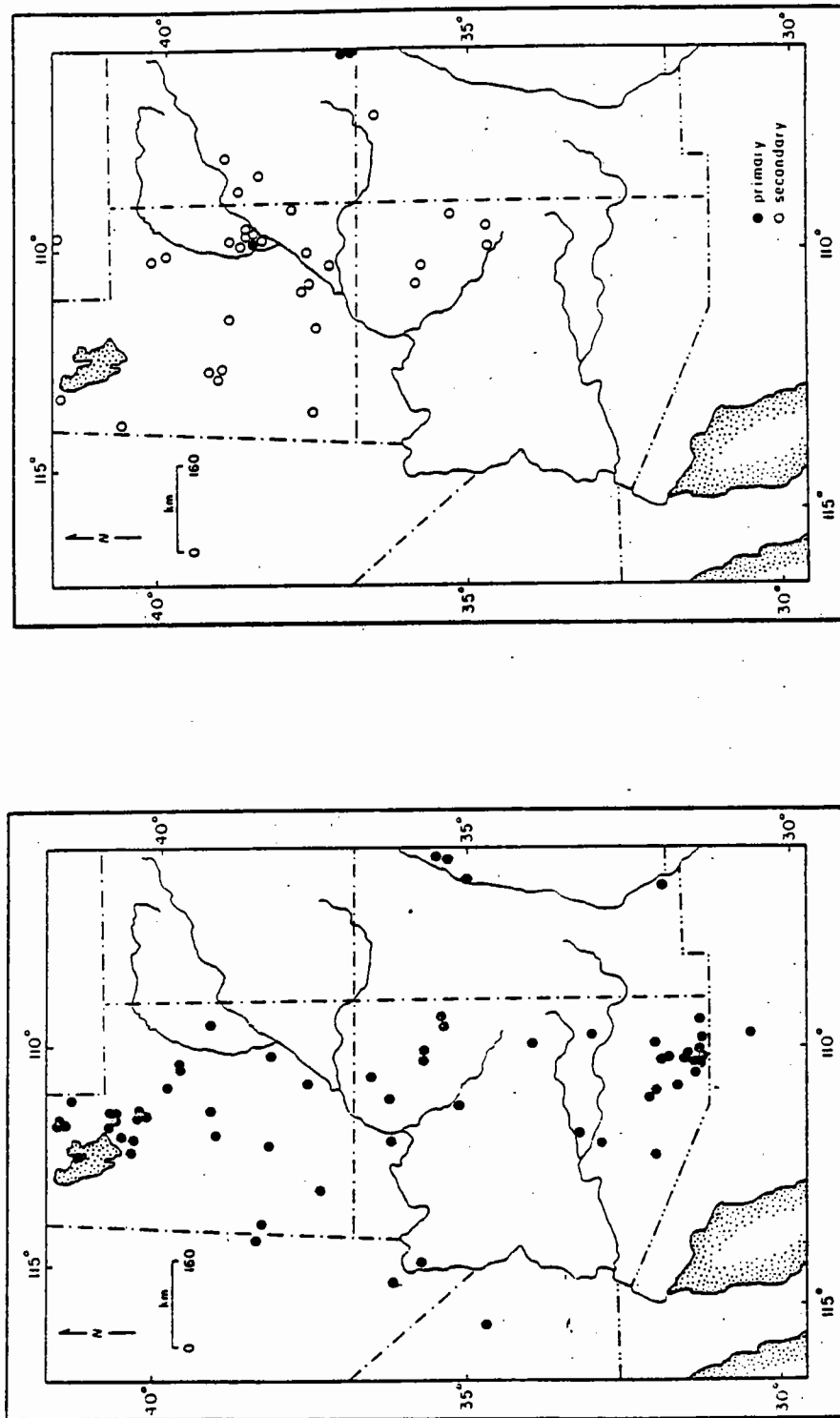


Figure 33. Distribution of reported bison sites and Folsom Culture fluted points (open circle = isolated Folsom point; closed circle = Folsom site).

Faunal Resources

Hunting groups such as Llano, Folsom, and Plano cultures were dependent on the exploitation of faunal resources, primarily big game. The association of Clovis hunters and mammoth is well documented in Arizona, New Mexico, Texas, Colorado, Wyoming, and Oklahoma. Figure 32 depicts the reported mammoth localities for the Southwest (including the Colorado Plateau) and a similar plot for the Clovis mammoth hunter distribution. Figure 33 presents similar data for reported bison localities and known Folsom sites. November, 1984 provided both the first Clovis site (Davis personal communication) and the first Folsom site (Davis 1985) for the Colorado Plateau. Discovery of Folsom points west of the Colorado River during the Phase I field work by the Northern Arizona University (NAU) archaeological contractor (Geib personal communication) indicates Paleoindian hunters were more widespread than many have previously thought on the central Colorado Plateau.

AREA-SPECIFIC (STUDY AREAS) UTILIZATION OF GEOLOGIC RESOURCES

Canyonlands National Park

In the examination of Big Pocket, Salt Pocket, and Devil's Lane portions of Canyonlands (Figure 34), it was evident that all categories of utilization of geologic resources, as outlined above, were available and used. Local chert and jasper outcrops in the Cedar Mesa Sandstone were widely quarried and utilized in projectile points and tool manufacture. This material is recognized by the bright, waxy-red luster of the jasper, in particular. Quartzites, cherts, and chalcedony make up the majority of other lithic raw materials for the hunting and butchering tools. Local sandstones provide the majority of pecked stone (grinding) tools. Clay and mud deposits along Salt Creek (Figure 35) or other water courses supplied most of the ceramic and

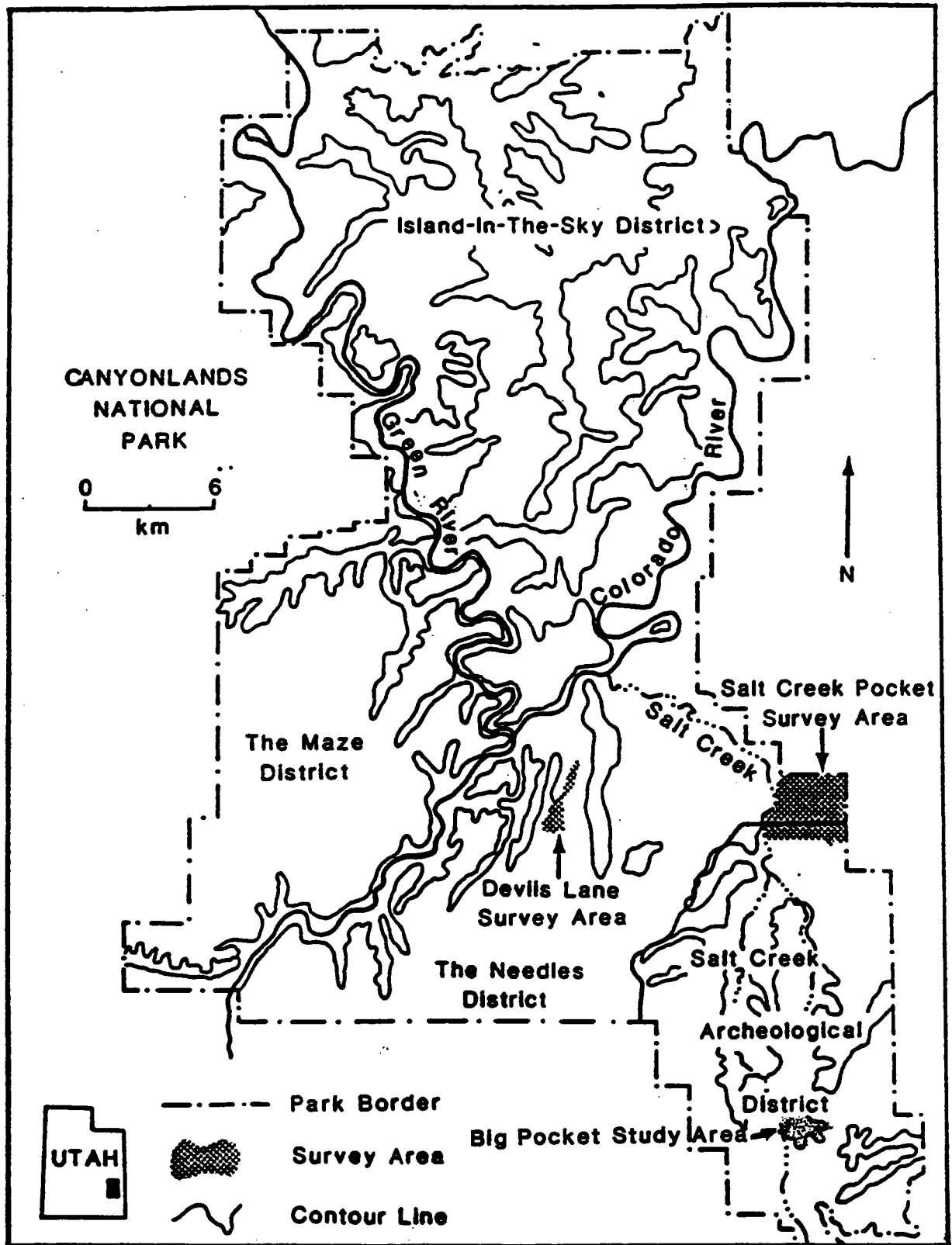


Figure 34. Canyonlands National Park location map.

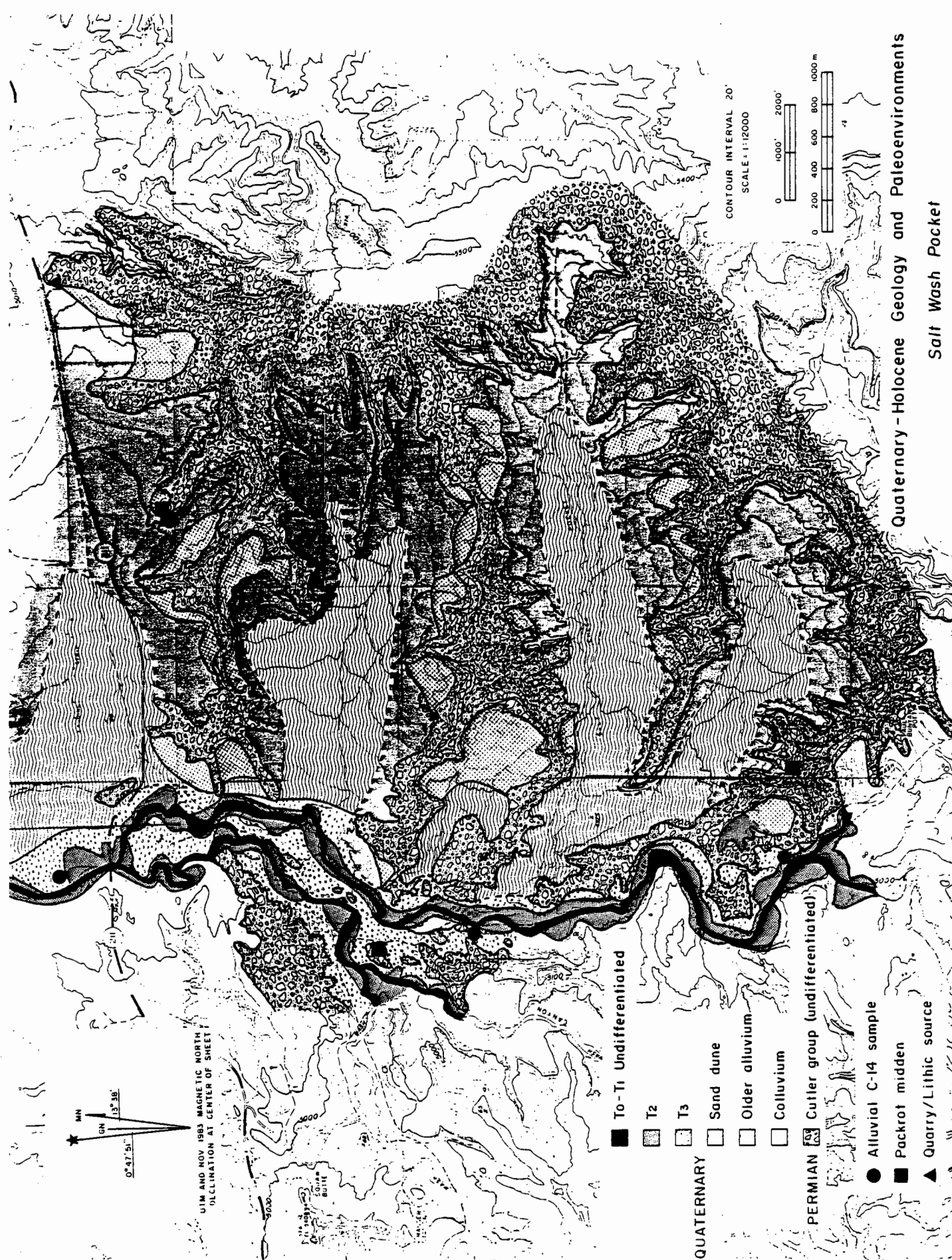


Figure 35. Salt Pocket Quaternary deposits, CANY.

Quaternary-Holocene Geology and Paleoenvironments

Salt Wash Pocket
Canyonlands National Park, Utah

mortar requirements of the populations. The terraces along major drainages appear to have been undissected during the Puebloan, and possibly the Basketmaker occupations, providing farmland with a high water table providing plants with moisture.

Devil's Lane (Figure 36), in the Grabens of Canyonlands National Park contained mostly colluvium (slope wash and alluvial material) with dune sands covering and interfingering with these deposits. Dunes at the southwestern end of Devil's Lane contained hearths and lithic materials. No C-14 dates are presently available for these localities. The pre-ceramic nature of the sites suggests an Archaic occupation and may reflect a hunter-gatherer economy, rather than a horticultural base.

Glen Canyon National Recreation Area

A. Canyons

The canyons adjacent to Bechan Cave (Figure 37) were given a majority of the Phase I research effort, due to the recognized alluvial sequences, and the potential for chronologic control due to cienega (wet ground) accumulations of organic materials. The chronology established in Bechan Cave from the dung unit and the cultural units within the overlying cave fill served as a cross check of the canyon alluvial record.

Again, local resources were reflected in the flaked stone and pecked stone tool assemblages. Quartzite cobbles from the Colorado River terrace gravels were relatively common cultural entities.

Terraces available for horticultural/agricultural use were the surfaces of T₃ and T₂ terraces in the canyons adjacent to Bechan Cave. It appears that the water table was high during the periods of occupation as indicated by cultural dates, the alluvium character, and data from Bechan Cave.

