DOLORES ARCHAEOLOGICAL PROGRAM TECHNICAL REPORTS

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Geology of the Dolores Project Area

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Under the supervision of
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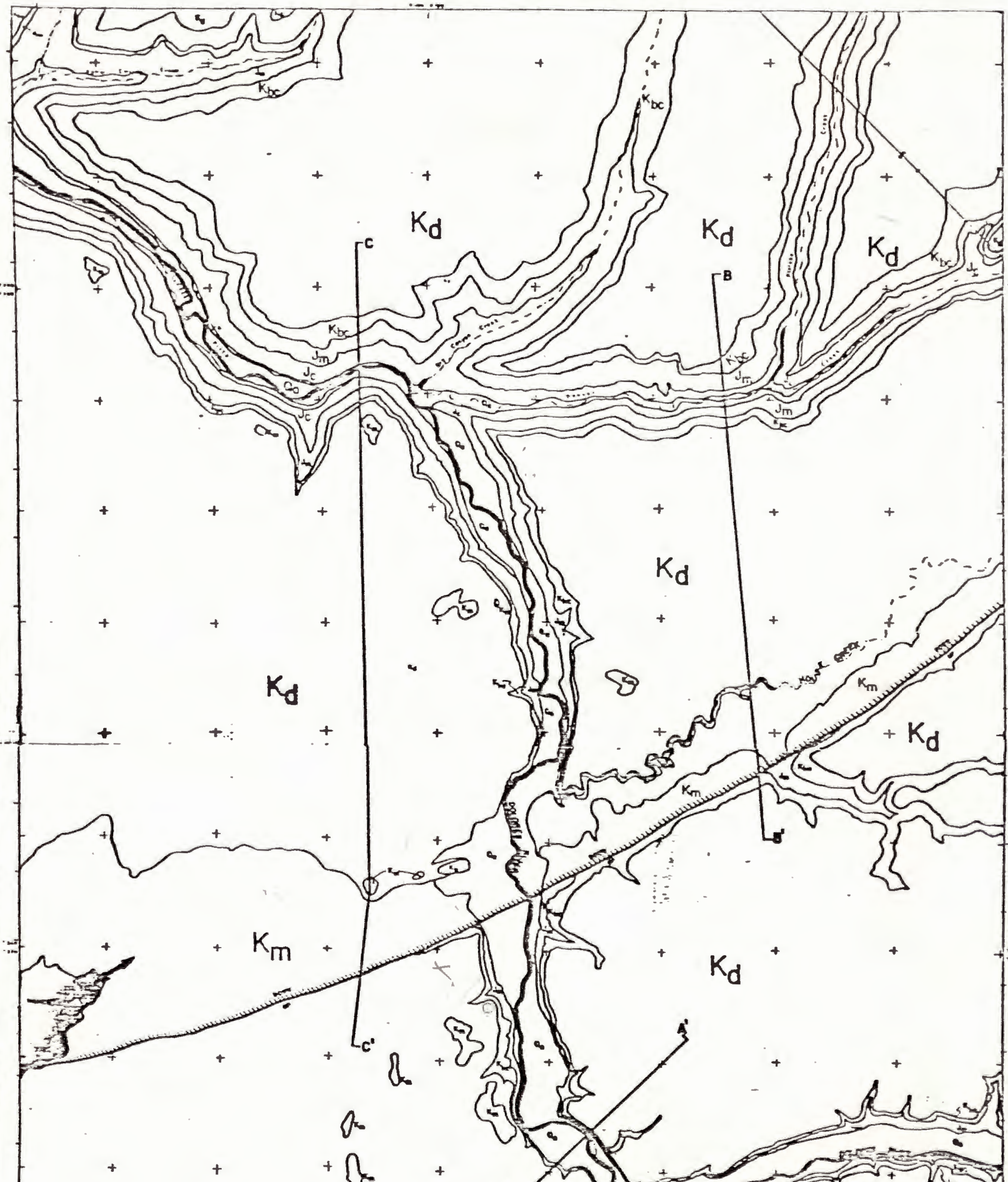

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ABSTRACT

Integrated geological studies for the Dolores Archaeological Program provide project wide descriptions of landforms, rock units, Quaternary sediments, soils, and drainage systems. Additionally, geological studies provide alternative chronological control for archaeological material recovery and climatic reconstructions.

During the 1979 field season preliminary geologic mapping of soils, landforms, bedrock, and drainage areas was completed. Archaeological stratigraphy was recorded and samples were taken for sedimentary analysis. The resulting data base provides a working baseline form which revisions and interpretations can be made with regards to settlement location, resource availability, and agricultural potentials.

PREFACE

Geological studies have continued to contribute informative data to the Dolores Archaeological Program since 1979. This chapter was prepared immediately after the 1979 field season and offers initial findings about geology in the project area. Since the preparation of this report, many new geologic interpretations and map revisions have been made. Other geological consultants and U.S.D.A. Soil Conservation Service (S.C.S.) personnel have been working in the project area resulting in the revised interpretations. Increased numbers of stratigraphic exposures within archaeological sites and with in Bureau of Reclamation excavations also allow increased visibility of geological phenomena within the project area. The integration of these new concepts will be seen in future geologic reporting in the series.

ACKNOWLEDGEMENTS

The 1979 field crew of Richard Glaser and James Hampson are recognized for their fieldwork and geological mapping contributions to this chapter. J.P. Panel and the Durango and Cortez Soil Conservation Service offices were also instrumental in the descriptions and soils mapping project during the 1979 field season. The Dolores Archaeological Project Environmental Studies Group willingly provided enthusiasm and incorporated geological studies into their research design.

GEOLOGY OF THE PROJECT AREA

Formal geological research was incorporated into the Dolores Archaeological Program (D.A.P.) as part of the 1979 summer excavation season. During development of the D.A.P. Research Design, questions about prehistoric economy and cultural ecology were posed which could not be answered adequately without baseline data about both the physical and biotic environments of southwestern Colorado. The principal investigators asked first for a statement of the potential for geological research to contribute information relevant to the several problem domains defined for the D.A.P. The statement of potential (Appendix A) emphasizes that geologic research would, first and foremost, provide a description of the physical geography, including delineation of landforms, rock units, sediments, soils, and drainages which could be described as components of the environment utilized by people. Second, the statement of potential indicates that geologic research would provide additional chronological control for archaeological materials; could acquire data about both cultural and natural chronologies within archaeological sites; and could provide information relevant to studies of prehistoric climate and climatic change.

When fieldwork began in 1979, three organizational tasks were undertaken. The first was to generate a specific set of questions about the local geology which would direct geologic research toward acquisition of information relevant to the archaeology and would provide a set of questions intended to integrate the geologic data into the archaeological program. The second was to establish a set of priorities to insure that the most critical work was done with the time, personnel, funds, and

facilities available. The third was to initiate a standardized system for recording data about site stratigraphy so that a minimum set of comparable information was collected from all excavated sites.

The initial priority for data acquisition was to record the stratigraphy in archaeological excavations. Stratigraphic documentation took precedence over all other work beause the record was destroyed by excavation. Very early in the season it became obvious that the best geologic record for the past 1000 years or so was contained within the archaeological sites. This record is deemed critical for both the geology and the archaeology since the processes of pithouse filling or room filling record very localized erosion-deposition cycles. It is anticipated that there is a pattern which will provide a basis for inferring short-term climatic phenomena which controlled the kinds and rates of local geologic processes throughout the span of Anasazi occupation. The Earth Resources Task Group devoted at least half of their working time to recording site stratigraphy and advising excavators. In addition to field description, sediment samples and monolith columns were taken for laboratory description and analysis.

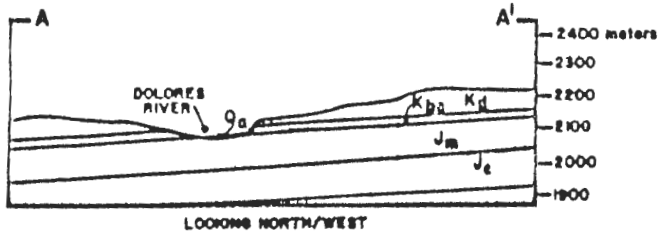
The second major priority was to locate the geologic provenience of ceramic and lithic materials utilized prehistorically. This was done by mapping the bedrock stratigraphy and noting the geologic source of materials found in archaeological sites. A great deal of geologic research has been done in surrounding areas, but only small scale or localized reservoir project maps were available prior to the 1979 season. Using the standard geologic section description and U.S.G.S area maps for control, program geologists mapped and described the bedrock in the project area at the standard U.S.G.S. 7.5 Minute Quadrangle scale of

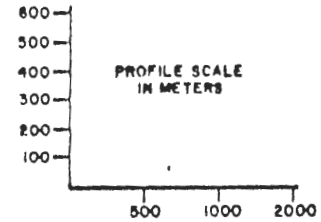
1:24,000 (Figure 9.1, 9.2, and Appendix B). The map provides a survey control for the archaeology, and it shows the locations of present day outcrops where local lithic resources can be found. Due to extensive erosion, the exposures have been modified through time and one cannot say precisely where aboriginal peoples procured tool stone, but the locations of the resources are certain. The geology map is not a final product--it is a working document. More thorough descriptions of the mapping units are necessary. Measured sections will be desirable because not all of the units in the D.A.P. area fit neatly into the Jurassic and Cretaceous formation sequence. In some localities, large scale maps which delineate individual members or distinctive beds within the formations may be useful for archaeological interpretation.

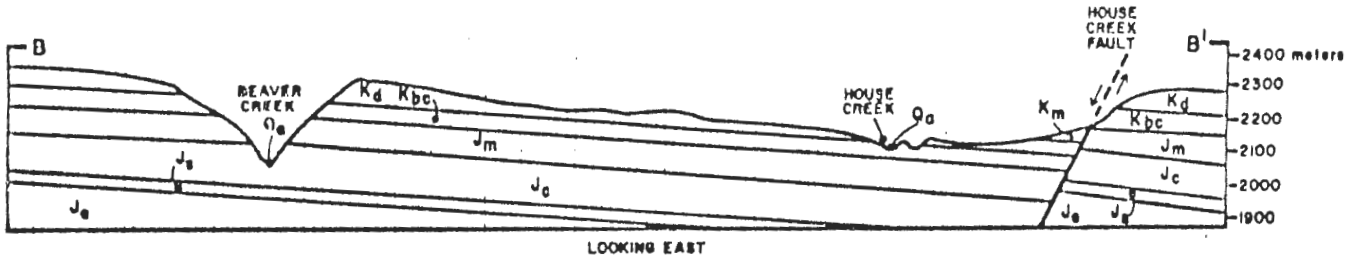
A map of the major landforms was made as the bedrock was being mapped (Figures 9.3 and 9.4). This map delineates the major landforms --the large scale topographic features--such as the dip slope, canyon walls, fault scarps, knobs, ridges, terraces, and fans. Like the others, this map is a working document. Many features, especially the canyon wall unit and the dip slope unit, are too gross. They contain smaller topographic features which are probably the archaeologically significant features. One aspect of the geomorphology, the drainage system, was mapped separately (Figure 9.5). The drainage-basin map delineates drainage basins, the divides between basins, and the drainage ways. Streams in the project area are classified by order, with the small, unbranched streams designated as first order, and the largest stream, the Dolores River, designated as sixth order. This is commonly termed the Strahler System (Strahler [1]).