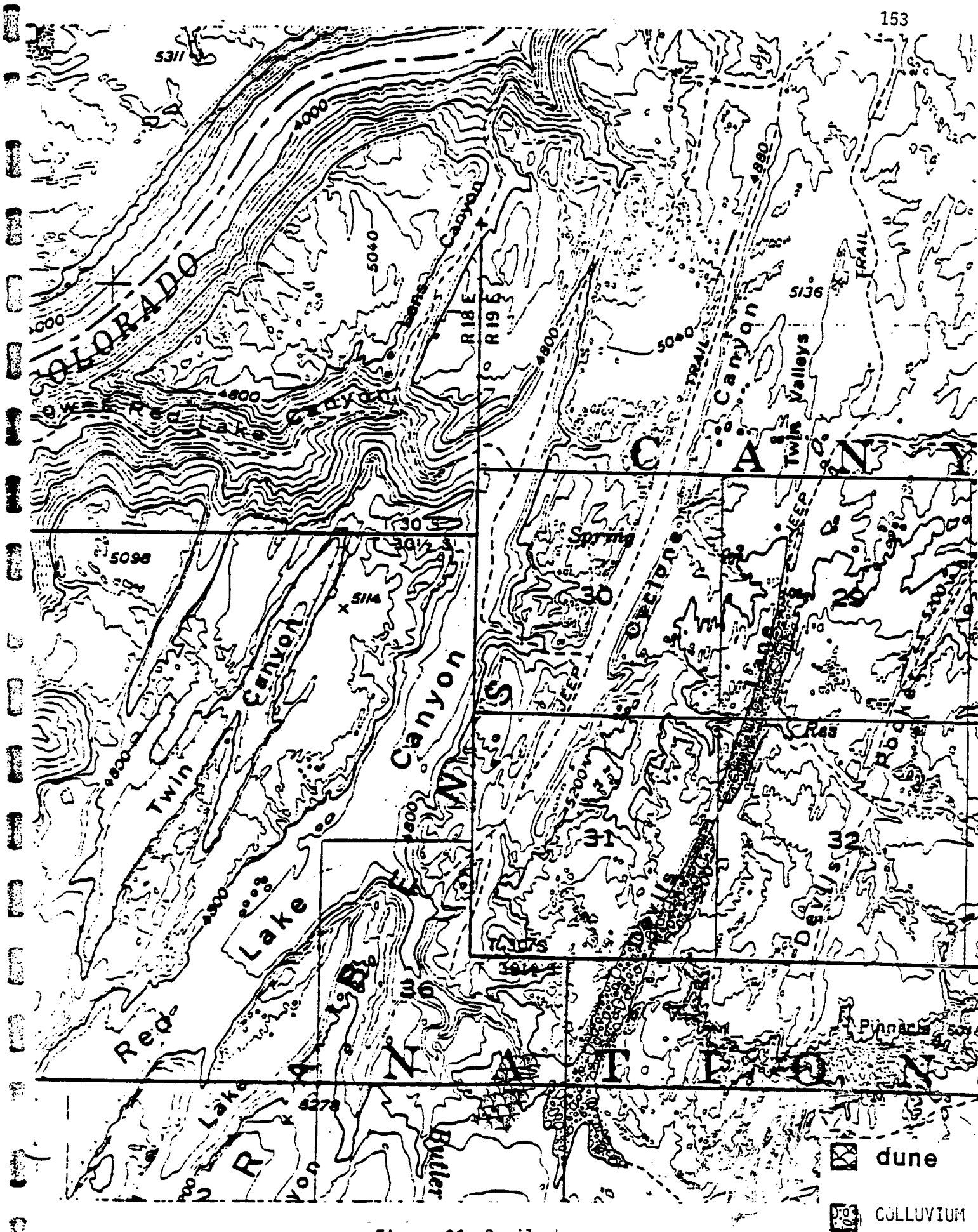


Figure 36: Devils Lane

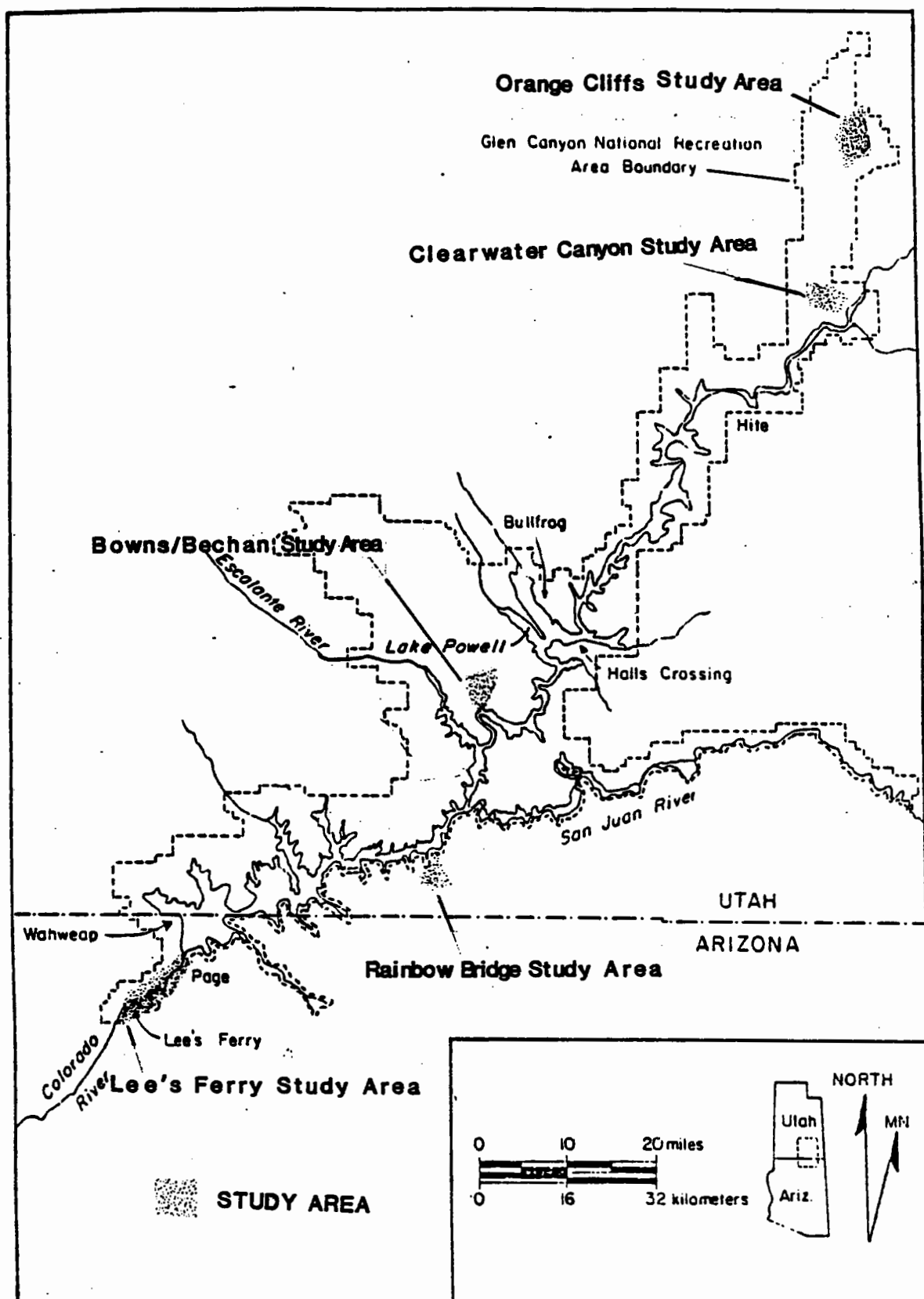


Figure 37. Glen Canyon National Recreation Area location map.

B. Lee's Ferry

Lee's Ferry is discussed as a different province for geologic/geomorphic reasons, as compared to the uplake canyons. Here, alluvial terraces along the Colorado River and Paria River are the areas of exploitation for agricultural and lithic purposes. They differ in size, makeup, and antiquity as compared to uplake canyons such as the ones near Bechan Cave.

The terraces of the Colorado River are preserved as much as 45 m above the present river level. The highest, oldest terraces were utilized primarily as sources of lithic raw material. The gravels armoring the terrace surfaces have been heavily prospected and exploited for quartzite, jasper, chalcedony, and petrified wood. Cortex flakes, cores, hammer stones, and waste flakes are common entities within these terrace cap gravels. These lithic resources have undoubtedly been utilized as long as cultural groups were in the area, due to rather sparse amounts of suitable lithic resources in the local geologic sequence.

Establishing a chronology of the river terraces such as those exposed between Glen Canyon Dam and Lee's Ferry introduces two temporal systems. The highest alluvium is an older Pliocene-Pleistocene terrace sequence exposed primarily downriver from Lee's Ferry; however, remnant gravel capped terraces of this age occur upriver as well. In addition to this old terrace sequence, there is the late Pleistocene-Holocene sequence similar to the sequences exposed in Bowns and Bechan Canyons and in the Salt Creek Drainage. Figure 38 illustrates the location and extent of both terrace systems in the canyon of the Colorado River. Talus and dunes make up the majority of non-terrace Quaternary deposits.

The low terraces along the Paria River and the Colorado River near Lee's Ferry were undoubtedly used for horticulture/agriculture by prehistoric

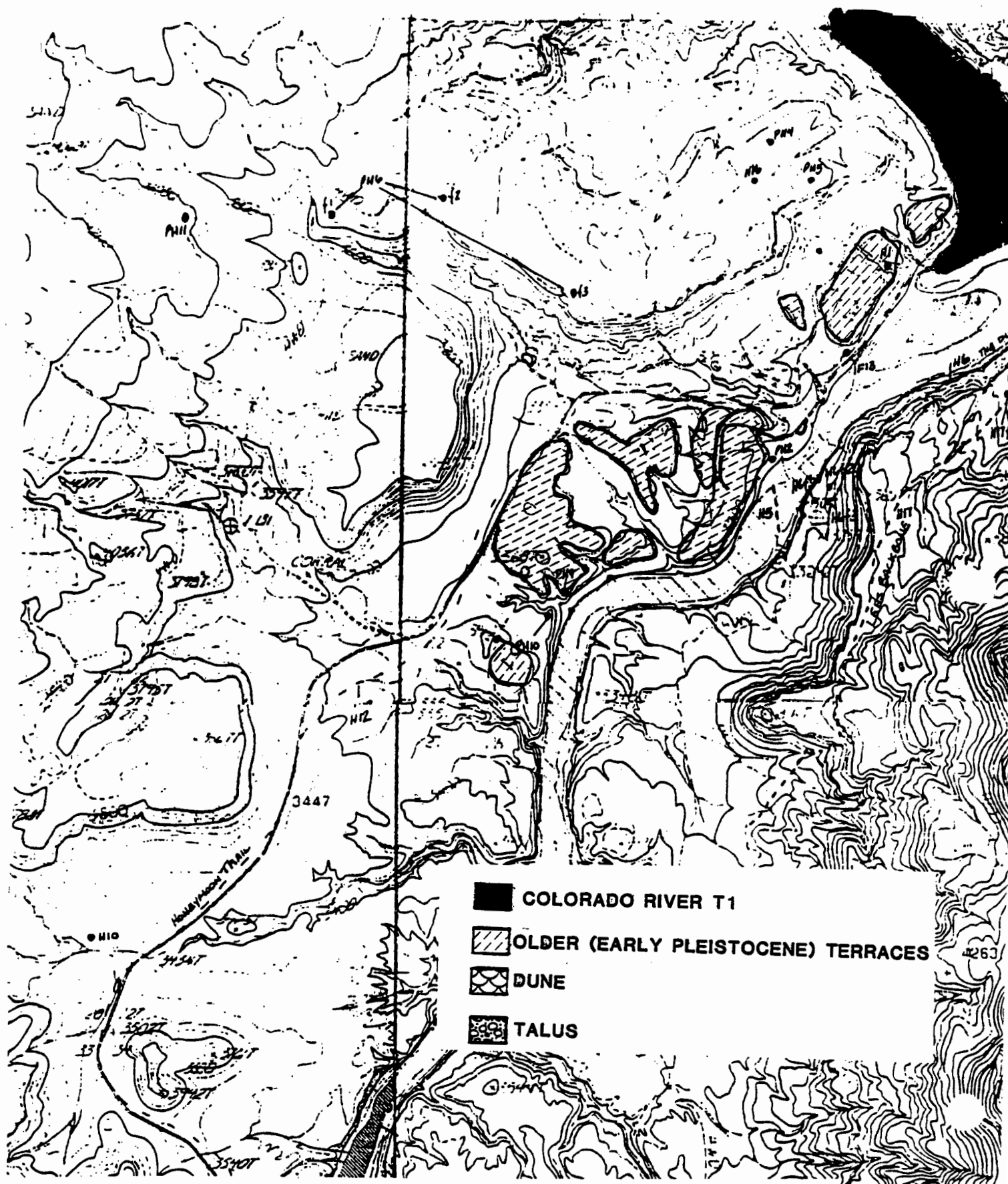
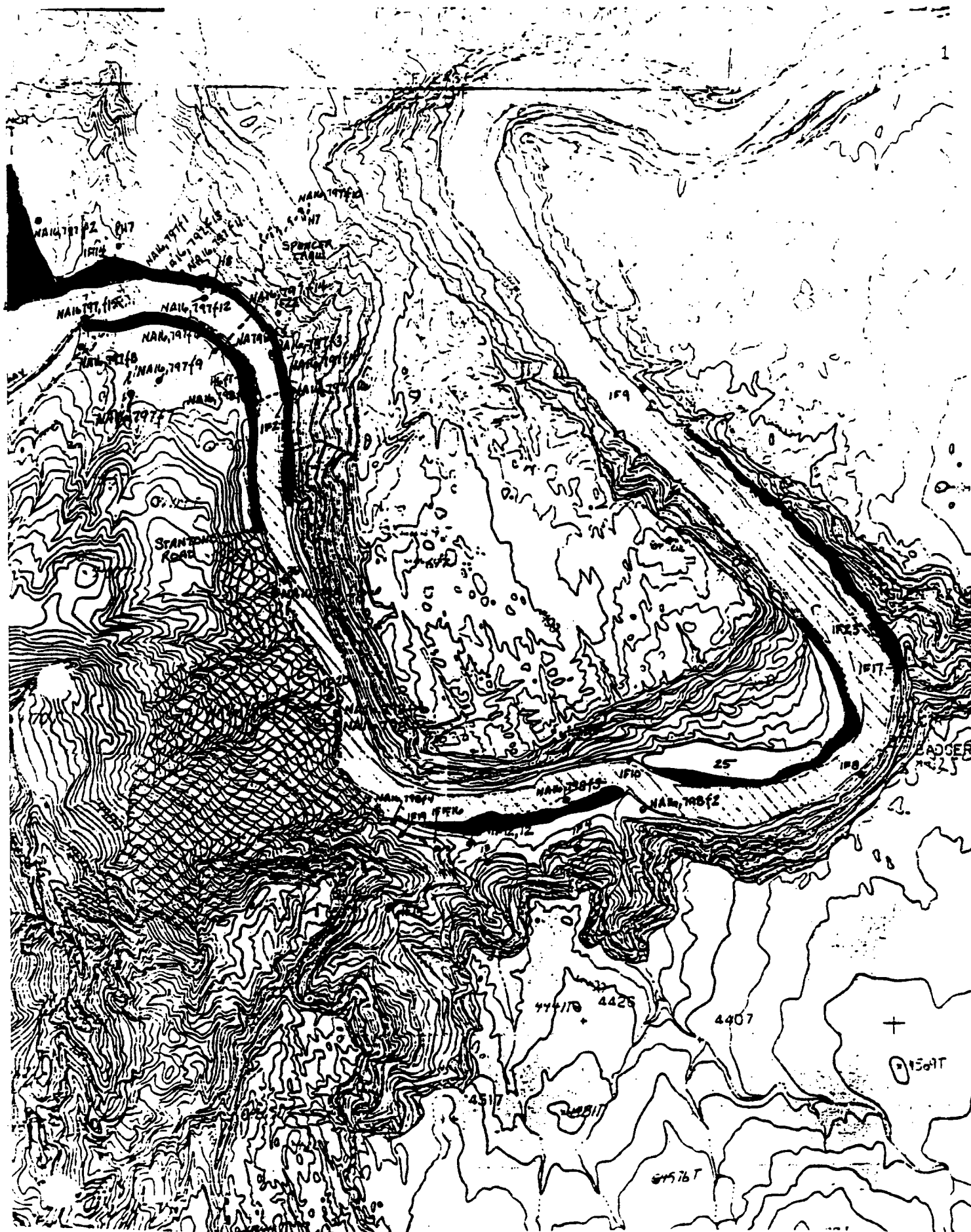
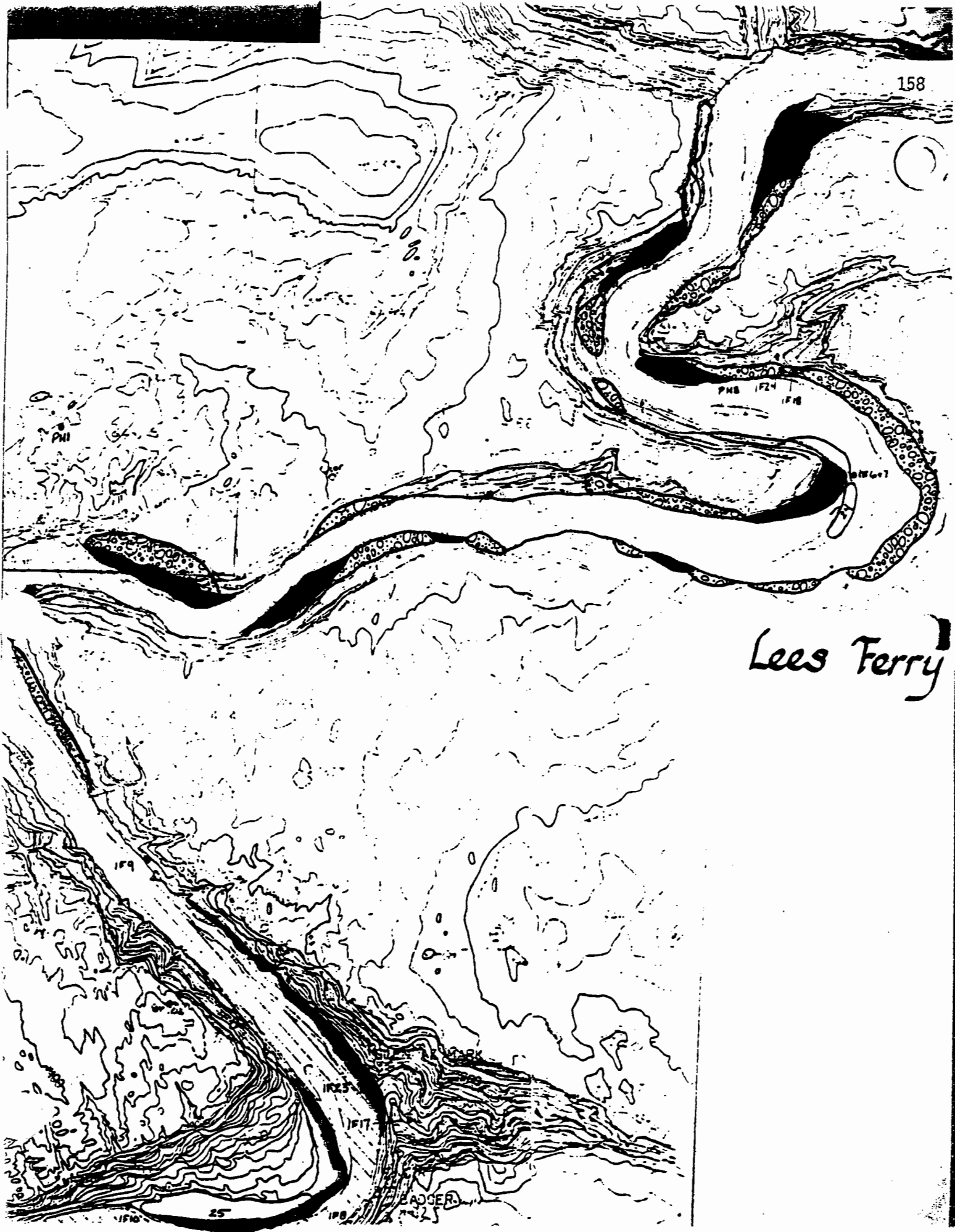
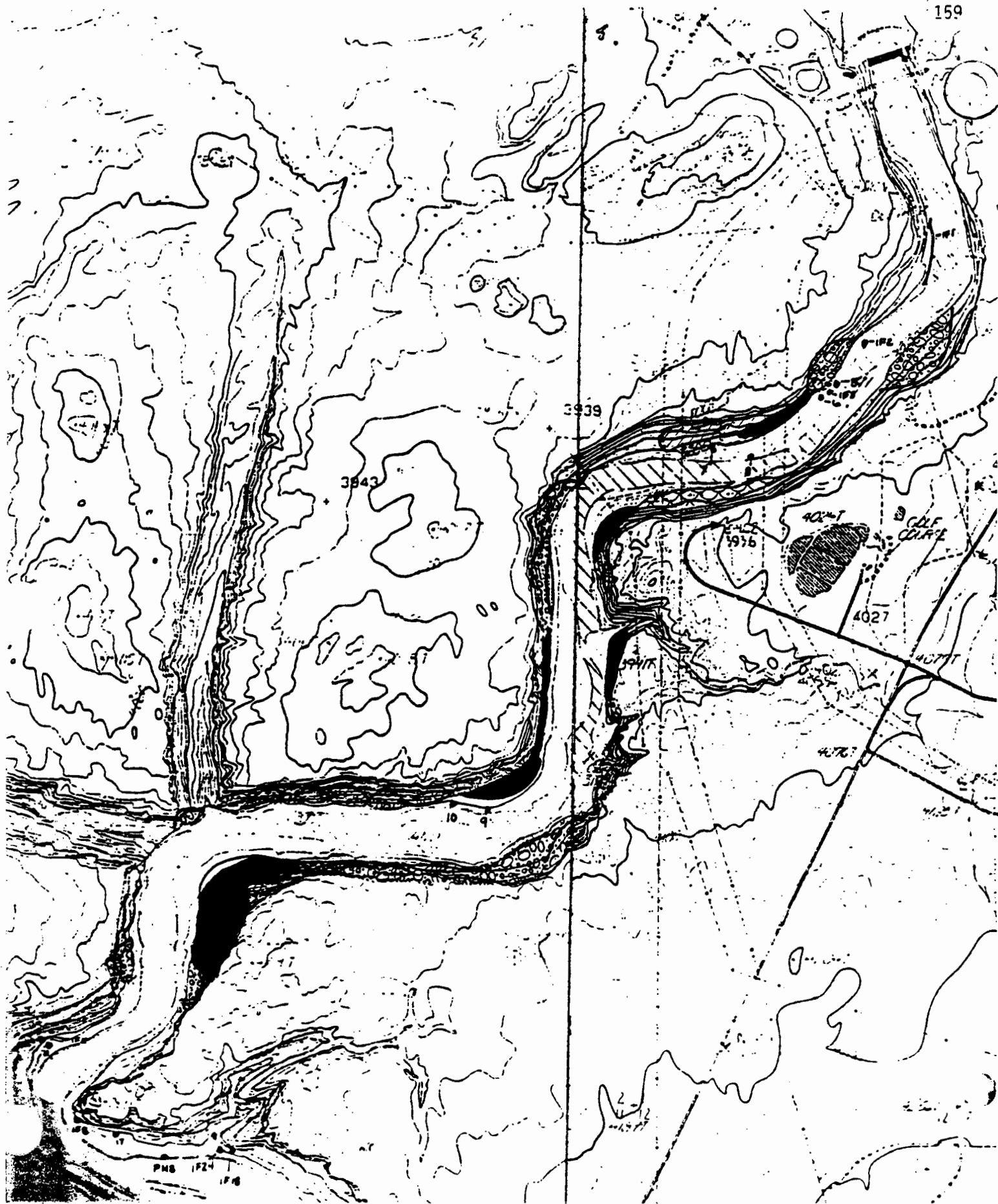