Work began on a map of the Quaternary deposits in the project area,

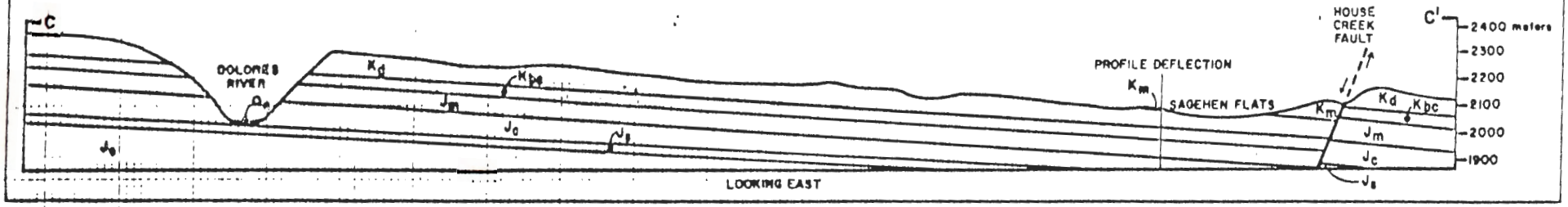
GEOLOGICAL PROFILES



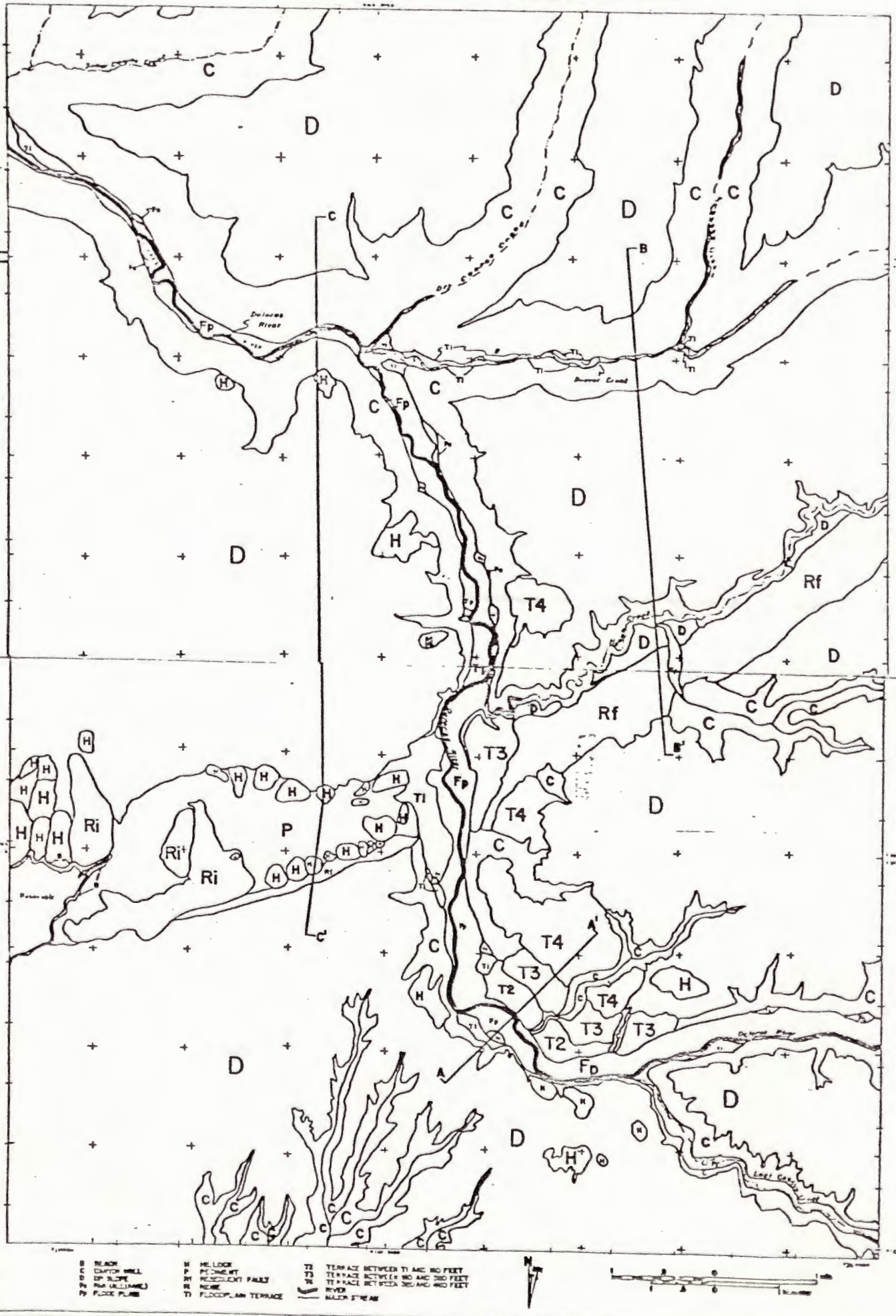




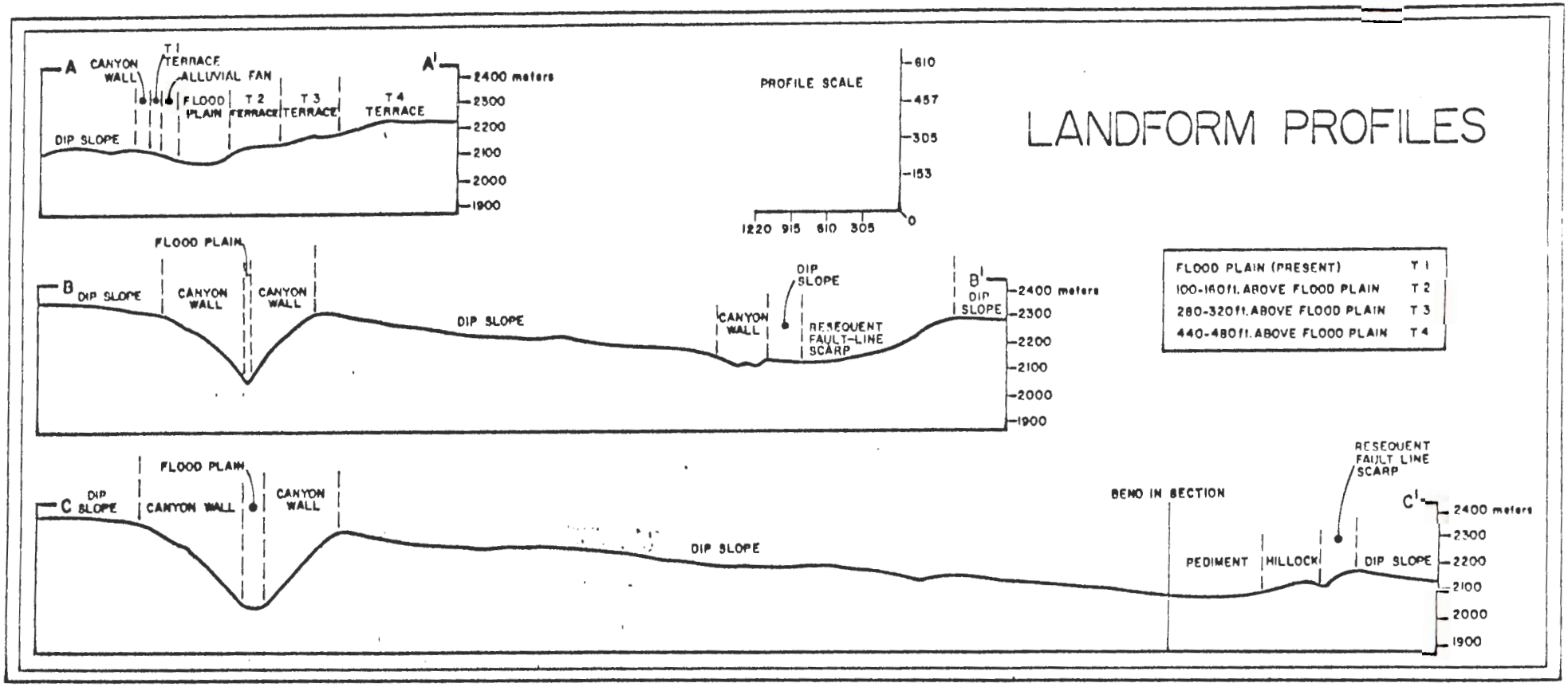
ALLUVIAL DEPOSITS	Qa
DAKOTA SANDSTONE	Kd
BURRO CANYON FORMATION	Kbc
MANCOS SHALE	Km
MORRISON FORMATION	Jm
JUNCTION CREEK SANDSTONE	Jc
SUMMERVILLE FORMATION	Js
ENTRADA SANDSTONE	Je