Figure 38. Quaternary deposits of the Lee's Ferry area, GCNRA.







groups. Flooding in both systems would have severely hampered large scale agriculture in this locality, however.

C. Rainbow Bridge

In compliance with the Phase I contract, Quaternary deposits in the area surrounding Rainbow Bridge were mapped (Figure 39). Most of the deposits were talus cones, dunes, and pediment remnants.

D. Orange Cliffs

1. Clearwater Canyon: Lowlands east of Black Ledge (Figure 40) near the head of Clearwater Canyon were surveyed in compliance with the contract specifications and due to the fact that Folsom artifacts were recovered from this locality by the archaeology contractors. The area is characterized by sand dunes resting on the slick rock at the head of the canyon. No stratigraphy or paleoenvironmental material was recovered.

2. The Spur: Two areas on North Point (Figure 41) were surveyed. The surficial material consists primarily of dune sand cover (of various ages) covering the slick rock. No paleoenvironmental material was recovered.

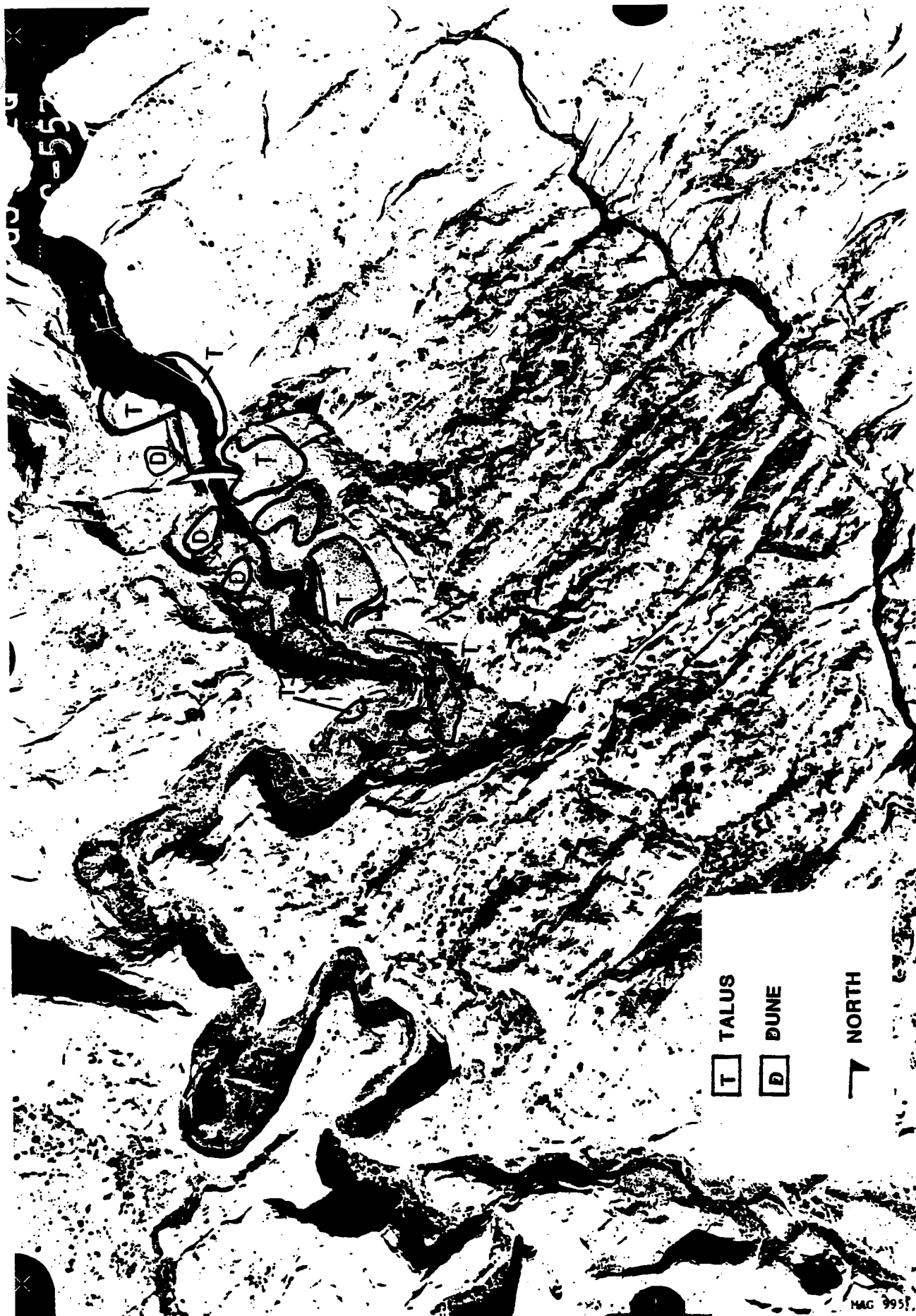


Figure 39. Quaternary deposits at Rainbow Bridge, GCNRA.

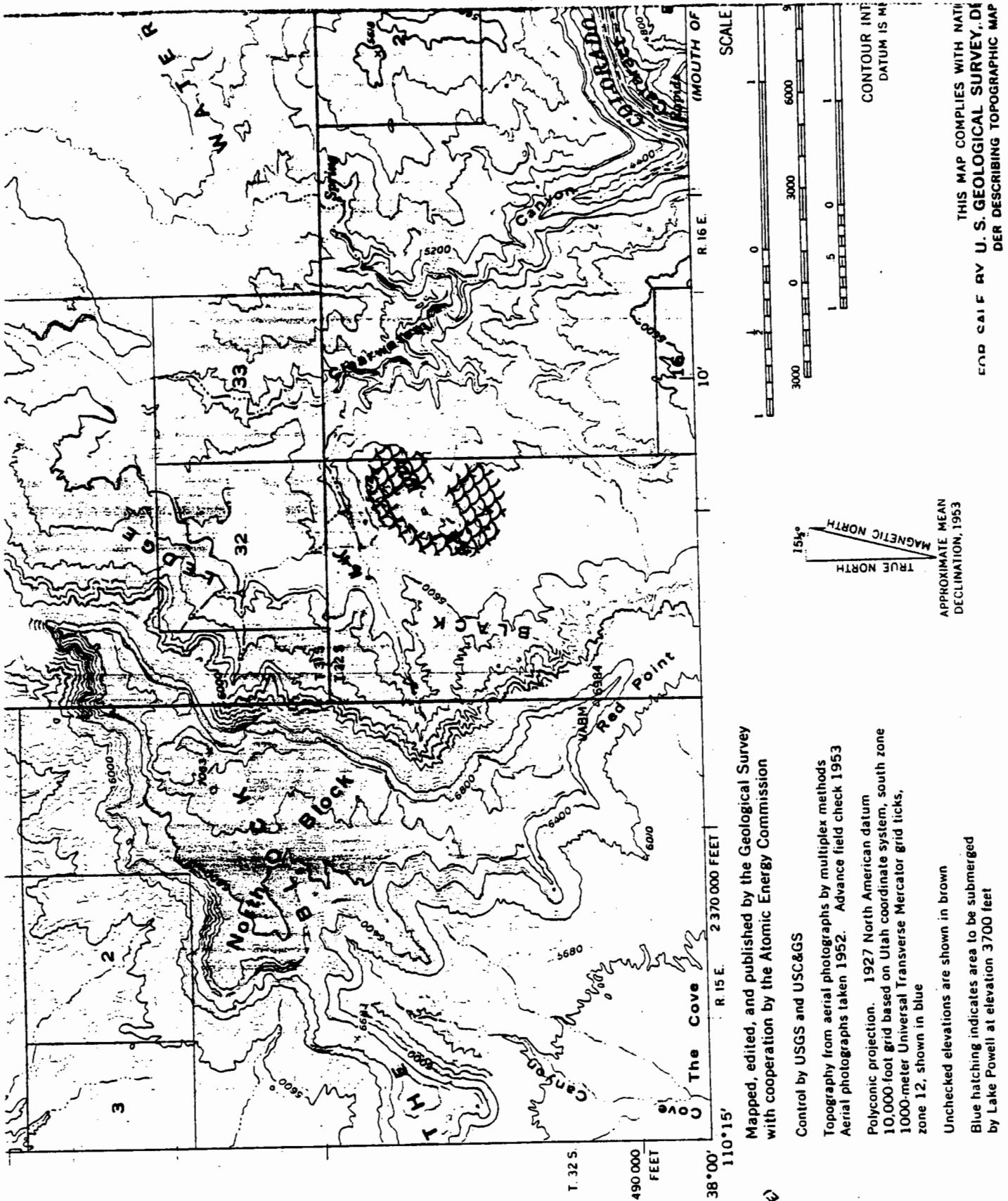
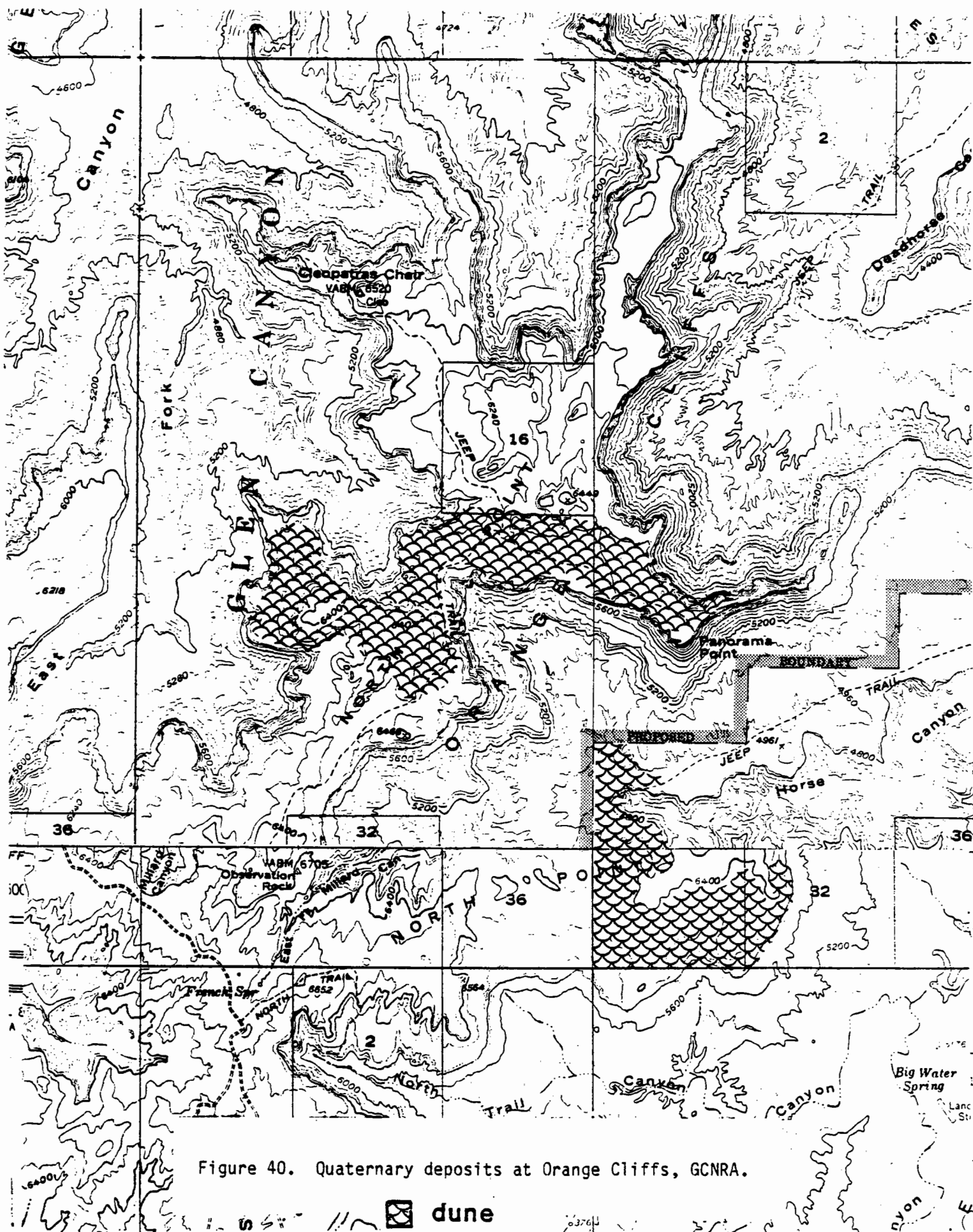


Figure 41. Quaternary deposits at Clearwater Canyon, GCNRA.



Chapter 10

SUMMARY AND CONCLUSIONS

Larry Agenbroad

Analysis of the contents of Bechan Cave began in February, 1983. Recognition of the dung blanket as being formed by extinct Pleistocene megafauna, notably mammoth, provided a unique chance to study a "one-of-a-kind" deposit for the New World. Logistical support by the National Park Service allowed us to initiate investigations on a no-cost basis. The results of our initial testing and analysis provided a major grant from the National Geographic Society.

As early as the initial visit to the cave, the potential of the alluvial deposits of the canyon was recognized. If these deposits contained material and information of equivalent age to the cave deposits, we would have a unique tie of both types of information - a first for North America.

Proposals submitted to the National Science Foundation received favorable reviews, but in two submissions each was rejected, primarily on the remarks of one "expert" in each case. The funding by the National Geographic Society for the cave study was followed by another smaller grant for analysis of the alluvium and its possible tie to the cave data base.

Funding for Phase I of the Canyonlands-Glen Canyon contract allowed the extra level of effort to incorporate studies by colleagues with expertise in ancillary and overlapping disciplines. Preliminary results of both the National Geographic and National Park Service research are presented in this Phase I report. It should also be emphasized that much of our data is still in the sorting, dating, and laboratory analysis stage, to be incorporated with new field data, for the Phase II report.

Emphasis was placed on the Bowns-Bechan area of Glen Canyon in this initial season due to the data already gathered and synthesized from the NGS investigations. The alluvial potential of Bowns led us to believe we could construct a paleoenvironmental change model which could be correlated to the cave fill and extended to other areas of the Parks. It appears that this promise has been fulfilled, and a tentative model is proposed, to be tested and refined with additional work and data retrieval. It also appears there is a preliminary synchronicity (Figure 42) with events recorded in the alluvium of Bowns-Bechan (GLCA) and Salt Creek (CANY) as well as the fill of Bechan Cave. The cave fill also provides an independent check on the cultural activity in the canyons that is preserved in the alluvial terraces.

Palynological and botanical data plus the pack rat studies allow separate, but supporting evidence to the pedologic and geochronologic model gained from the alluvium. Cultural remains document human activity in the study area for at least 8,000 years, and to greater than 11,000 years when one considers the Folsom presence at the Montgomery site in the lower Green River and the Lime Ridge Clovis site near the San Juan (both sites investigated in November 1984). The C-14 control of all aspects of the research is resulting in a sequence of events which can be tied to an absolute chronology framework.

Evidence from Natural Bridges National Monument (NABR) has provided the oldest paleoenvironmental information from the Colorado Plateau. It has also documented the first occurrence of the extinct mountain goat (O. harringtoni) for the state of Utah. This locality, Bowns Canyon and the Cottonwood site near Bluff, Utah have provided the first records of marmot (M. flaviventris) in S.E. Utah.

The site in Cedar Breaks National Monument (CEBR) provided a 9,000-year-old date in its lowest datable horizon. It promises valuable cultural and

C-14 DATES
NPS QUATERNARY STUDIES
CONTRACT # CX-1200-4-A062

Time (BP) x1000 yrs	<u>Glen Canyon Nat'l Recr. Area</u>			<u>Canyonlands Nat'l Park</u>
	<u>Bechan Cave</u>	<u>Canyon Alluvium</u>	<u>Long Canyon</u>	<u>Alluvium</u>
0		.75		.200 - Big Pocket
	.570 - cultural	.215		
1	.1240	.940		.310 - Salt Cr
2	.1310 } cultural	.950 - cultural		.580 - Salt Cr
	.1400			.1640 - Salt Cr
				.1735 - Salt Cr
3	.2080		.2540	.2430 - Salt Cr
	.2640 } cultural			
4		.4025		
		.4090		.4510 - Salt Cr
5		.4965	.5240	.4830 - Salt Cr
6	.5500 - cultural	.5300 - cultural		
7			.6640	
8	.7525 } cultural		.7635	
	.7795			
9			.9545	
10		.10,020		
11	.11670			
12	.11850			
13	.12400 } dung			
	.12620			
14	.12900			
	.13505			
15			.14,860	
16				
17				
18			.17,430	
19				
20				
21				
22				
23				
24				
25				
>40,000				

Figure 42. Synchronicity of alluvial events and cultural presence.

— denotes degradation (cut) in alluvial sequence.

paleoenvironmental data for high altitudes (3,048 m) for the early to middle Holocene. As soon as permits are available, this site will be sampled further.

Salt Creek and the Grabens in Canyonlands (CANY) have provided a Holocene alluvial record and several pack rat middens containing remains of Pleistocene forests. These samples are currently being analyzed and dated. The information will enhance and expand the summary data presented by Betancourt (this report).

Using the data base gathered through the first contract year, an exciting, testable, C-14 controlled model has been constructed. It will be refined and extended in Phase II. Already, Phase II research has provided exciting new localities which hold promise of at least as much new information as the previous research.

Phase I has demonstrated the validity of many of our hypotheses listed in the preliminary research design. It has allowed us to construct a C-14 controlled model, based on several interdisciplinary lines of evidence which provides an initial basis for interpretation of paleoenvironmental change and the relationship of extinct and modern fauna and flora to these changes. It also documents the presence of human groups in the study area and surrounding region, which will allow us to formulate models of human interaction with, exploitation of, and adaptation to these environmental changes.

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APPENDIX I

Soil Descriptions

This section contains the soil field descriptions for the geosols of the Bechan Canyon Area. These descriptions follow the specifications found in Soil Taxonomy, written by the Soil Survey Staff.

There are eight field descriptions representing the characteristics of eight soil profiles. Soils can be classified on the basis of their field characteristics and their laboratory data. Among the important field properties are depth, color (according to the Muncel color system), texture, structure, consistence (wet, dry, and moist), reaction to HCl, and other properties such as amount of roots, charcoal, pore space, etc.

FIELD DESCRIPTION: SOIL 1

Classification: Fluvent (0 - 280.5cm.); Haplargid (280.5 - 442.5cm.).

Location: Bechan Canyon, Glen Canyon N.R.A.

Physiographic Position: South facing terrace (T3b). Elevation is ca. 4000'.

Topography: Terrace slope of 1 percent to the southeast.

Drainage: Well drained soil. Rapid to very rapid permeability.

Vegetation: Atriplex canescens; Salvia sp.

Parent Material: Dominantly alluvium with eolian material (0 - 34cm.), and possibly some colluvium as well.

Remarks: The upper 34cm. of the section may be of dune origin and not "Tsegi" alluvium. The colors of the thick red Bw horizon in the bottom (Altithermal?) buried soil may be inherited from the parent material (Kayenta alluvium?), or may be due to natural soil forming processes. Unidentified dark green mottles (organics?) occur throughout the horizons.

- A 0 - 15cm. (0-6 inches). Reddish brown to yellowish red (5YR 4/4 - 6/4, moist) medium sand; weak coarse subangular blocky structure; very friable (moist), non-sticky and non-plastic(wet); slightly effervescent; interfingering of A and C horizons, abrupt smooth boundary.
- C 15 - 34cm. (6-13 inches). Reddish yellow (7.5YR 6/6) medium sand; weak fine to medium subangular blocky structure; soft(dry), very friable(moist), non-sticky and non-plastic(wet); non-effervescent; many modern roots, some weak crossbedding; abrupt smooth boundary.
- Ab 34 - 49cm. (13-19 inches). Strong brown (7.5YR 4/6 - 5/6) fine sand; moderate fine to coarse subangular blocky structure with moderate fine granular peds in the upper portion of the horizon; slightly hard(dry), very friable(moist), non-sticky and non-plastic(wet); slightly effervescent; many rootlets filled with calcium carbonate, some up to 2 mm in length; clear smooth boundary.
- C' 49 - 61cm. (19-24 inches). Strong brown to reddish yellow (7.5YR 6/6 - 5/6) medium sand; weak fine to coarse subangular blocky structure; soft(dry), very friable(moist), non-sticky and non-plastic(wet); slightly effervescent; rootlets and small lime concretions present throughout the horizon, abrupt smooth boundary.
- Ab' 61 - 70.5cm. (24-27 inches). Brown to strongly brown (7.5YR 5/4 - 5/6) fine to medium sandy loam; moderately weak fine to coarse subangular blocky structure soft(dry), very firm(moist), non-sticky and non-plastic(wet); slightly effervescent; small (less than 2 mm) rootlets and few lime concretions; clear smooth boundary.
- C'' 70.5 - 90.5cm. (27- 35 inches). Reddish yellow (7.5YR 6/6) medium sand; weak fine to coarse subangular blocky structure; soft(dry), very friable (moist), non-sticky and non-plastic(wet); non-effervescent; small lime concretions, abrupt smooth boundary.

- Ab'' 90.5 - 99.5cm. (35-39 inches). Brown to dark brown (7.5YR 4/4) sandy loam; strong medium to coarse crumb structure and moderate to strong, fine to medium subangular blocky; slightly hard(dry), friable(moist), slightly sticky and slightly plastic(wet); violently effervescent; roots, root casts and insect holes near the bottom of the horizon; this is the best developed A horizon; abrupt wavy boundary.
- C1 99.5 - 125.5cm. (39-49.5 inches). Reddish yellow (5YR 6/6) medium sand; moderate fine to coarse angular blocky structure; slightly hard(dry), very friable(moist), non-sticky and non-plastic(wet); slightly effervescent; traces of charcoal, less than 5 percent lime concretions; clear smooth boundary.
- C2 125.5 - 153.5cm. (49.5-60.5 inches). Light reddish brown (5YR 6/4) fine to medium sand; strong fine to coarse subangular blocky structure; slightly hard(dry), very friable(moist), non-sticky and non-plastic(wet); slightly effervescent; some very fine lime concretions and lime rootlets; dark green mottles prominent in some sections of this horizon; diffuse smooth lower boundary.
- C3 153.5 - 203cm. (60.5-80 inches). Light red (5YR 7/6) fine to medium sand; moderate fine to coarse subangular blocky and moderate fine to coarse angular blocky; slightly hard(dry), friable(moist), non-sticky and non-plastic(wet); slightly effervescent; many modern roots, rootlets, and vesicles; abrupt smooth boundary.
- Ab''' 203 - 207cm. (80-82 inches). Pinkish-grey (5YR 6/2) fine sand moderate fine to medium subangular blocky structure; slightly hard(dry), friable(moist), non-sticky and non-plastic(wet); violently effervescent; many vesicles and modern rootlets; less than 5 percent lime concretions; charcoal is present throughout this horizon, which appears to be a laterally discontinuous unit; abrupt wavy boundary.
- C''' 207 - 280.5cm. (82-110 inches). Reddish yellow (5YR 7/6) fine to medium sand; strong coarse subangular blocky structure; slightly hard(dry), friable(moist), non-sticky and non-plastic(wet); slightly effervescent; many vesicles and an abrupt smooth boundary.
- Ab'''' 280.5 - 284cm. (110-112 inches). Strong brown (7.5YR 4/6) sandy loam; moderate fine to coarse angular blocky structure; hard(dry); friable(moist), sticky and plastic(wet); violently effervescent; reworked A horizon and an abrupt smooth boundary.
- Bw1 284 - 326cm. (112-130 inches). Reddish yellow (5YR 6/6) sandy loam; moderate medium to coarse angular blocky structure; hard(dry), very friable(moist), slightly sticky and slightly plastic(wet); slightly effervescent; charcoal, many small lime concretions, and vesicles present; medium sized chert pebbles (less than 1.5 cm.); diffuse wavy lower boundary.
- Bw2 326 - 350.5cm. (130-138 inches). Yellowish red (5YR 5/6) fine to medium sand; moderate fine to coarse subangular blocky structure; hard(dry), very friable(moist), non-sticky and non-plastic(wet); slightly effervescent; many modern rootlets, vesicles, charcoal and small to medium (1.0 - 2.0 cm.) pebbles and a gradual smooth boundary.

- C1 350.5 - 411.5cm. (138-162 inches). Reddish yellow (5YR 7/6) fine to medium sand; weak fine to coarse subangular blocky structure; slightly hard(dry), friable(moist), non-sticky and non-plastic(wet); slightly effervescent; this horizon consists of a repeated sequence of red - buff - red - buff layers with the red layers slightly effervescent and the buff layers violently effervescent; in contact with the lower buff horizon is a boulder horizon (25 cm. to 75 cm. diameter); abrupt smooth boundary.
- C2 411.5 - 442.5cm.(162-174 inches). Red (2.5YR 4/8, moist) silt loam; weak fine to coarse subangular blocky structure; very friable(moist), slightly sticky and slightly plastic(wet); slightly effervescent; abrupt smooth boundary with the bedrock.
- R Kayenta Fm. Marginal marine deposits of siltstones, sandstones and limestones.

FIELD DESCRIPTION: SOIL 2

Classification: Fluvent
 Location: Bounds Canyon, Glen Canyon N.R.A
 Vegetation: Willow, globe mallow, cottonwood.
 Parent material: Alluvial deposits from the Navajo Fm.
 Physiographic Position: T1 terrace about 2 meters above stream level.
 Drainage: Well drained.
 Elevation: ca 4000 feet.
 Topography: Flat terrace top.
 Remarks: This is profile 2. Overbank deposits of the T0 terrace are observed overtopping the T1 terrace. Tree ring date of a cottonwood on the T1 terrace is 25 years.

- Oi 1 to 0 cm. Gray (2.5 YR 5/0 d).
- C 0 to 20 cm. Reddish yellow (7.5 YR 7/6 d) very fine sand; weak, moderate to coarse subangular blocky structure; soft (dry); very friable (moist): nonsticky, nonplastic (wet); noneffervescent; clear wavy boundary.
- A 20 to 43 cm. Strong brown (7.5 YR 5/6 d) very fine sand; weak, moderate to coarse subangular blocky structure; soft (dry); very friable (moist); non-sticky, nonplastic (wet); slightly effervescent; clear wavy boundary.
- C1 43 to 92 cm. Reddish yellow (7.5 YR 7/6 d) very fine sand; weak, medium to coarse subangular blocky structure; soft (dry); very friable (moist); non-sticky, nonplastic (wet); noneffervescent; abrupt smooth boundary.

FIELD DESCRIPTION: SOIL 3

Classification: Fluvent
 Location: Bechan Canyon, Glen Canyon N.R.A.
 Physiographic position: T2 terrace on the east side of confluence.
 Topography: Flat.
 Elevation: ca. 4000 feet.
 Drainage: Well drained.
 Parent material: Alluvial deposits of Navajo SS.

Vegetation: Mixed grasses, cottonwood, spanish sword, prickly pear cactus.
 Remarks: Profile 3. T2 terrace here is about 3 meters below T3 in elevation

- O; 0.5 to 0 cm. Gray (2.5 YR 7/6 d).
- C 0 to 13 cm. Reddish yellow (7.5 YR 6/6 d). very fine sand, weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; abrupt smooth boundary; cicada holes and seed pods present.
- Ab 47 to 59 cm. Brown (7.5 YR 5/4 d) very fine sand; moderate fine to medium subangular blocky structure; slightly hard (dry); friable (moist); slightly sticky, slightly plastic (wet); strongly effervescent; abundant roots and rootlets; abrupt smooth boundary.
- C" 9 to 80 cm. Reddish yellow (5YR 6/6 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; abundant roots and rootlets; abrupt smooth boundary.
- Ab" 80 to 93 cm. Reddish yellow (5 YR 6/6 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; many fine lime masses; abrupt smooth boundary.
- C' " 92 to 121 cm. Reddish yellow (5 YR 6/6 d) very fine sand; weak fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; few roots; lime masses occurring in discrete concretions and filaments; abrupt smooth boundary.
- Ab''' 121 to 135 cm. Reddish brown (5 YR 5/4 d) very fine sand; moderate fine to medium angular blocky structure; soft (dry); very friable (moist); slightly sticky, nonplastic (wet); strongly effervescent; many fine distinct lime masses and root casts of CaCO₃; abrupt smooth boundary.
- C'''' 133-166 cm. Reddish yellow (7.5 YR 6/6 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky nonplastic (wet); noneffervescent; few modern and ancient roots; root casts of CaCO₃; abrupt smooth boundary.
- Ab''' 166 to 175 cm. Strong brown (7.5 YR 5/6 m) very fine sand; weak fine to medium subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; abrupt smooth boundary.
- CV 175 to 183 cm. Strong brown (7.5 YR 5/6 m) very fine sand; weak, fine to medium subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; fine charcoal flecks; abrupt smooth boundary.
- Ab'''' 183 to 193 cm. Reddish yellow (7.5 YR 6/6 m) very fine sand; weak, fine subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet); few fine distinct reddish yellow (7.5 YR 6/8 m) limonite stains; many, fine, prominent brown (7.5 YR 5/2 m) organic stains; few, fine, distinct charcoal flecks; slightly effervescent; clear smooth boundary.
- CVI 193 to 223 cm. Reddish yellow (7.5 YR 6/6 d) very fine sand; weak, fine to medium subangular blocky structure; slightly hard (dry); very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; few modern roots and rootlets; few, fine, prominent charcoal flecks abrupt smooth boundary.

- AbV 223 to 231 cm. Light reddish brown (5 YR 6/3 d) very fine sand; moderate, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); few, fine, prominent charcoal flecks; strongly effervescent; clear wavy boundary.
- C1 231 to 296 cm. Reddish yellow (7.5 YR 6/6 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; few roots; few, fine, faint lime masses; diffuse smooth boundary.
- C2 296 to 313 cm. Reddish yellow (7.5 YR 6/6 d) very fine sand; moderate, fine to medium, subangular blocky structure; slightly hard (dry); very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; moderate, faint lime masses; diffuse smooth boundary.
- C3 313 to 359 cm. Strong brown (7.5 YR 5/6 m) very fine sand; weak, moderate to coarse subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; plentiful roots; few, fine, prominent charcoal flecks; few, fine, distinct reddish yellow (7.5 YR 6/8 m) limonite stains; abrupt smooth boundary.
- 2C 359 to 389 cm. Strong brown (7.5 YR 5/6 m) very fine sandy gravel; 20 percent gravels less than 40 cm. long; single grain structure; very friable (moist); nonsticky, nonplastic (wet); strongly effervescent; coarsening upward sequence from sands to gravels; abrupt smooth boundary.
- 3C 389 to 418 cm. Reddish yellow (7.5 YR 6/6 m) very fine sandy gravel; very weak, fine to medium subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; abundant roots; abrupt smooth boundary.
- 4C 418 to 468+ cm. Yellowish red (5 YR 5/6 m) very fine sandy gravel; 15 percent gravels less than 7 cm.; weak, fine to medium subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet); strongly effervescent; boulders are rounded to angular blocky; buried boundary.

FIELD DESCRIPTION: SOIL 4

Classification: Fluvent

Location: Bounds Canyon, N.RA

Physiographic position: T3 terrace ca 300 feet south of confluence.

Topography: Flat terrace top

Elevation: ca 4000 feet.

Drainage: Well drained

Parent material: Alluvial deposits of the Navajo Fm.

Vegetation: Grasses, sage, juniper.

Remarks: Profile 4 of the T3 terrace. Age determination of equivalent terraces in this canyon is about 4500 B.P. (C-14).

Oi 1 to 0 cm. Gray (7.5 YR 5/0 d).

A 0 to 24 cm. Strong brown (7.5 YR 4/6 d) very fine sand; weak, fine to medium subangular blocky structure; soft to slightly hard (dry); very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; abundant rootlets; abrupt smooth boundary.