PRELIMINARY GENERAL LANDFORM MAP



LANDFORM PROFILES



MODERN STREAM ORDER-DRAINAGE BASIN MAP

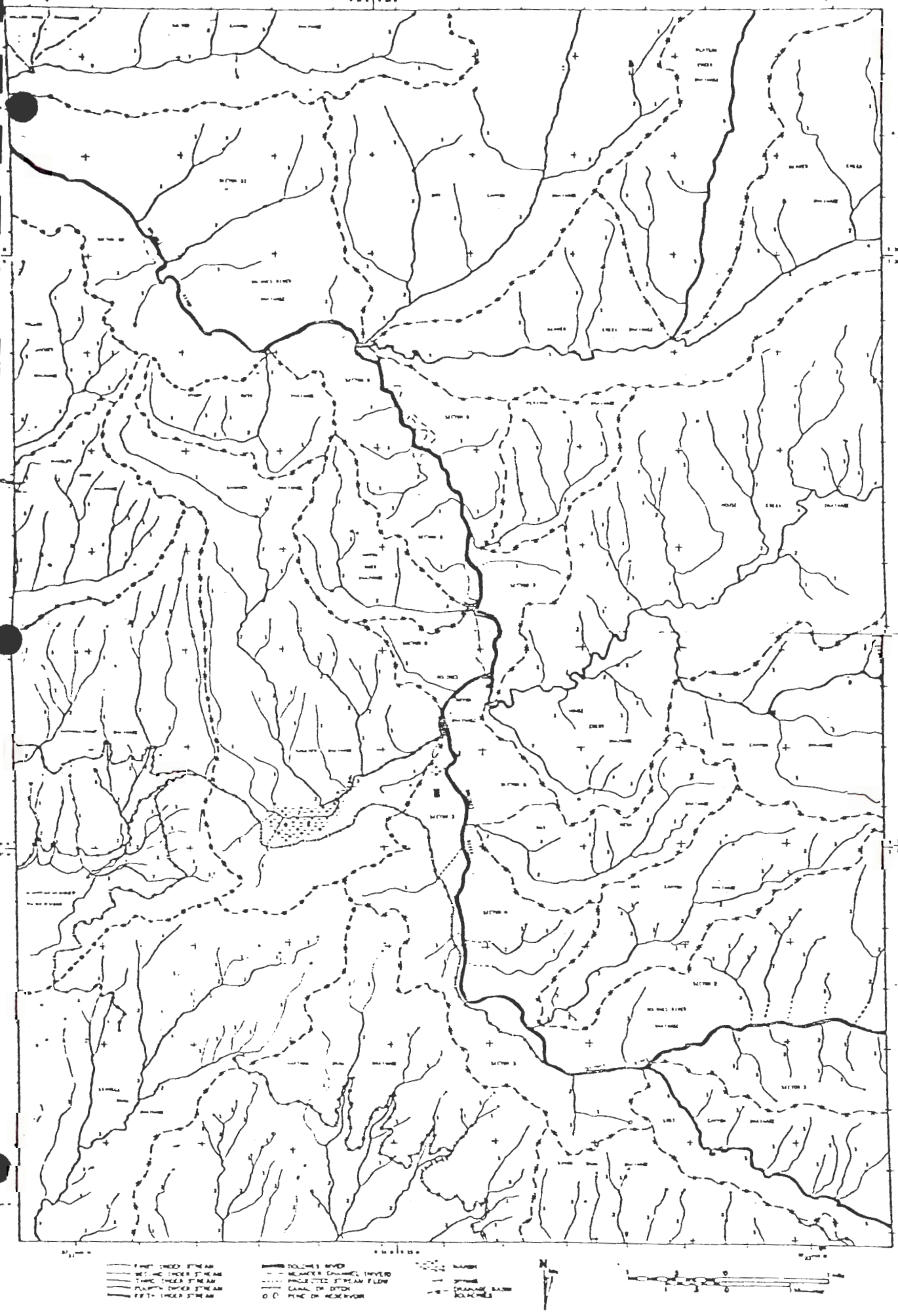


FIGURE 9.2

SOILS MAP

Table 9.C.1 Identification Legend Cortez Soil Survey Area, January 1979 (page 3 of 3)

SL	Rubble land
T1-B	Weber loam, 1-3 percent slopes
T1-C	Weber loam, 3-6 percent slopes
*VO-B	Otero fine sandy loam, 1-3 percent slopes
VO-C	Otero fine sandy loam, 3-6 percent slopes
VOA-B	Otero fine sandy loam, alkali, 1-3 percent slopes
VOB-B	Otero fine sandy loam, seeped, 1-3 percent slopes
VOC-B	Otero clay loam, 1-3 percent slopes
VOC-C	Otero clay loam, 3-6 percent slopes
*V1-B	Hesperus loam, 1-3 percent slopes
V1-C	Hesperus loam, 3-6 percent slopes
V1-D	Hesperus loam, 6-12 percent slopes
*WO-B	Ackmen loam, 1-3 percent slopes
WO-C	Ackmen loam, 3-6 percent slopes
WOB-B	Ackmen loam, seeped, 1-3 percent slopes
W1-B	Zigwied clay loam, 1-3 percent slopes
W1B-B	Zigwied clay loam, seeped, 1-3 percent slopes
W1C-B	Zigwied clay loam, very wet and saline, 1-3 percent slopes
*XTO-E	Ustic Torriorthents
Z	Gullies

*Indicates units recognized in D.A.P. area. Descriptions of these units follow.

but only preliminary mapping was completed. The Quaternary stratigraphy consists of complex deposits of loess, alluvium, and colluvium. Distinguishing different stratigraphic units and determining both the depositional and erosional geochronology will be a major task.

A detailed soils map for the project area was not included in the initial objectives because of insufficient control data. However, descriptions of U.S.D.A. Soil Conservation Service (S.C.S.) mapping units were obtained, as were some preliminary manuscript maps. This, and the assistance of S.C.S. personnel familiar with the soils in the area, provided the basis for a detailed reconnaissance soils map (Figure 9.6 and Appendix C). A detailed soils map to the series or complex level was judged to be of greater importance to the archaeology than was the Quaternary stratigraphy map because soils constitute one of the principal economic resources considered in the research questions. Therefore, priorities were reordered and the soils map was made but the Quaternary stratigraphy map was not made.

In addition to the major geologic soils mapping projects, the Program geologists devoted a great deal of time to the geology of archaeological sites. In addition to making profile descriptions, the geologists aided excavators and laboratory personnel with rock identification, soils identification, and preserving stratigraphic samples and monoliths. The geology field workers also wrote brief background reports on the geology of each of the archaeological sites for inclusion in the site reports. Before the field season started a bibliography relevant to the geology of the project area was compiled and copies of important works were made for the program library. A list of available maps and air photos was compiled in conjunction with the bibliography. These materials are on file at the

D.A.P. laboratory.

Another of the initial tasks was to write a manual to assist project personnel with descriptions of the fill in the archaeological sites. The objective was to provide a standard terminology for stratigraphic descriptions and to provide a set of criteria to be used in the field for distinguishing and describing both sedimentary and soils features. The D.A.P. Stratigraphic Description Manual was included in the Program Field Manual (Kane et al. [2]) The manual was based on a modification of the Soil Conservation Service description system (Soil Survey Staff [3]). This manual seems to have worked reasonably well for crew members who had some exposure to either geology or pedology and crew members who were simply interested had little trouble learning to use the book. A problem was encountered with the recording forms intended to code information for computer retrieval. The first form was a failure and was substantially modified by midseason.

By the end of the 1979 excavation season, a working description of the physical environment of the project area had been presented in the form of maps and descriptive legends. From these documents it is possible to define the geographic situation of any site in terms of a specified set of variables. For instance, a site may be situated on the dip slope with Dakota Sandstone bedrock, in an area of deep loess with a Witt loam soil, and adjacent to a first order stream. The site may be 300 m from the nearest exposure of suitable building stone and 1500 m from the nearest exposure of suitable tool stones. The association of such variables at each site provides the basis for determining the regularities in geographic constraints in settlement patterns within the project area. Simple inspection clearly indicates that most Basketmaker Period sites

occur in a geographic configuration different from that of most Pueblo period sites. This would indicate that Basketmaker people and Pueblo people were selecting for different environmental factors when choosing a place to live. Exactly which factors were determinants and why they were so are open questions.