- C 24 to 60 cm. Reddish yellow (7.5 YR 6/6 d) very fine sand; single grained structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; abundant modern rootlets; cicada holes of 10 cm. diameter; abrupt smooth boundary.
- Ab 60 to 106 cm. Pinkish gray (7.5 YR 6/2 d) loamy fine sand; moderate. fine to medium subangular blocky structure; slightly hard to hard (dry); friable (moist); slightly sticky slightly plastic (wet); violently effervescent; many fine rootlets; very fine, common pores; dark brown (7.5 YR 4/4 d) iron oxide stains; clear smooth boundary.
- Bk 106 to 138 cm. Reddish yellow (7.5 YR 6/6 d) very fine sand with common large distinct, strong brown (7.5 YR 5/8 d) limonite stains; moderate, medium to coarse angular blocky structure; slightly hard (dry); very friable (moist); nonsticky, nonplastic (wet); violently effervescent; possible MnO₂ stains; very common fine pores; clear, smooth boundary.
- Ck 138 to 168 cm. Light brown (7.5 YR 6/4 d) very fine sand with common, medium, prominent strong brown (7.5 YR 8/4 d) lime masses; soft (dry); very friable (moist); nonsticky, nonplastic (wet); violently effervescent; very fine, common random, distinct, impeded pores; diffuse smooth boundary.
- C1 168 to 188 cm. Pink (7.5 YR 7/4 d) very fine sand; moderate, medium to coarse subangular blocky structure; soft to slightly hard (dry); very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; common, medium, prominent, strong brown (7.5 YR 5/8 d) limonite stains; gradual smooth boundary.
- C2 188 to 212 cm. Reddish yellow (7.5 YR 7/6 d) very fine sand; weak, medium to coarse subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; few, fine, faint lime masses; few fine roots; abrupt smooth boundary.
- Ab'' 212 to 245 cm. Light yellowish brown (10 YR 6/4 d) very fine sand; moderate, fine to medium angular blocky structure; slightly hard to hard (dry); very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; few, medium, distinct strong brown (7.5 YR 5/8 d) limonite stains; clear smooth boundary.
- C1' 245 to 295 cm. Light brown (7.5 YR 6/4 d) very fine sand; weak, fine to medium subangular blocky structure; soft to slightly hard few, fine, distinct lime masses; clear smooth boundary; grades laterally into a dark yellow limonite stained horizon.
- C2' 295 to 339 cm. Strong brown (7.5 YR 5/6 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; clear smooth boundary.
- C3 339 to 403 cm. Pink (7.5 YR 7/4 d) very fine sand; weak, fine to coarse subangular blocky structure; soft (dry); very friable (moist); nonsticky nonplastic (wet); noneffervescent: few, fine, faint lime filaments; fluvial cross beds; abrupt smooth boundary.
- Ab'' 403 to 415 cm. Brown (7.5 5/4 m) very fine sand; weak, fine to medium subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet); non-effervescent; few, fine roots, slight bioturbation; abrupt smooth boundary.

- C' 415 to 430 cm. Reddish yellow (7.5 YR 6/6 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); non-sticky, nonplastic (wet); noneffervescent; few fine rootlets; abrupt smooth boundary.
- Ab1 430 to 440 cm. Dark brown (7.5 YR 3/2 m) very fine sand; moderate, fine to medium subangular blocky structure; friable (moist); nonsticky, nonplastic (wet); strongly bioturbated; few fine pores; clear smooth boundary.
- Ab2 440 to 449 cm. Strong brown (7.5 YR 4/6 m) very fine sand; weak, fine to medium subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet); strongly bioturbated; abrupt smooth boundary.
- C'' 449 to 460 cm. Reddish yellow (7.5 YR 6/6 d) very fine sand; weak fine subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; some bioturbation; abrupt smooth boundary.
- Ab^{VIII} 620 to 628 cm. Dark gray brown (10 YR 4/2 m) loamy sand; moderate, fine to medium subangular blocky structure; friable (moist); slightly sticky, slightly plastic (wet); noneffervescent; some bioturbation; few fine roots; abrupt smooth boundary.
- C^{VIII} 628 to 653 cm. Dark yellowish brown (10 YR 4/6 m) very fine sand; weak fine to medium subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet), noneffervescent; common, medium, distinct reddish yellow (7.5 YR 4/4 m) limonite stains; abrupt smooth boundary.
- Ab^{IX} 653 to 672 cm. Dark yellowish brown (10 YR 4/4 m) very fine sand; weak, fine to medium subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet); noneffervescent; few, fine faint charcoal flecks; some bioturbation; abrupt smooth boundary.
- C^{IX} 672 to 753 cm. Brown (7.5 YR 5/4 m) very fine sand; weak, fine to medium subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet); noneffervescent; much modern root activity from slope vegetation; abrupt smooth boundary.
- R 753+ cm. Red (2.5 YR 4/6 m) Navajo SS.

FIELD DESCRIPTION: SOIL 5

Classification: Aridisol

Location: Bounds Canyon, Glen Canyon N.R.A.

Physiographic position: T3 Terrace, west facing profile.

Topography: Flat.

Elevation: ca. 4000 feet.

Drainage: Well drained

Parent material: Alluvial deposits of the Navajo Fm.

Vegetation: Short grasses, sage

Remarks: Profile 5 is a composite profile of an upstream section (0 to 126 cm.) and a section 25 feet downstream (126 to 447 cm.) On the basis of morphology, the upper 54 cm. of the top section is considered to be dune material. The lower section was initially thought to be isochronous with the profile 1 Altithermal soil. It now seems quite clear that while this soil exhibits

a higher degree of oxidation than the younger T1 and T2 terrace soils, the texture and structure are not as well developed as the Altithermal and therefore is interpreted to be a post Altithermal soil.

- Oi 1 to 0 cm. Gray (7.5 YR 5/0 d).
- A 0 to 12 cm. Strong brown (7.5 YR 5/6 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; many modern rootlets; clear smooth boundary.
- C 12 to 54 cm. Reddish yellow (7.5 YR 6/8 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky nonplastic (wet); noneffervescent; plentiful modern roots; abrupt smooth boundary.
- Ab' 54 to 63 cm. Brown (7.5 YR 5/4 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet) noneffervescent; insect holes; few modern roots; clear smooth boundary.
- C' 63 to 107 cm. Reddish yellow (7.5 YR 6/6 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; many modern roots; abrupt smooth boundary.
- Ab'' 107 to 114 cm. Strong brown (7.5 YR 5/6 m) very fine sand; weak fine to medium subangular blocky structure; very friable (moist); slightly effervescent; few modern roots; clear smooth boundary.
- C'' 114 to 126 cm. Reddish yellow (7.5 YR 5/6 m) very fine sand; weak fine to medium subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; few, fine charcoal flecks; few modern roots; abrupt smooth boundary.
- Ab''' 126 to 136 cm. Dark brown (7.5 YR 4/2 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); strongly effervescent; clear smooth boundary; bioturbation causes mixing of the C and Ab horizon; Ab thins laterally.
- Bw 136 to 180 cm. Reddish yellow (5 YR 6/6 d) very fine sand; weak, fine to medium angular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); strong to violent effervescence; few ancient and modern roots; common, moderate, distinct lime masses; diffuse smooth boundary.
- Bk 180 to 236 cm. Reddish yellow (7.5 YR 6/6 d) very fine sand; weak, fine to coarse subangular blocky structure; soft to slightly hard (dry); very friable (moist); nonsticky, nonplastic (wet); slight to strong effervescence; few ancient roots; few, large prominent lime masses; abrupt smooth boundary.
- C''' 236 to 291 cm. Reddish yellow (7.5 YR 6/6 d) very fine sand; weak, fine to coarse subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); none to slight effervescence; few ancient roots; abrupt smooth boundary.
- 2CK 291 to 310 cm. Strong brown (7.5 YR 5/6 m) very fine gravelly sand; single grained parting to weak, fine to medium subangular blocky structure; loose to friable (moist); nonsticky, nonplastic (wet); none to slight effervescence; abundant, coarse, prominent lime masses; abrupt smooth boundary.

- 3C 310 to 323 cm. Reddish yellow (7.5 YR 6/6 m) very fine sand; very friable (moist); nonsticky, nonplastic (wet); none to slight effervescence; common medium prominent pinkish white (7.5 YR 8/2 m) lime filled root casts; abrupt smooth boundary.
- 4Ck 323 to 417 cm. Yellow red (5YR 4/6m) loamy fine sand with 40 percent gravels of less than 40 cm. in length; friable (moist); slightly sticky, slightly plastic (wet); strong to violent effervescence; smooth boundary.
- 5c 417 to 447+ cm. Yellowish red (5YR 5/8 m) very fine sand; weak, fine to medium subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet); noneffervescent; buried boundary.

FIELD DESCRIPTION: SOIL 6

Classification; Haplargid (167 to 239 cm.)

Location: Bounds Canyon, Glen Canyon N.R.A.

Physiographic position: T2 terrace, east facing profile.

Topography: Mildly undulating dune topped terrace.

Elevation: ca 4000 feet.

Drainage: Well drained.

Parent material: Navajo SS.

Vegetation: Grasses, sage.

Remarks: Profile 6 is more well developed soil than profile 5 on the basis of color, texture, and structure. It is possible that this is an Altithermal equivalent, yet its stratigraphic position and elevation indicate it as being a T2 terrace equivalent.

- Oi .5 to 0 cm. Yellowish red (5 YR 3/5 d).
- C1 0 to 30 cm. Light reddish brown (5 YR 6/4 d) very fine sand; moderate to strong, fine to medium granular parting to moderate, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); slight to strong effervescence; many modern rootlets; some charcoal; diffuse smooth boundary.
- C2 30 to 95 cm. Yellowish red (5 YR 5/8 d) very fine sand; weak, fine to coarse angular blocky structure; slightly hard to hard (dry); very friable (moist); nonsticky, nonplastic (wet); slight to strong effervescence; some coarse colluvium; many fine rootlets; diffuse smooth boundary.
- C3 95 to 167 cm. Reddish yellow (7.5 YR 7/6 d) very fine sand; weak, fine to coarse angular blocky structure; slightly hard to hard (dry); very friable (moist); nonsticky, nonplastic (wet); strong effervescence; few large distinct white (7.5 YR 8/0 d) lime masses; few, large distinct strong brown limonite stains; clear smooth boundary.
- Bw1 167 to 211 cm. Red (2.5 YR 5/6 d) fine sandy loam; strong, medium to coarse angular blocky to prismatic structure; hard (dry); friable (moist); sticky, plastic (wet); violent effervescence; many discontinuous pores; common, fine, distinct lime masses; diffuse smooth boundary.
- Bw2 211 to 239 cm. Yellowish red (5YR 5/6 d) fine sandy loam; weak, medium to coarse angular blocky to prismatic structure; hard (dry); firm (moist); slightly sticky, slightly plastic (wet); violent effervescence; few, fine to coarse lime masses; clear smooth boundary.

- C 239 to 302 cm. Pink (5 YR 7/2 d) very fine sand; moderate, medium to coarse angular blocky structure; slightly hard to hard (dry); very friable (moist); nonsticky, nonplastic (wet); strong to violent effervescence; few modern roots; clear smooth boundary.
- 2C 302 to 365 cm. Pink (5 YR 7/4 d) very fine to coarse sand; weak, fine to medium subangular blocky structure; hard (dry); friable (moist); nonsticky, nonplastic (wet); violent effervescence; thins laterally into strong brown (7.5 UR 5/6 d) limonite stained area; few modern rootlets; diffuse smooth boundary.
- C' 265 to 295+ cm. Strong brown (7.5 YR 5/8 m) very fine sand; weak, fine to medium angular blocky structure; firm (dry); nonsticky, nonplastic (wet); boundary buried.

FIELD DESCRIPTION: SOIL 7

Classification: Fluvent

Location: Bounds Canyon, Glen Canyon N.R.A.

Physiographic position: T1 terrace, facing the northeast.

Topography: Flat.

Elevation: ca 4000 feet.

Drainage: Well drained.

Parent material: Alluvial deposits of the Navajo Fm.

Vegetation: Horse tail Mormon tea, grasses.

Remarks: This is profile 7 of the modern terrace. The profile is very wet and has an abundance of modern vegetation leading to high amounts of organic matter and bioturbated horizons.

- Oi .5 to 0 cm. Gray (7.5 YR 5/0) modern litter.
- A 0 to 9 cm. Brown (7.5 YR 5/4 m) very fine sand; moderate fine to medium granular structure parting to weak, fine to medium subangular structure; slightly sticky, slightly plastic (wet); slight to strong effervescence; many modern roots give the granular structure; clear smooth boundary.
- C 9 to 16 cm. Brown (7.5 YR 5/4 m) very fine sand; weak, fine to medium subangular blocky structure; nonsticky, nonplastic (wet); slight to strong effervescence; many modern roots; abrupt smooth boundary.
- Ab 16 to 26 cm. Brown (7.5 YR 5/4 m) very fine sand; weak, fine to medium subangular blocky structure; nonsticky, nonplastic (wet); noneffervescent; many modern roots; few, fine to coarse yellowish red (5 YR 4/6 m) limonite stains; clear smooth boundary.
- C' 26 to 33cm. Pale brown (10 UR 6/3 m) very fine sand; weak, fine to medium subangular blocky structure; nonsticky, nonplastic (wet); noneffervescent; many modern roots; some bioturbation; horizon grades laterally to a strong brown (7.5 YR 3/4 m) limonite stained zone; abrupt smooth boundary. .SPB
- Ab' 33 to 39 cm. black (7.5 YR 2/0 m) very fine sand; weak, fine to medium subangular blocky structure; very fine sand; nonsticky, nonplastic (wet); many modern roots; some bioturbation; horizon thins laterally; clear smooth boundary.
- C'' 39 to 58 cm. Brown (7.5 YR 5/4 m) very fine sand; massive structure nonsticky, nonplastic (wet); noneffervescent; many modern roots; grades laterally into a strong brown (7.5 YR 5/6 m) stained area; abrupt smooth boundary.

R Navajo Fm.

FIELD DESCRIPTION: SOIL 8

Classification: Fluvent

Location: Bounds Canyon, Glen Canyon N.R.A.

Physiographic position: T3 terrace, west facing profile.

Elevation: ca 4000 feet.

Drainage: Well drained.

Parent material: Alluvial deposits of the Navajo Fm.

Vegetation: Juniper, short grasses, prickly pear cactus.

Remarks: Profile 8. This is the first terrace with clear and consistent sedimentary structures including, ripples, cross laminae, channel deposits, and a fining upwards sequence.

- Oi 1 to 0 cm. Light red (2.5 YR 7/4 d) organic matter.
- C 0 to 135 cm. Strong brown (7.5 YR 5/6 d) very fine sand; weak, fine to coarse angular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; cross beds of eolian origin; clear smooth boundary.
- Ab 131 to 135 cm. Gray to dark brown (7.5 5/0 - 4/4 d) very fine sand; moderate fine to medium angular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); interlayers of undecomposed organic matter and very fine sand; mouse bollases; clear smooth boundary.
- C' 135 to 154 cm. Strong brown (7.5 YR 5/6 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; many fine rootlets buried by eolian conditions; clear smooth boundary.
- Ab' 154 to 173 cm. Brown (7.5 YR 5/4 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); slightly effervescent; many fine roots; few fine pores; some mice-bollases; diffuse smooth boundary.
- Eb 173 to 195 cm. Light brown (7.5 YR 6/4 d) very fine sand; weak, fine to medium granular to angular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); none to slight effervescence; many fine roots; diffuse smooth boundary.
- Bt1 195 to 212 cm. Pinkish gray (5 YR 6/2 d) fine sandy loam; moderate fine to medium subangular blocky structure; hard (dry); friable (moist); slightly sticky, slightly plastic (wet); strongly effervescent; common, fine to medium pores; some fine roots; clear smooth boundary
- Bt2 212 to 224 cm. White (5 YR 8/2 d) clay; moderate, fine to medium angular blocky structure; hard (dry); firm (moist); very sticky, very plastic (wet); strong effervescence; few faint lime masses, diffuse smooth boundary.
- Ck 224 to 324 cm. Pink (7.5 YR 7/4 d) very fine sand; weak, fine to medium angular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); none to violent effervescence; few, medium distinct lime masses; abrupt wavy boundary.

- Ab'' 324 to 341 cm. Pale brown (10 YR 6/3 d) very fine sand; weak, fine to coarse angular blocky structure; soft to slightly hard (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; some bioturbation; few, fine rootlets with limonite stains; abrupt wavy boundary.
- C'' 341 to 371 cm. Pink (10 YR 7/4 d) very fine sand; weak, fine to medium angular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; few, fine roots; abrupt smooth boundary.
- Ab''' 371 to 391 cm. Light brown (7.5 YR 6/4 d) very fine sand; weak fine to medium angular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); slight to strong effervescence; some bioturbation; few fine charcoal flecks; few large distinct lime masses; clear smooth boundary.
- C''' 390 to 420 cm. Reddish yellow (7.5 YR 7/6 d) very fine sand; weak, fine to medium angular blocky structure; soft to slightly hard (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; few fine lime masses and roots; abrupt smooth boundary; fining up sequences; cross beds; small (less than 1 meter) channel deposits.
- C'''' 420 to 525 cm. Reddish yellow (7.5 7/6 d) very fine sand; weak, medium to coarse angular blocky structure; soft (dry); very friable (moist) nonsticky, nonplastic (wet); noneffervescent; some lime masses and root casts; cross beds of fluvial origin; fining up sequence except top 50 cm. is massive; abrupt smooth boundary.
- Ab'''' 520 to 529 cm. Light gray (7.5 6/0 d) very fine sand; weak, fine angular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); strong to violent effervescence; and some bioturbation; few fine pores; this A horizon thins laterally and interbeds with the C below it; abrupt smooth boundary.
- C1 529 to 568 cm. Reddish yellow (7.5 YR 7/6 d) fine sands to coarse gravels; soft (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; channel deposits which show a fining up sequence; strong brown (7.5 YR 5/8 d) limonite stains; abrupt wavy boundary.
- C2 568 to 700 cm. Pink (7.5 YR 7/4 d) very fine sand; weak, fine to medium subangular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; fining up sequence of very fine to coarse sands; lower 12 cm. is strongly effervescent; few, large distinct strong brown (7.5 YR 5/8 d) limonite stains; abrupt smooth boundary.
- Ab^V 700 to 703 cm. Reddish yellow (7.5 YR 6/6 d) very fine sand; weak, fine to medium subangular blocky structure; soft to slightly hard (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; bioturbation brings darker A material into the C horizons above and below to give the appearance of worm burrows; abrupt wavy boundary.
- C^V 703 to 810 cm. Strong brown (7.5 YR 5/6 d) very fine sand; weak, fine to medium angular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; few fine lime masses; fining up sequence with channel gravels; fine cross beds; abrupt smooth boundary.
- Ab^{VI} 810 to 822 cm. Very dark gray to reddish yellow (7.5 YR 3/0 - 5/6 d) very fine sand; weak, fine to coarse angular blocky structure; soft (dry); very friable (moist); nonsticky, nonplastic (wet); noneffervescent; some charcoal; bioturbated A into C horizons; clear wavy boundary.

- C^{VI} 822 to 850 cm. Reddish yellow (7.5 YR 6/6 d) very fine sand; friable (moist); nonsticky, nonplastic (wet); noneffervescent; few, large, distinct brown (7.5 YR 5/4 m) organic masses; some bioturbation; fine ripples; abrupt smooth boundary.
- Ab^{VII} 850 to 865 cm. Brownish yellow to brown (10 YR 6/6 - 5/3 d); very fine sandy loam; weak, fine to medium subangular blocky structure; friable (moist); sticky, plastic (wet); strong to violent effervescence; horizon thins laterally into fine sand lenses; bioturbation; ancient roots; few, moderate, distinct lime masses; abrupt wavy boundary.
- C^{VII} 865 to 1015 cm. Reddish yellow to pink (7.5 YR 7/6 - 7/4 d) fine to very fine sand; single grained to weak, medium angular blocky structure; soft (dry); nonsticky, nonplastic (wet); noneffervescent; fluvial cross beds; fine large distinct strong brown (7.5 YR 5/6 d) limonite stains; abrupt smooth boundary.
- 2C 1015 to 1051 cm. Strong brown (7.5 YR 5/6 m) very fine sand to coarse cobbles; granular to very weak angular blocky structure; very friable (moist); nonsticky, nonplastic (wet); abrupt smooth boundary; cpbbles are less than 18 cm. in diameter.
- 3C 1051 to 1077+ cm. Strong brown (7.5 YR 5/6 m) very fine sand; weak, fine to medium subangular blocky structure; very friable (moist); nonsticky, nonplastic (wet); noneffervescent; lower 2 cm. is yellowish brown (10 YR 5/8 m) limonite stained; abrupt smooth boundary.

APPENDIX II

Soil Analysis

This section contains the tables of laboratory data which have been completed to date. These properties include particle size, pH, percent organic matter (% O.M.), and percent calcium carbonate (% CaCO_3).

Laboratory data is essential for correct paleoenvironmental interpretation and identification of past pedogenic properties and soil forming conditions.

PROFILÉ 1

Location	Depth	gravel %	particle size %				B.D.	pH	EC*	% O.M.	CaCO ₃ %	MgCO ₃ %	fine earth fraction		
			sand	silt	clay	% Fe							% Al	% Mn**	
A	0-15		78.00	11.00	11.00		8.0				4.2				
C	15-34		88.00	5.00	7.00		8.2				.45				
Ab	34-49		76.00	15.00	9.00		7.6				3.35				
C ¹	49-61.5		87.00	11.00	8.00		7.5				2.05				
Ab ¹	61.5-70.5		90.00	1.00	9.00		8.0				1.95				
C ¹¹															
Ab ¹¹	90.5-99.5		83.00	4.00	13.00		8.0				5.4				
C ¹	99.5-125.5		92.00	1.00	7.00		7.7				1.9				
C ²	125.5-153.5		86.00	3.00	11.00		7.7				2.95				
C ³	153.5-205		92.00	2.00	6.00		7.8				2.5				
Ab ¹¹¹	203-207														
C ¹¹¹	207-280.5		95.00	1.00	6.00		8.1				2.5				
Ab ¹¹¹¹	280.5-284		64.00	18.00	18.00		7.8				6.05				
B _w ¹	284-326		76.00	8.00	16.00		7.9				6.15				

[illegible]

* L. in millimols/cm₂ ** Sodium dithionite extracted *** I=illite, K=kaolinite, C=chlorite, M=montmorillonite, V=vermiculite, H=halloysite, Q=quartz, F=feldspar; xx=abundant, xxx=moderate, x=minor, T=trace quantities
 A*** A=argillite, W=weathered, q=quartz, SS=sandstone, L=limestone, D=dolomite, V=volcanic

WORK FILE 3

[illegible][illegible]

* L. in millimols/cm² ** Sodium dithionite extracted *** I=illite, K=kaolinite, C=chlorite, M=montmorillonite,
V=vermiculite, H-halloysite, Q=quartz, F=feldspar; xxx=abundant, xx=moderate, x=minor, t=trace quantities
**** A=illite, B=bentonite, C=clay, D=diatom, E=ectoparasitic, F=feldspar, G=glass, H=halloysite, I=illite, J=jadeite, K=kaolinite, L=limonite, M=montmorillonite, N=nepheline, O=olivine, P=potash feldspar, Q=quartz, R=rhyolite, S=silica, T=titanium, U=uranium, V=volcanic

APPENDIX III

Pollen Tables

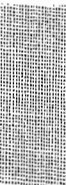


Table A-1: Raw scores (percentage scores in parentheses) for pollen counts of alluvial samples from Bechan, Glen Canyon National Recreation Area. Percentage scores are not presented unless there is a statistically relevant 100 or more in the total pollen count.

	A (%)	A ₁	A ₂	A ₃	A ₄	A ₅
Poaceae	1 (0.4)	7	1	1	3	1
Asteraceae						
Low Spine	11 (4.8)	0	0	0	0	1
High Spine	6 (2.6)	0	0	0	0	0
Fenestrata	0	0	0	0	0	0
<u>Cheno-Am</u>	79 (35)	0	0	18	0	0
<u>Pinus ponderosa</u>	99 (43)	1	0	0	0	0
<u>Pinus edulis</u>	18 (0.8)	0	0	0	0	0
<u>Juniperus</u>	9 (0.4)	0	0	0	0	0
<u>Ephedra</u>						
<u>nevadensis</u>	0	0	0	0	0	0
<u>torreyana</u>	3 (1.3)	0	0	0	0	0
<u>Betula</u>						
<u>fontinalis</u>	0	0	0	0	0	0
spp.	0	0	0	0	0	0
<u>Alnus</u>	1 (0.4)	0	0	0	0	0
<u>Malvaceae</u>	2 (0.8)	0	0	0	0	0
<u>Salix</u>	0	0	0	0	0	0
Total	228	8	1	19	3	2

Table A-2: Raw scores (percentage scores in parentheses) for pollen counts of alluvial samples from Bechan, Glen Canyon National Recreation Area. Percentage scores are not presented unless there is a statistically relevant 100 or more in the total pollen count.

	B ₃	B _{4L}	B _{4H}	B _{4T}	B ₅	B ₆	B ₇	B ₈	B ₉
Poaceae	0	33	3	4	0	3	0	5	7
Asteraceae	0	3	9	0	1	3	0	0	3
Low Spine	0	0	0	0	1	0	0	1	0
High Spine	0	0	0	0	0	0	0	1	0
Fenestrata	0	0	0	0	0	0	0	0	0
Cheno-Am	0	3	0	0	1	8	0	1	9
<u>Pinus ponderosa</u>	0	0	0	0	0	0	0	0	0
<u>Pinus edulis</u>	0	0	0	0	0	0	0	0	0
<u>Juniperus</u>	0	3	0	0	0	2	0	0	0
<u>Ephedra</u>									
<u>nevadensis</u>	0	0	0	0	0	0	0	0	0
<u>torreyana</u>	0	0	0	0	0	0	0	0	0
<u>Betula</u>									
<u>fontinalis</u>	0	0	0	0	0	0	0	0	0
spp.	0	0	0	0	0	0	0	0	0
<u>Alnus</u>	0	0	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0	0	0
<u>Salix</u>	0	0	0	0	0	0	0	1	0
Total	0	42	12	4	3	16	0	8	20

Table A-3: Raw scores (percentage scores in parentheses) for pollen counts of alluvial samples from Bechan, Glen Canyon National Recreation Area. Percentage scores are not presented unless there is a statistically relevant 100 or more in the total pollen count.

	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉	C ₁₀ (%)	C _{11a}	C _{11b}	C ₁₂	C ₁₃	C ₁₄
Poaceae	3	8	30	30	2	0	9	1	0	9 (1.8)	3	8	4	1	2
Asteraceae															
Low Spine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
High Spine	0	0	0	2	0	1	1	0	0	0	1	0	0	0	0
Fenestrata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cheno-Am	0	1	0	0	0	3	0	0	0	498 (97)	0	0	0	10	0
Pinus ponderosa	0	0	0	0	0	0	0	2	0	4 (0.8)	0	0	0	0	0
Pinus edulis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juniperus	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0
Ephedra															
nevadensis	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
torreyana	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Betula															
fontinalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alnus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salix	0	1	0	0	0	0	0	0	0	0	0	0	0	5	0
Total	3	10	30	38	2	4	11	3	0	511	3	9	6	16	2

Table A-4a: Raw scores (percentage scores in parentheses) for pollen counts of alluvial samples from Bechan, Glen Canyon National Recreation Area. Percentage scores are not presented unless there is a statistically relevant 100 or more in the total pollen count.

	D ₁	D ₂	D ₃	D ₄	D _{5a}	D _{5b}	D _{5c}	D ₆	D _{7a}	D _{7b}	D _{7c}
Poaceae	11	3	4	11	0	21	7	5	15	8	3
Asteraceae											
Low Spine	0	0	0	5	0	3	0	3	4	3	7
High Spine	0	0	0	1	0	0	0	0	4	0	3
Fenestrata	0	0	0	0	0	1	0	0	0	0	0
Chenop-Arn	2	0	1	9	3	2	0	1	10	4	5
<u>Pinus ponderosa</u>	1	0	0	0	1	1	0	0	17	4	9
<u>Pinus edulis</u>	0	0	0	0	0	0	0	0	0	0	0
<u>Juniperus</u>	0	0	0	0	0	0	0	0	0	0	0
<u>Ephedra</u>											
<u>nevadensis</u>	0	0	0	0	0	0	0	0	0	0	0
<u>torreyana</u>	0	0	0	0	0	0	0	0	0	2	1
<u>Betula</u>											
<u>fontinalis</u>	0	0	0	0	0	0	0	0	0	0	0
spp.	0	0	0	0	0	0	0	0	1	0	0
<u>Alnus</u>	0	0	0	0	0	0	0	0	1	0	0
Malvaceae	0	0	0	1	0	0	0	0	0	0	1
<u>Salix</u>	0	0	0	0	0	0	0	0	0	4	0
Total	14	3	5	27	3	28	7	9	52	25	29

Table A-4b: Raw scores (percentage scores in parentheses) for pollen counts of alluvial samples from Bechan, Glen Canyon National Recreation Area. Percentage scores are not presented unless there is a statistically relevant 100 or more in the total pollen count.

	D _{8a}	D _{8b}	D ₉	D _{10a}	D _{10b}	D _{11a}	D _{11b}	D ₁₂	D ₁₃	D ₁₄
Poaceae	8	1	6	1	3	0	5	0	3	6
Asteraceae										
Low Spine	0	0	0	0	0	0	0	2	6	1
High Spine	4	0	0	0	0	0	0	0	0	0
Fenestrata	0	0	0	0	0	0	0	0	0	0
Cheno-Am	16	1	0	0	0	0	2	0	62	0
<u>Pinus ponderosa</u>	1	0	0	0	0	0	0	0	0	0
<u>Pinus edulis</u>	0	0	0	0	0	0	0	0	0	0
<u>Juniperus</u>	0	0	0	0	0	0	0	0	0	0
<u>Ephedra</u>										
nevadensis	0	0	0	0	0	0	0	0	0	0
torreyana	0	0	0	0	0	0	0	0	0	0
<u>Betula</u>										
fontinalis	0	0	0	0	0	0	0	0	0	0
spp.	0	0	0	0	0	0	0	0	0	0
<u>Alnus</u>	0	0	0	0	0	0	0	0	0	0
Malvaceae	0	0	0	0	0	0	0	0	0	0
<u>Salix</u>	0	0	0	0	0	0	0	0	0	0
Total	29	0	6	1	3	0	7	2	71	7

Table A-4c: Raw scores (percentage scores in parentheses) for pollen counts of alluvial samples from Bechan, Glen Canyon National Recreation Area. Percentage scores are not presented unless there is a statistically relevant 100 or more in the total pollen count.

	D ₁₅	D ₁₆	D ₁₇	D ₁₈	D ₁₉	D ₂₀
Poaceae	4	0	1	4	9	6
Asteraceae						
Low Spine	2	0	10	6	0	2
High Spine	0	0	0	0	0	0
Fenestrata	0	0	0	0	0	0
Cheno-Am	2	0	18	2	9	5
<u>Pinus ponderosa</u>	0	0	37	1	1	5
<u>Pinus edulis</u>	0	0	0	0	0	0
<u>Juniperus</u>	0	0	0	0	0	0
<u>Ephedra</u>						
<u>nevadensis</u>	0	0	0	0	0	0
<u>torreyana</u>	0	0	0	0	0	0
<u>Betula</u>						
<u>fontinalis</u>	0	0	0	0	0	0
spp.	0	0	0	0	0	0
<u>Alnus</u>	0	0	0	0	0	0
Malvaceae	0	0	3	0	0	0
<u>Salix</u>	0	0	0	0	0	0
Total	7	0	69	13	19	11

Table A-5 Raw scores (percentage scores in parentheses) for pollen counts of alluvial samples from Bechan, Glen Canyon National Recreation Area. Percentage scores are not presented unless there is a statistically relevant 100 or more in the total pollen count.

	E ₁	E ₂ (x)	E ₃	E ₄ (x)	E ₅ (x)	E ₆ (x)
Poaceae	2	88 (24)	10	250 (99)	115 (55)	225 (99+)
Asteraceae						
Low Spine	0	128 (35)	4	0	0	0
High Spine	0	34 (09)	0	0	0	0
Fenestrata	0	0	0	0	0	0
<u>Cheno-Am</u>	0	71 (19)	6	3 (1.0)	1 (0.5)	0
<u>Pinus ponderosa</u>	1	38 (10)	4	0	96 (45)	2 (0.8)
<u>Pinus edulis</u>	0	0	0	0	0	0
<u>Juniperus</u>	0	0	0	0	0	0
<u>Ephedra</u>						
<u>nevadensis</u>	0	6 (1.6)	0	0	0	0
<u>torreyana</u>	0	4 (1.0)	0	0	0	0
<u>Betula</u>						
<u>fontinalis</u>	0	0	0	0	0	0
spp.	0	0	0	0	0	0
<u>Alnus</u>	0	0	0	0	0	0
<u>Malvaceae</u>	0	0	0	0	0	0
<u>Salix</u>	0	0	0	0	0	0
Total	3	369	24	253	211	227

Table A-6: Raw scores (percentage scores in parentheses) for pollen counts of alluvial samples from Bechan, Glen Canyon National Recreation Area. Percentage scores are not presented unless there is a statistically relevant 100 or more in the total pollen count.

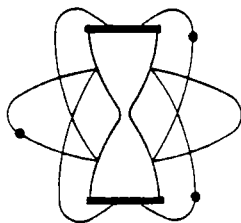
	F1	F2	F3 (%)	F4	F5	F6	F7	F8	F9 (%)	F10	F11	F12	F13	F14	F15
Poaceae	12	15	132 (57)	13	0	7	27	3	65 (58)	9	45	20	3	12	26
Asteraceae															
Low Spine	2	0	14 (.06)	2	0	0	0	1	0	0	0	0	0	2	0
High Spine	0	0	12 (.05)	0	0	0	0	0	0	0	0	0	0	0	0
Fenestrata	0	0	1 (.4)	0	0	0	0	0	0	0	0	0	0	0	0
Cheno-Am	5	0	10 (.04)	5	0	0	4	0	9 (.08)	2	2	1	0	1	3
Pinus ponderosa	3	1	49 (.21)	10	6	0	1	4	30 (.27)	6	34	4	2	8	10
Pinus edulis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juniperus	2	0	7 (.03)	3	0	0	0	0	1 (.9)	0	0	0	0	0	0
Ephedra															
nevadensis	0	0	2 (.8)	0	0	0	0	0	0	0	1	1	0	0	0
torreyana	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula															
fontinalis	2	0	0	0	0	0	1	0	7 (.06)	0	0	0	0	0	0
spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alnus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	0	0	6 (2.5)	0	0	0	0	0	1 (.9)	0	0	0	0	3	0
Salix	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	27	16	233	33	6	7	33	8	113	17	80	26	5	25	44

APPENDIX IV
C-14 Dates Data Sheets: Phase I

C¹⁴ Dates 1984/85

Canyonlands National Park, Glen Canyon National Recreation Area,
Bridges National Monument, Cedar Breaks National Monument

<u>Sample#</u>	<u>Brief Description</u>	<u>C-14 Lab No.</u>	<u>C-14 Date (B.P.)</u>
1	BC#1 - alluvial unit	GX - 10758	4090±155
2	BC#2 - oak forest	GX - 10759	0±75
3	BC#3 - archaic hearth	GX - 10938	no date - too little C
4	BC#4 - root from T _{3a}	GX - 10939	4025±95
5	BCA-B-3 - "altithermal" soil	GX - 11017	no date - too little C
6	B-11 - buried cottonwood	GX - 11020	no date - CaCO ₃ Cast
7	BCA-B-15 - T ₃ base at bend	GX - 11019	4165±95
8	BCA-B-17 "hearth" over "altithermal" soil	GX - 11018	950±160
9	BC#9(T _{3a}) - below cut and fill	GX - 11143	940±200
10	BC#1-(T _{3b}) - Above cut and fill	GX - 11144	215±80
11	BC#11(T ₄ ?) - at confluence, below T ₃ cut	GX - 11145	10,020±270
12	BC#12 - dune arch site at confluence	GX - 11146	5300±235
13	LC#1 - pack rat midden	GX - 11192	14860±460
14	LC#2 - pack rat midden	GX - 11193	6640±190
15	LC#3 - pack rat midden	GX - 11194	7635±290
16	LC#4 - pack rat midden	GX - 11195	2540±140
17	LC#5 - pack rat midden	GX - 11196	5240±190
18	LC#6 - pack rat midden	GX - 11197	17,430±770
19	LC#7 - pack rat midden	GX - 11198	9545±370
20	SC#1 - Salt Creek upper contact, Big Pocket	GX - 11228 GX - 11337	0±200 1525±130
21	BC#13 - T ₂ alluvium Bechan Begay	GX - 11337	4260±170
22	BC#14 - T _{3a} /T _{3b} cut and fill	GX - 11338	1290±75
23	BC#15 - hearth, dune on T ₃ top	GX - 11339	3000±145
24	BC#16 - hearth, upper T ₃ below dune	GX - 11340	1315±75
25	BC#17 - T ₂ hearth at falling dune	GX - 11405	9005±175
26	CB#1 - lower log in strat site	GX - 11316	>39,800
27	NB#1 - lower goat dung	GX - 11313	23,350±1740
28	NB#2 - upper goat dung	GX - 11561	2550±80
29	BC#18 - upper unit at Big Bend	GX - 11562	2510±80
30	BC#19 - next lower at Big Bend	GX - 11563	3750±165
31	BC#20 - 2nd from bottom at Big Bend	GX - 11564	4120±170
32	BC#21 - bottom unit at Big Bend		


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24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No.	~~GX~~ - 10758	Date Received:	12-04-84
Your Reference:	Letter of 11-26-84.	Date Reported:	12-31-84
Submitted by:	Larry D. Agenbroad Geology Dept. Northern Arizona University Flagstaff, AZ 86011		

Sample Name: ~~BCA~~ #1. Alluvial fill unit with plant detritus and charcoal, Locality #1, Sample #1. Bechan Cave Canyon Alluvium, Utah.