Even though all the work done in 1979 (and additional work done in 1980) is preliminary baseline descriptive work, there is sufficient information available to test for general correlations among archaeological sites of different kinds and ages and different geologic, geomorphic, and soils features. Such studies could be run as tests on a specific hypothesis or they could be run blindly to see what is associated with what and to what degree. Either way, a first approximation of a settlement system can be made. Both norms and discrepancies from norms will provide clues for needed additional information on the environment.

Again, all the work completed thus far is baseline description of the modern physical geography. Limitations of time, people, and financial support have precluded any detailed analytic work. The site stratigraphy data currently exist as drawings, raw verbal descriptions, and samples in storage. To make intrasite comparisons and correlations or to investigate the possibility of microclimatic controls, detailed descriptions of preserved sections and mechanical analysis of sediment samples will be necessary. There are many areas where it is now impossible to decide whether a geologic deposit is eolian or alluvial in origin. Laboratory work is critical. The only basis for rating present day local soils for agriculture potential is inspection of modern cultivation practices. Local descriptions and laboratory tests for chemical and physical factors affecting plant growth are necessary.

Perhaps the most significant factor to consider when using the present physical environment as the basis for a model of a past physical environment is that geologic processes in the D.A.P. area are dynamic. Erosion has been the dominant process since the uplift and deformation of the Mesozoic sediments. Several hundreds of feet of sediment have been removed and there is good evidence that much of the Mancos Shale has been eroded from the southern half of the project area within the past few tens of thousands of years. Erosion during the span of human occupation might not have been as dramatic, but, even so, the combination of steep gradients, poorly resistant sediments, scattered vegetation and seasonal storm or runoff patterns have surely combined to alter the forms of the surface landscape significantly. If the environment has been dynamic, one must assume that patterns of human interaction with the environment were also dynamic, and any models of prehistoric cultural ecology must include this dynamic dimension.

The present environment provides a baseline for extrapolation. It cannot be transported backward in time without considering changes which have occurred, and those changes can only be determined through extensive, detailed research.

APPENDIX A

DESIGN MEMOS: THE POTENTIAL FOR GEO-ARCHAEOLOGY

INTRODUCTION

The general potential for geo-archaeological research in conjunction with the D.A.P. is best summarized by considering each problem domain delineated for the project and specifying how the study of landforms, sediments, soils, and site stratigraphy can contribute to answering questions within each domain. With a broadly conceived multidisciplinary archaeological project such as the D.A.P. the potential contribution of geo-archaeological research is great.

Problem Domain 1: Ecological Adaptations[1]

Ecology is the study of the dynamic interrelationships between organisms and their environments. In archaeology, the general emphasis in ecological studies is on the cultural systems which articulated peoples with the environments in which they lived. Geology is especially relevant to this domain because landforms, rock types, clastic sediments, and soils constitute a major component of the physical environment to which people adapt. Geologic research describes the physical environment and thereby establishes a basic framework for the study of human adaptation.

From an archaeologist's point of view--not a geologist's--the geologic component of the environment must be divided into two parts. The first is that which can be considered to have been constant and unchanging. The major stratigraphic systems, geologic structures, and

[1]The names of Research Design Problem Domians use in the first part of this appendix relects the terminology current when the original memo was prepared. Some of these names have since changed and these changes are reflected in the General Discussion Section which follows, ed.

landforms--hardrock geology--have not changed dramatically over the past 10-15 thousand years. The other part is the dynamic aspect of the physical environment, this consists of the landforms and sediments which were formed or altered during the span of human occupation. River terraces, alluvial fans, talus slopes, and cave sediments are examples of parts of the physical environment which must be considered as variables in the ecologic equation.

Climate is also an aspect of the physical environment. Because many geologic processes are in some measure or other climatically controlled, studies of depositional, erosional, and weathering phenomena provide one basis for inferring past climate regimes. This aspect of geologic research supplements data about past environments derived from botanical and zoological studies. The combination of geology, botany, and zoology provides the description of the total environment, the bio-physical environment, in which people operated.

Problem Domain 2: Paleodemography

Geologic research would not contribute directly to paleodemographic studies, but indirectly, the studies of environmental parameters would be applicable to delineating settlement patterns and settlement systems by providing data relevant to the geographic units in which settlements are distributed and in which settlement systems operated. Natural differences within and between different areas could be important determinants in settlement systems either through space or through time.

Problem Domain 3: Community Activities and Social Organization

Geologic research would not contribute directly to studies of

community organization and social organization, but there might be indirect contributions. Site stratigraphy could be important to delineating diachronic communities within a site, and micro-stratigraphy within sites might also be useful for correlating synchronic archaeological units. This would be most important for preceramic periods, but the potential for application in ceramic-period sites should not be slighted.

Problem Domain 4: Foreign Relations

Apart from identifying exotic materials and sources for trade materials, geologic research would not contribute greatly to the study of inter-areal cultural relationships. Even the most hardened environmental determinist would have to admit that artifacts are far more sensitive indicators of connections between peoples than are geological features!

Problem Domain 5: Culture Process

Due to the kinds of information about the physical environment described under Problem Domain 1, geologic research can contribute to studies of culture change by providing information about the environmental system within which culture change took place. Changes in culture systems can take place independently of the environmental system, but some changes take place either as a reaction to changes in the environmental system or as a result of changes in adaptations to the environmental system. When changes in the environmental system can be documented, one can assume that there might have been corresponding changes or adjustments on the culture side of the ecologic equation. If they are discernable, the kind of adjustment or the magnitude of change is important for determining culture process which is a function of ecologic relationships rather than change

which is a function of social relationships. Equally important, but more difficult to determine, are environmental changes which might be a result of human activity or changes in human activity.