AGE = 4090 +/- 155 C-14 Years B.P. (C-13 corrected).

Description: Sample of charcoal and plant matter in sediment.

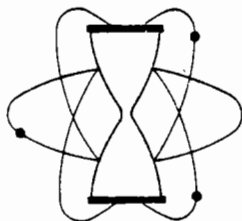
Pretreatment: The charcoal fragments were separated from any sand, silt, rootlets, or other foreign matter. The sample was then treated with hot dilute HCl and with hot dilute NaOH to remove carbonates and organic contaminants. After washing and drying, the charcoal was then combusted to carbon dioxide for the analysis.

Comment:

$\delta^{13}\text{C}_{\text{POB}} = -26.0 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No. **GX-10759**
 Your Reference: Letter of 11-26-84.
 Submitted by: Larry D. Agenbroad
 Geology Dept.
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 12-04-84

Date Reported: 12-31-84

Sample Name: **BCA #2**. Dead forest on surface of alluvial flats.
 Bechan Cave Canyon Alluvium, Utah.
 AGE = Recent, actual age was (-10 +/- 75) B.P.
 (100.1 +/- 0.9)% of modern. Indicates 20th century wood.

Description: Sample of wood.

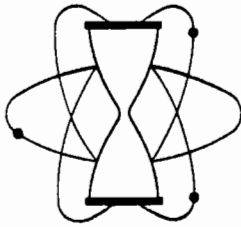
Pretreatment: The wood was cleaned of dirt or other foreign material and was split into small pieces. It was then treated with hot dilute HCl to remove any carbonates and with hot dilute NaOH to remove humic acids and other organic contaminants. After washing and drying it was combusted to recover carbon dioxide for the analysis.

Comment:

$\delta^{13}C_{PDB} = -25.4 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 10938

Your Reference: Letter of 02-21-85.

Submitted by: Larry D. Agenbroad
Geology Dept.
Northern Arizona University
Flagstaff, AZ 86011

Date Received: 03-05-85

Date Reported: 05-13-85

Sample Name: BCA #3. Disseminated charcoal in alluvium beneath nonceramic cultural horizon, Bechan Cave alluvium, SE Utah.

AGE = Sufficient charcoal could not be cleanly separated.

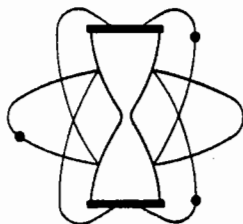
Description: Sample of charcoal.

Pretreatment: The charcoal fragments were separated from any sand, silt, rootlets, or other foreign matter. The sample was then treated with hot dilute HCl and with hot dilute NaOH to remove carbonates and organic contaminants. After washing and drying, the charcoal was then combusted to carbon dioxide for the analysis.

Comment:

 $\delta^{13}\text{C}_{\text{PDB}} = \text{‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 10939
 Your Reference: Letter of 02-21-85.
 Submitted by: Larry D. Agenbroad
 Geology Dept.
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 03-05-85

Date Reported: 05-13-85

Sample Name: BCA #4. Older unit of 3rd terrace above stream, 8.40m below
 modern terr. surface, 7.38m above stream; within coarser grained
 T-3 unit. Bechan Cave alluvium, SE Utah.
 AGE = 4025 +/- 95 C-14 Years B.P. (C-13 corrected).

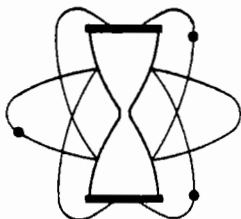
Description: Sample of charcoal.

Pretreatment: The charcoal fragments were separated from any sand,
 silt, rootlets, or other foreign matter. The sample was
 then treated with hot dilute HCl and with hot dilute NaOH
 to remove carbonates and organic contaminants. After
 washing and drying, the charcoal was then combusted to
 carbon dioxide for the analysis.

Comment:

 $\delta^{13}\text{C}_{\text{PDB}} = -28.2 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11017
 Your Reference: Letter of 03-11-85.
 Submitted by: Eric Karlstrom
 Dept. of Geography
 Box 15016
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 03-22-85

Date Reported: 05-29-85

Sample Name: BCA-B-3.

 AGE = *BC 45* Sample too small for analysis.

Description: Sample of charcoal.

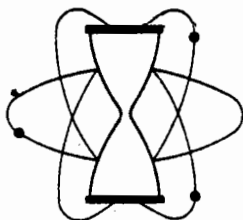
Pretreatment: The charcoal fragments were separated from any sand, silt, rootlets, or other foreign matter. The sample was then treated with hot dilute HCl and with hot dilute NaOH to remove carbonates and organic contaminants. After washing and drying, the charcoal was then combusted to carbon dioxide for the analysis.

Comment:

 $\delta^{13}\text{C}_{\text{PDB}} = \text{‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11020

Your Reference: Letter of 03-11-85.

Submitted by: Eric Karlstrom
 Dept. of Geography
 Box 15016
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 03-22-85

Date Reported: 05-29-85

Sample Name: B-11.

AGE = *250* Sample could not be analysed. See comment below.

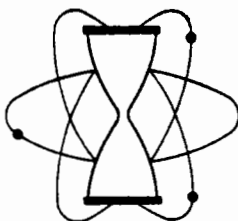
Description: Sample of wood.

Pretreatment:

Comment: Sample was a ghost composed of rootlets and carbonate cement.
 It completely dissagregated to rootlets upon treatment with HCl.

$\delta^{13}\text{C}_{\text{PDB}}$ = ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11019
 Your Reference: Letter of 03-11-85.
 Submitted by: Eric Karlstrom
 Dept. of Geography
 Box 15016
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 03-22-85

Date Reported: 05-29-85

Sample Name: BCA-B-15.

AGE = *BC-17* 4165 +/- 95 C-14 Years B.P. (C-13 corrected).

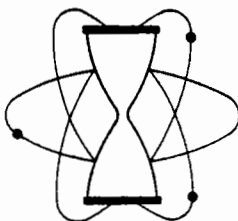
Description: Sample of wood charcoal.

Pretreatment: The charcoal fragments were separated from any sand, silt, rootlets, or other foreign matter. The sample was then treated with hot dilute HCl and with hot dilute NaOH to remove carbonates and organic contaminants. After washing and drying, the charcoal was then combusted to carbon dioxide for the analysis.

Comment:

$\delta^{13}\text{C}_{\text{PDB}} = -27.7 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11018
 Your Reference: Letter of 03-11-85.
 Submitted by: Eric Karlstrom
 Dept. of Geography
 Box 15016
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 03-22-85

Date Reported: 05-29-85

Sample Name: BCA-B-17.

 AGE = *BC-8* 950 +/- 160 C-14 Years B.P. (C-13 corrected).

Description: Sample of charcoal.

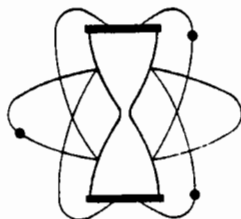
Pretreatment: The charcoal fragments were separated from any sand, silt, rootlets, or other foreign matter. The sample was then treated with hot dilute HCl and with hot dilute NaOH to remove carbonates and organic contaminants. After washing and drying, the charcoal was then combusted to carbon dioxide for the analysis.

Comment:

 $\delta^{13}\text{C}_{\text{PDB}} = -16.0 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11143
 Your Reference: Letter of 04-22-85.
 Submitted by: Larry D. Agenbroad
 Geology Dept.
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 04-26-85

Date Reported: 07-31-85

Sample Name: BC #9 (T3a). Material from below cut and fill in the T3 alluvium of canyon fill. Bechan area, So. Utah.

AGE = 940 +/- 200 C-14 Years B.P. (C-13 corrected).

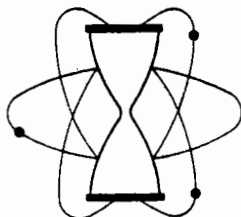
Description: Sample of wood.

Pretreatment: The wood was cleaned of dirt or other foreign material and was split into small pieces. It was then treated with hot dilute HCl to remove any carbonates and with hot dilute NaOH to remove humic acids and other organic contaminants. After washing and drying it was combusted to recover carbon dioxide for the analysis.

Comment:

$\delta^{13}\text{C}_{\text{PDB}} = -26.7 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No. **IGX- 11144**
 Your Reference: Letter of 04-22-85.
 Submitted by: Larry D. Agenbroad
 Geology Dept.
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 04-26-85

Date Reported: 07-31-85

Sample Name: **BC #10 (T3b). Root(?) in T3b above cut and fill. Canyon alluvial fill adjacent to Bechan Cave, So. Utah.**

AGE = 215 +/- 80 C-14 Years B.P. (C-13 corrected).

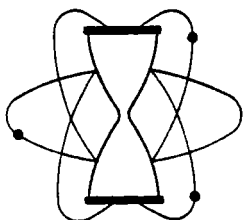
Description: Sample of wood.

Pretreatment: The wood was cleaned of dirt or other foreign material and was split into small pieces. It was then treated with hot dilute HCl to remove any carbonates and with hot dilute NaOH to remove humic acids and other organic contaminants. After washing and drying it was combusted to recover carbon dioxide for the analysis.

Comment:

$\delta^{13}\text{C}_{\text{POB}} = -26.8 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11145
 Your Reference: Letter of 04-22-85.
 Submitted by: Larry D. Agenbroad
 Geology Dept.
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 04-26-85

Date Reported: 07-31-85

Sample Name: BC #11 (T4?). Charcoal horizon beneath T3 cut and fill at confluence of canyons. Canyon all. adj. to Bechan Cave, So. Utah.

AGE = 10,020 +/- 270 C-14 Years B.P. (C-13 corrected).

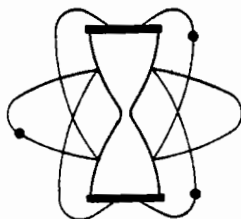
Description: Sample of charcoal. HCl pt only, see below.

Pretreatment: The charcoal fragments were separated from any sand, silt, rootlets, or other foreign matter. The sample was then treated with hot HCl to remove any carbonates. The size of the sample did not permit the use of a NaOH treatment. The sample was then washed and dried prior to combustion to recover carbon dioxide for the analysis.

Comment:

$\delta^{13}\text{C}_{\text{PDB}} = -25.7 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. **GX- 11146**

Your Reference: **Letter of 04-22-85.**

Submitted by: **Larry D. Agenbroad
Geology Dept.
Northern Arizona University
Flagstaff, AZ 86011**

Date Received: **04-26-85**

Date Reported: **07-31-85**

Sample Name: **BC #12 (dune site). Arch. buried hearth covered by falling dune.
Canyon alluvium adjacent to Bechan Cave, So. Utah.**

AGE = **5300 +/- 235 C-14 Years B.P. (C-13 corrected).**

Description: **Sample of charcoal.**

Pretreatment: **The charcoal fragments were separated from any sand, silt, rootlets, or other foreign matter. The sample was then treated with hot dilute HCl and with hot dilute NaOH to remove carbonates and organic contaminants. After washing and drying, the charcoal was then combusted to carbon dioxide for the analysis.**

Comment:

$\delta^{13}\text{C}_{\text{PDB}} = -23.7 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11192

Date Received: 05-20-85

Your Reference: Letter of 05-13-85.

Date Reported: 06-12-85

 Submitted by: Julio L. Betancourt
 Dept. of Geosciences
 Lab. of Paleoenv. Studies
 University of Arizona
 Tucson, AZ 85721

Sample Name: Long Canyon #1. Long Canyon, Kane Co., Utah.

AGE = 14,860 +/- 460 C-14 Years B.P. (C-13 corrected).

Description: Neotoma fecal pellets.

 Pretreatment: The wood was cleaned of dirt or other foreign material and was split into small pieces. It was then treated with hot dilute HCl to remove any carbonates and with hot dilute NaOH to remove humic acids and other organic contaminants. After washing and drying it was combusted to recover carbon dioxide for the analysis.

 Comment: *Sample loaded with Tinea fungus (blue spruce).*
 $\delta^{13}\text{C}_{\text{PDB}} = -23.6 \text{ ‰}$

 Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11193

Date Received: 05-20-85

Your Reference: Letter of 05-13-85.

Date Reported: 06-12-85

 Submitted by: Julio L. Betancourt
 Dept. of Geosciences
 Lab. of Paleoenv. Studies
 University of Arizona
 Tucson, AZ 85721

Sample Name: Long Canyon #2. Long Canyon, Kane Co., Utah.

AGE = 6640 +/- 190 C-14 Years B.P. (C-13 corrected).

Description: Neotoma fecal pellets.

Pretreatment: The wood was cleaned of dirt or other foreign material and was split into small pieces. It was then treated with hot dilute HCl to remove any carbonates and with hot dilute NaOH to remove humic acids and other organic contaminants. After washing and drying it was combusted to recover carbon dioxide for the analysis.

Comment:

dominant plant is Utah juniper
 $\delta^{13}\text{C}_{\text{PDB}} = -22.2 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.


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REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11194

Date Received: 05-20-85

Your Reference: Letter of 05-13-85.

Date Reported: 06-12-85

 Submitted by: Julio L. Betancourt
 Dept. of Geosciences
 Lab. of Paleoenv. Studies
 University of Arizona
 Tucson, AZ 85721

Sample Name: Long Canyon #3. Long Canyon, Kane Co., Utah.

AGE = 7635 +/- 290 C-14 Years B.P. (C-13 corrected).

Description: Neotoma fecal pellets.

 Pretreatment: The wood was cleaned of dirt or other foreign material
 and was split into small pieces. It was then treated
 with hot dilute HCl to remove any carbonates and with
 hot dilute NaOH to remove humic acids and other organic
 contaminants. After washing and drying it was combusted
 to recover carbon dioxide for the analysis.

Comment:

dominant plant is Utah juniper
 $\delta^{13}\text{C}_{\text{PDB}} = -22.1 \text{ ‰}$

 Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11195

Your Reference: Letter of 05-13-85.

Submitted by: Julio L. Betancourt
 Dept. of Geosciences
 Lab. of Paleoenv. Studies
 University of Arizona
 Tucson, AZ 85721

Date Received: 05-20-85

Date Reported: 06-12-85

Sample Name: Long Canyon #4. Long Canyon, Kane Co., Utah.

AGE = 2540 +/- 140 C-14 Years B.P. (C-13 corrected).

Description: Neotoma fecal pellets.

Pretreatment: The wood was cleaned of dirt or other foreign material and was split into small pieces. It was then treated with hot dilute HCl to remove any carbonates and with hot dilute NaOH to remove humic acids and other organic contaminants. After washing and drying it was combusted to recover carbon dioxide for the analysis.

Comment:

dominant plant is Utah juniper

$\delta^{13}\text{C}_{\text{PDB}} = -22.8 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11196

Date Received: 05-20-85

Your Reference: Letter of 05-13-85.

Date Reported: 06-12-85

 Submitted by: Julio L. Betancourt
 Dept. of Geosciences
 Lab. of Paleoenv. Studies
 University of Arizona
 Tucson, AZ 85721

Sample Name: Long Canyon #5. Long Canyon, Kane Co., Utah.

AGE = 5240 +/- 190 C-14 Years B.P. (C-13 corrected).

Description: Neotoma fecal pellets.

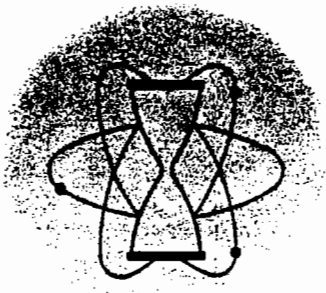
Pretreatment: The wood was cleaned of dirt or other foreign material and was split into small pieces. It was then treated with hot dilute HCl to remove any carbonates and with hot dilute NaOH to remove humic acids and other organic contaminants. After washing and drying it was combusted to recover carbon dioxide for the analysis.