A more abstract, but no less important, contribution of geology to the study of culture change and culture processes is the study of the limiting factors in the environmental system. It may seem prosaic, but the association of agricultural communities with areas where soils, moisture regimes, and temperature regimes are suitable for agriculture is not a product of chance. Such associations are the result of peoples' perceptions of the potentials and limits of their physical environment and application of culture mechanisms for operating within those constraints. Changed perceptions, changed mechanisms, or changed environments all can be both products of and contributors to culture change. The significance of geo-archaeology in this context is that it can help discern the importance of the environmental side of the ecologic equation to changes which took place within the culture side of the ecologic equation.

The Geo-Archaeological Problem Domain

The hyphenated hybrid word "geo-archaeology" generally designates a study of geology to contribute directly to the solution of archaeological problems. Seldom recognized is the fact that the study of archaeological problems can contribute to understanding geologic phenomena. The synergistic effect comes about because the initial problems that must be confronted are geologic problems, determining the processes and phenomena which contributed to the formation of a particular set of geologic features in a particular area. These problems are relevant to the archaeologist because archaeological materials occur in or on geologic

features. The initial solution of geologic problems thus provides one framework for ordering archaeological data in time and space.

Within archaeological sites, the geologic strata can be the result of human activity as well as geologic processes. Distinguishing between the two and evaluating their relative importance contributes to understanding both the archaeological and geological phenomena. Because archaeologists normally are concerned with much shorter time periods than are geologists, archaeological information is frequently useful for distinguishing geologic features which might not have been of great enough duration or widespread enough to be of great geologic significance. But such minor geologic features could represent some localized phenomenon which might have had a profound effect on prehistoric peoples.

Specific kinds of questions within the geo-archaeological domain must range from purely operational questions about site stratigraphy to grand interpretation questions about the interrelationships between cultural systems and natural systems. Formulating questions about the geology of the project area and the included archaeological sites and then relating such questions to specific archaeological problems must be the first phase in developing the geo-archaeological problem domain. Once basic questions have been formulated, the routine of fieldwork and analysis must be scheduled to coordinate with construction schedules and excavation schedules.

At the very least, geological research will help to establish and to document stratigraphic and chronologic controls for archaeological material. At the very best, it will contribute to an understanding of how prehistoric (and historic) peoples have adapted to the particular place at different periods of time, and perhaps, it might contribute to an understanding of why some people were successful and why some were not.

GENERAL DISCUSSION

The foremost objective of the D.A.P. is to understand the dynamics of Anasazi community organization in terms of relationships between cultural and natural systems. A prerequisite for such a study is knowledge about the physical and biological systems within which cultural systems operated and to which the Anasazi people were adapted. Geologic research is considered necessary to delineate and describe the physical system, to provide chronologic control, and to evaluate the importance of both permissive and limiting factors within the physical environment.

The General Research Design for the project is developed from a series of questions within a set of five problem domains to guide research and data acquisition. This statement follows the same format by providing generalized questions about the geology of the area which will integrate geologic research with the archaeological research. The questions are first expressed under the heading "Geologic Research Domain" and then reorganized according to the relevant archaeological problem domain.

Geologic Research Domain

General Logic: The geology of southwestern Colorado constitutes a major element of the physical environment. Rock types, landforms, soils, and water resources, among other attributes of the physical geography, are parts of the physical constraints imposed on cultural systems by the environment. To understand the interaction of cultural and natural systems, questions about the kind of constraints presently considered important are posed.

I. What is the physical geography?

A. What are the landforms?

B. What are the major stratigraphic units?

C. What are the soil types?

D. What are the major resources?

1. What are the mineral resources?

2. What are lithic resources?

3. What are agricultural soils resources?

4. What are water resources?

E. Where are resources located?

F. What factors can be inferred to be of possible importance even though there may be no direct evidence for their significance in the archaeological record?

G. What is the correlation between sites by type and geographic variables?

H. What is the correlation between sites by age and geographic variables?

II. What is the geochronology?

A. What is the relative and absolute age of geomorphic units?

B. What is the relative and absolute age of stratigraphic units?

C. What is the variation within and between sites which relates to the geochronology?

III. What are the relevant geologic processes?

A. Which processes are related to human activity?

B. Which geologic processes reflect climatic variation?

C. What geologic changes would have affected food production or human settlement?

D. What are chronologic correlates with other data sets, i.e., geology, palynology, and paleobotany?

E. What are correlations between observed geologic/environmental change and observed cultural rhythms?

F. If a strong correlation exists, can some cause-effect relationship be inferred?

G. How is a cause-effect relationship to be distinguished from a coincidental relationship?

IV. Are there other considerations?

Problem Domain 1: Economy and Adaptations

Question 1 - What resources were available in the area in each period?

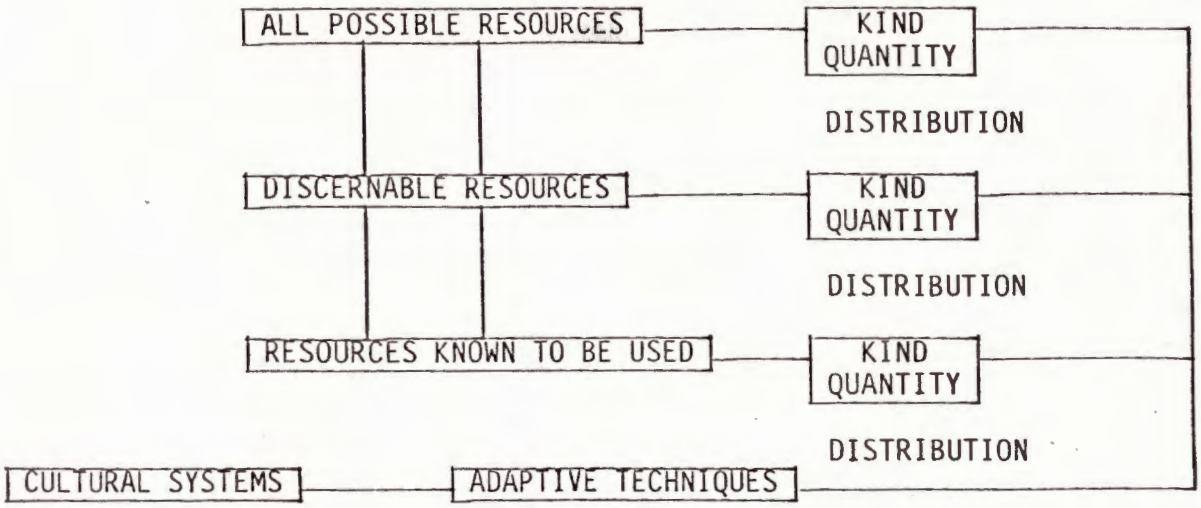
(From geology question I. D.--What are the major resources?)