Comment:

dominant plant is Uxalis juniper
 $\delta^{13}\text{C}_{\text{PDB}} = -22.9 \text{ ‰}$

 Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11197

Date Received: 05-20-85

Your Reference: Letter of 05-13-85.

Date Reported: 06-12-85

 Submitted by: Julio L. Betancourt
 Dept. of Geosciences
 Lab. of Paleoenvironmental Studies
 University of Arizona
 Tucson, AZ 85721

Sample Name: Long Canyon #6. Long Canyon, Kane Co., Utah.

AGE = 17,430 +/- 770 C-14 Years B.P. (C-13 corrected).

Description: Neotoma fecal pellets.

Pretreatment: The wood was cleaned of dirt or other foreign material and was split into small pieces. It was then treated with hot dilute HCl to remove any carbonates and with hot dilute NaOH to remove humic acids and other organic contaminants. After washing and drying it was combusted to recover carbon dioxide for the analysis.

 Comment: *very few or no conifers noted in washing*
 $\delta^{13}\text{C}_{\text{PDB}} = -22.9 \text{ ‰}$

 Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11198

Date Received: 05-20-85

Your Reference: Letter of 05-13-85.

Date Reported: 06-12-85

 Submitted by: Julio L. Betancourt
 Dept. of Geosciences
 Lab. of Paleoenv. Studies
 University of Arizona
 Tucson, AZ 85721

Sample Name: Long Canyon #7. Long Canyon, Kane Co., Utah.

AGE = 9545 +/- 370 C-14 Years B.P. (C-13 corrected).

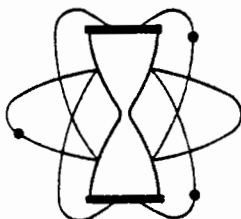
Description: Neotoma fecal pellets.

Pretreatment: The wood was cleaned of dirt or other foreign material and was split into small pieces. It was then treated with hot dilute HCl to remove any carbonates and with hot dilute NaOH to remove humic acids and other organic contaminants. After washing and drying it was combusted to recover carbon dioxide for the analysis.

Comment:

dominant plant is Utah juniper
 $\delta^{13}\text{C}_{\text{PDB}} = -22.6 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11336
 Your Reference: Letter of 06-25-85.
 Submitted by: Larry D. Agenbroad
 Geology Dept.
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 07-01-85

Date Reported: 10-30-85

Sample Name: BC #13. Hearth in T2 alluvium at Bechan Begay.
 Alluvium adjacent to Bechan Cave, Utah.

AGE = 1525 +/- 130 C-14 Years B.P. (C-13 corrected).

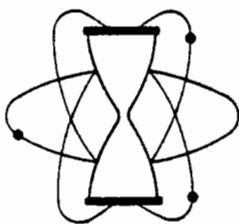
Description: Sample of charcoal in sandy sediment.

Pretreatment: The charcoal fragments were separated from any sand,
 silt, rootlets, or other foreign matter. The sample was
 then treated with hot HCl to remove any carbonates.
 The size of the sample did not permit the use of a NaOH
 treatment. The sample was then washed and dried prior
 to combustion to recover carbon dioxide for the analysis.

Comment:

$\delta^{13}\text{C}_{\text{PDB}} = -24.4 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK
Our Sample No. GX- 11337

Date Received: 07-01-85

Your Reference: Letter of 06-25-85.

Date Reported: 10-30-85

Submitted by: Larry D. Agenbroad
Geology Dept.
Northern Arizona University
Flagstaff, AZ 86011

Sample Name: BC #14. Upper T3a just below T3b/T3a cut and fill contact.
Alluvium adjacent to Bechan Cave, Utah.

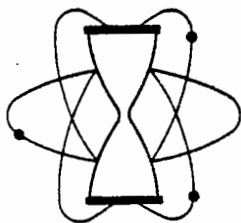
AGE = 4260 +/- 170 C-14 Years B.P. (C-13 corrected).

Description: Sample of charcoal in sandy sediment.

Pretreatment: The charcoal fragments were separated from any sand, silt, rootlets, or other foreign matter. The sample was then treated with hot HCl to remove any carbonates. The size of the sample did not permit the use of a NaOH treatment. The sample was then washed and dried prior to combustion to recover carbon dioxide for the analysis.

Comment:
 $\delta^{13}\text{C}_{\text{POB}} = -26.3 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11338
 Your Reference: Letter of 06-25-85.
 Submitted by: Larry D. Agenbroad
 Geology Dept.
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 07-01-85

Date Reported: 10-30-85

Sample Name: BC #15. Hearth 1m bs in dune sand at top of T3. Loc. 19-36 NAU-
 ANTHRO. Alluvium adjacent to Bechan Cave, Utah.

AGE = 1290 +/- 75 C-14 Years B.P. (C-13 corrected).

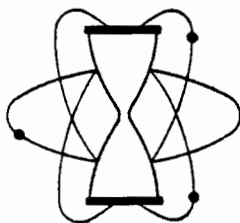
Description: Sample of charcoal in sandy sediment.

Pretreatment: The charcoal fragments were separated from any sand,
 silt, rootlets, or other foreign matter. The sample was
 then treated with hot HCl to remove any carbonates.
 The size of the sample did not permit the use of a NaOH
 treatment. The sample was then washed and dried prior
 to combustion to recover carbon dioxide for the analysis.

Comment:

$\delta^{13}\text{C}_{\text{PDB}} = -22.2 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11339

Date Received: 07-01-85

Your Reference: Letter of 06-25-85.

Date Reported: 10-30-85

 Submitted by: Larry D. Agenbroad
 Geology Dept.
 Northern Arizona University
 Flagstaff, AZ 86011

Sample Name: BC #16. Hearth in T3b alluvium. Upper level of T3b just below sand containing BC#15. Alluvium adjacent to Bechan Cave, Utah.

AGE = 3000 +/- 145 C-14 Years B.P. (C-13 corrected).

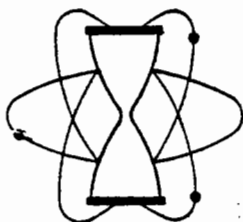
Description: Sample of charcoal in sandy sediment.

Pretreatment: The charcoal fragments were separated from any sand, silt, rootlets, or other foreign matter. The sample was then treated with hot HCl to remove any carbonates. The size of the sample did not permit the use of a NaOH treatment. The sample was then washed and dried prior to combustion to recover carbon dioxide for the analysis.

Comment:

 $\delta^{13}\text{C}_{\text{POB}} = -22.6 \text{ ‰}$

 Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11340
 Your Reference: Letter of 06-25-85.
 Submitted by: Larry D. Agenbroad
 Geology Dept.
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 07-01-85

Date Reported: 10-30-85

Sample Name: BC #17. Hearth in T2(?) terrace near large falling dune at
 canyon confluence. Alluvium adjacent to Bechan Cave, Utah.

AGE = 1315 +/- 75 C-14 Years B.P. (C-13 corrected).

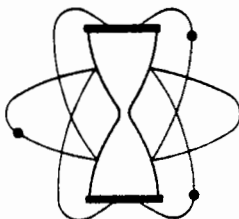
Description: Sample of charcoal in sandy sediment.

Pretreatment: The charcoal fragments were separated from any sand,
 silt, rootlets, or other foreign matter. The sample was
 then treated with hot HCl to remove any carbonates.
 The size of the sample did not permit the use of a NaOH
 treatment. The sample was then washed and dried prior
 to combustion to recover carbon dioxide for the analysis.

Comment: NOTE: C-13 value indicates mostly C-4 plants in sample.

$\delta^{13}\text{C}_{\text{PDB}} = -13.5 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 11228	Date Received:	05-21-85
Your Reference:	Sample submission form.	Date Reported:	07-30-85
Submitted by:	Larry D. Agenbroad Geology Dept. Northern Arizona University Flagstaff, AZ 86011		

Sample Name: Salt Creek #1. T3(?) terrace, east side cr at "Big Pocket" confluence. Top of T3 below recent alluvium.

AGE = Recent, less than 200 C-14 Years B.P.
(99.7 +/- 1.9)% of the modern standard activity.

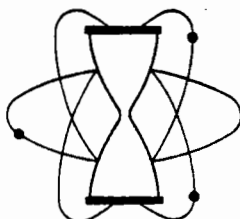
Description: Sample of charcoal.

Pretreatment: The charcoal fragments were separated from any sand, silt, rootlets, or other foreign matter. The sample was then treated with hot dilute HCl and with hot dilute NaOH to remove carbonates and organic contaminants. After washing and drying, the charcoal was then combusted to carbon dioxide for the analysis.

Comment:

$\delta^{13}\text{C}_{\text{PDB}} = -25.1 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11405
 Your Reference: Letter of 07-20-85.
 Submitted by: Larry D. Agenbroad
 Geology Dept.
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 07-25-85
 Date Reported: 08-07-85

Sample Name: North Point #1 Cedar Breaks.

AGE = 9005 +/- 175 C-14 Years B.P. (C-13 corrected).

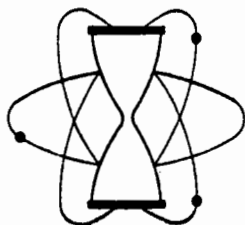
Description: Sample of wood charcoal.

Pretreatment: The charcoal fragments were separated from any sand,
 silt, rootlets, or other foreign matter. The sample was
 then treated with hot dilute HCl and with hot dilute NaOH
 to remove carbonates and organic contaminants. After
 washing and drying, the charcoal was then combusted to
 carbon dioxide for the analysis.

Comment:

$\delta^{13}\text{C}_{\text{PDB}} = -23.5 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged
 by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.
 The age is referenced to the year A.D. 1950.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11312
 Your Reference: Letter of 06-19-85.
 Submitted by: Jim I. Mead
 Vertebrate Paleontology
 Northern Arizona University
 NAU Box 6030
 Flagstaff, AZ 86011

Date Received: 06-24-85

Date Reported: 07-29-85

Sample Name: BL Cave, Area E, Layer O. Natural Bridges Nat. Mon., Utah.
 Dung of extinct mountain goat, *Oreamnos harringtoni*.

AGE = Greater than 39,800 C-14 Years B.P.

Description: Dung pellets.

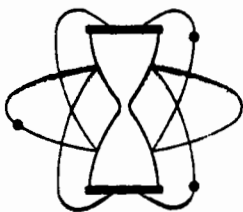
Pretreatment: The plant matter was cleaned of dirt or other foreign material.
 It was then treated with hot dilute HCl to remove any
 carbonates. The delicate nature of the plant matter did not
 permit a NaOH treatment. After washing and drying the sample
 was combusted to recover carbon dioxide for the analysis.

Comment:

$\delta^{13}\text{C}_{\text{PDB}} = -25.2 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11313

Date Received: 06-24-85

Your Reference: Letter of 06-19-85.

Date Reported: 07-29-85

 Submitted by: Jim I. Mead
 Vertebrate Paleontology
 Northern Arizona University
 NAU Box 6030
 Flagstaff, AZ 86011

 Sample Name: BL Cave, Area E, Layer 2. Natural Bridges Nat. Mon., Utah.
 Dung of extinct mountain goat, *Oreamnos harringtoni*.

AGE = 23,350 +1740, -1430 C-14 Years B.P. (C-13 corrected).

Description: Dung pellets.

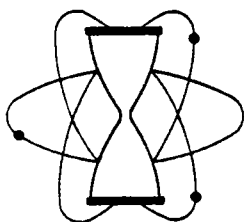
 Pretreatment: The plant matter was cleaned of dirt or other foreign material.
 It was then treated with hot dilute HCl to remove any
 carbonates. The delicate nature of the plant matter did not
 permit a NaOH treatment. After washing and drying the sample
 was combusted to recover carbon dioxide for the analysis.

Comment:

 $\delta^{13}\text{C}_{\text{PDB}} = -26.0 \text{ ‰}$

 Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11562
 Your Reference: Letter of 09-17-85.
 Submitted by: Larry D. Agenbroad
 Geology Dept.
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 09-24-85

Date Reported: 10-28-85

Sample Name: Sample BC #19.

AGE = 2510 +/- 80 C-14 Years B.P. (C-13 corrected).

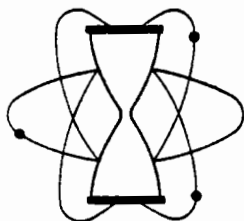
Description: Sample of wood.

Pretreatment: The wood was cleaned of dirt or other foreign material and was split into small pieces. It was then treated with hot dilute HCl to remove any carbonates and with hot dilute NaOH to remove humic acids and other organic contaminants. After washing and drying it was combusted to recover carbon dioxide for the analysis.

Comment:

$\delta^{13}\text{C}_{\text{PDB}} = -25.8 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.


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RADIOCARBON AGE DETERMINATION
REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11563
 Your Reference: Letter of 09-17-85.
 Submitted by: Larry D. Agenbroad
 Geology Dept.
 Northern Arizona University
 Flagstaff, AZ 86011

Date Received: 09-24-85

Date Reported: 10-28-85

Sample Name: Sample BC #20.

AGE = 3750 +/- 165 C-14 Years B.P. (C-13 corrected).

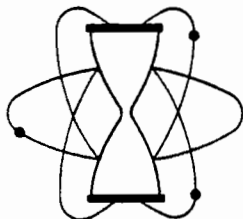
Description: Sample of finely divided charcoal in sand.

Pretreatment: The charcoal fragments were separated from any sand, silt, rootlets, or other foreign matter. The sample was then treated with hot HCl to remove any carbonates. The size of the sample did not permit the use of a NaOH treatment. The sample was then washed and dried prior to combustion to recover carbon dioxide for the analysis.

Comment:

 $\delta^{13}\text{C}_{\text{PDB}} = -27.1 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No. GX- 11564

Your Reference: Letter of 09-17-85.

Submitted by: Larry D. Agenbroad
Geology Dept.
Northern Arizona University
Flagstaff, AZ 86011

Date Received: 09-24-85

Date Reported: 10-28-85

Sample Name: Sample BC #21.

AGE = 4120 +/- 170 C-14 Years B.P. (C-13 corrected).

Description: Sample of charcoal.

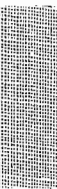
Pretreatment: The charcoal fragments were separated from any sand, silt, rootlets, or other foreign matter. The sample was then treated with hot dilute HCl and with hot dilute NaOH to remove carbonates and organic contaminants. After washing and drying, the charcoal was then combusted to carbon dioxide for the analysis.

Comment:

$\delta^{13}\text{C}_{\text{PDB}} = -26.5 \text{ ‰}$

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C . The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

APPENDIX V
Paleontological Data Sheets



Part D - Paleontology Locality

Bridges N. M., UTA
Locality No.(s), Bare Ladder Ruin

1. Type of Locality: ☐ Invertebrate ☐ Plant ☒ Vertebrate ☐ Trace ☐ Other
2. Formation/Horizon/Geologic Age: Pleistocene, cave fill
3. Description of Geology and Topography: Cave fill from the overhang containing Bare Ladder Ruin. Currently more than 40 feet above stream. Geomorphic evidence suggests presence of a Pleistocene terrace to +30 feet to allow entry to alcove by goats, rats, people
4. Location of Outcrop: Bare Ladder Ruin, Bridges National Monument
Cedar Mesa SS
5. Map Ref.: USGS Quad: _____ Scale _____ Min. _____ Ed. _____
_____ of _____ of _____ of Sec. _____ T. _____ R. _____ Meridian _____
6. County San Juan 7. Federal Admin. Unit(s) NPS
8. Specimens Collected and Field Accession No.: _____
9. Repository: NAU/MNA
10. Specimens Observed and Disposition: long bones of *Oreannos harringtoni*
11. Ownership: ☐ Priv. ☐ State ☐ BLM ☐ USFS ☒ NPS ☐ Ind. ☐ Mil. ☐ Other
12. Recommendations for Further Work or Mitigation: no additional material evident; may be worth while to excavate a portion of the midden
13. Type of Map made by Recorder: detailed arch map by Nickens & Associates, Montrose, CO
14. Published References: _____
15. Remarks: 1st record of *O. harringtoni* from the state of Utah, extends the known range of the specimens known from the Grand Canyon.
16. Sensitivity: ☐ Critical ☒ Significant ☐ Important ☐ Insignificant
17. Recorded by: Azenbroad & Mead

Part D - Paleontology Locality

Locality No.(s) GC-BC-P 1-85

1. Type of Locality: ☐ Invertebrate ☐ Plant ☒ Vertebrate ☐ Trace ☐ Other
2. Formation/Horizon/Geologic Age: Terrace 4 of the canyon fill. Estimated to be 10000-15000 BP
3. Description of Geology and Topography: Specimen weathering from the cutbank face of T4 at the "Big Bend" in Bowns Canyon, (east end).
4. Location of Outcrop: Big bend in Bowns Canyon
5. Map Ref.: USGS Quad: Rincon Scale 15 Min. 15 Ed. 15
of 15 of 15 of Sec. 15 T. 15 R. 15 Meridian 15
6. County 15 7. Federal Admin. Unit(s) Glen Canyon National Rec. Area
8. Specimens Collected and Field Accession No.: (1) fragment of pelvis (GC-BC-P 1/85)
9. Repository: Northern Arizona University, Flagstaff, Az. Dept. Geol.
10. Specimens Observed and Disposition: 15
11. Ownership: ☐ Priv. ☐ State ☐ BLM ☐ USFS ☒ NPS ☐ Ind. ☐ Mil. ☐ Other
12. Recommendations for Further Work or Mitigation: 15
13. Type of Map made by Recorder: Geol. field map and section from field notes
14. Published References: 15
15. Remarks: Marmota pelvis fragment in the T4 alluvium, above the "Big Bend" in Bowns Canyon
16. Sensitivity: ☐ Critical ☒ Significant ☐ Important ☐ Insignificant
17. Recorded by: Aganbroad & Elder