1. What are the mineral resources?
2. What are the lithic resources?
3. What are the agricultural soils resources?
4. What are the water resources?

From geology question I. E.--Where are resources located?

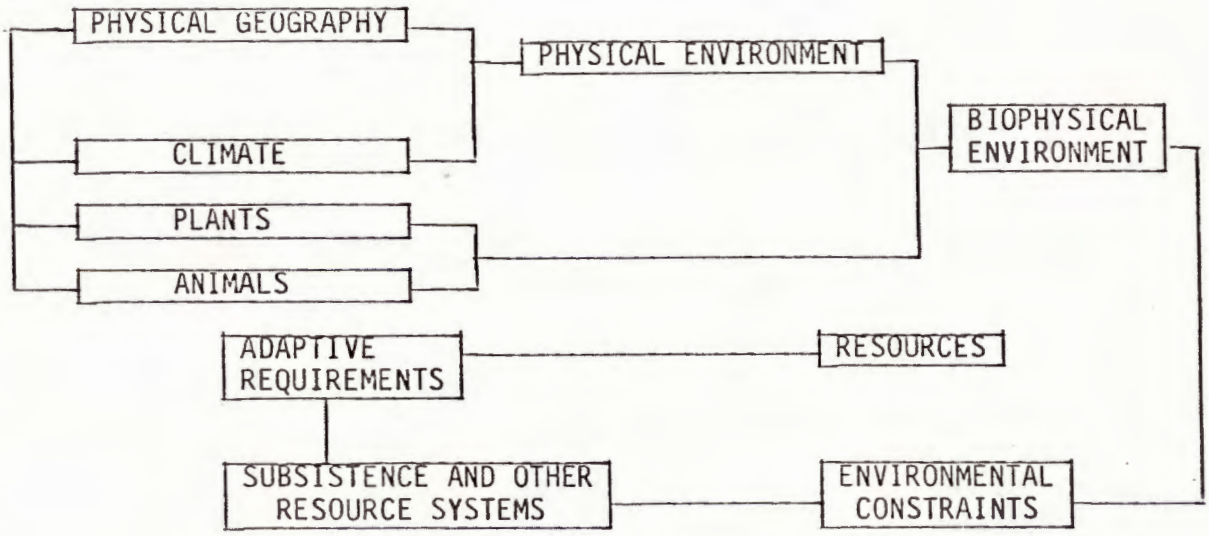
Question 3 - How were resources used?

From the geology:



Is there temporal variation in availability or use of resources?

Question 4 - How were the resource techniques and the levels of use combined to form subsistence and other resource systems?



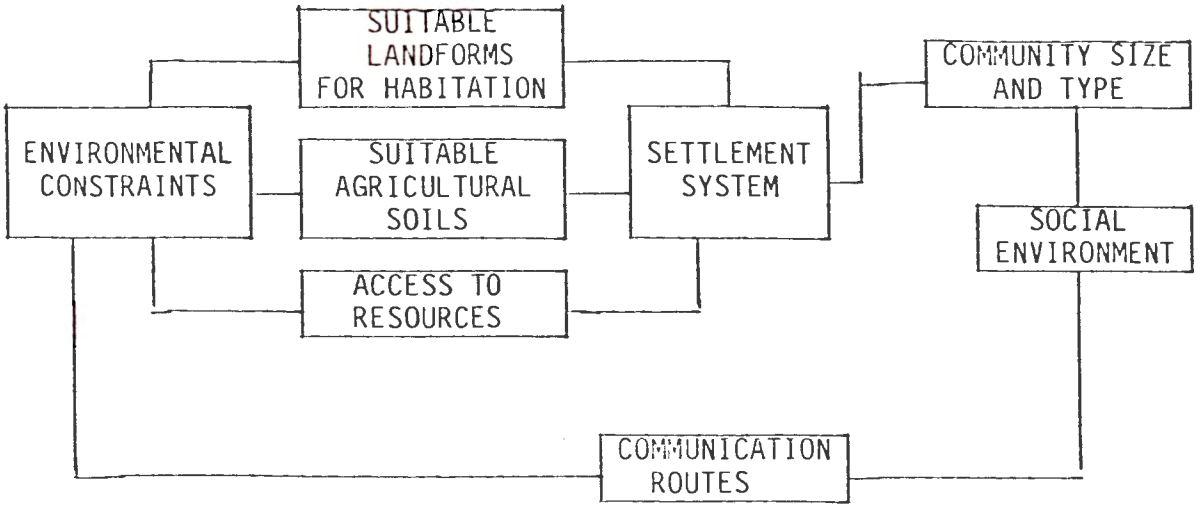
Problem Domain 2: Paleodemography

Question 3 - How was population distributed over the area in each period?

From geology - What is the physical geography?

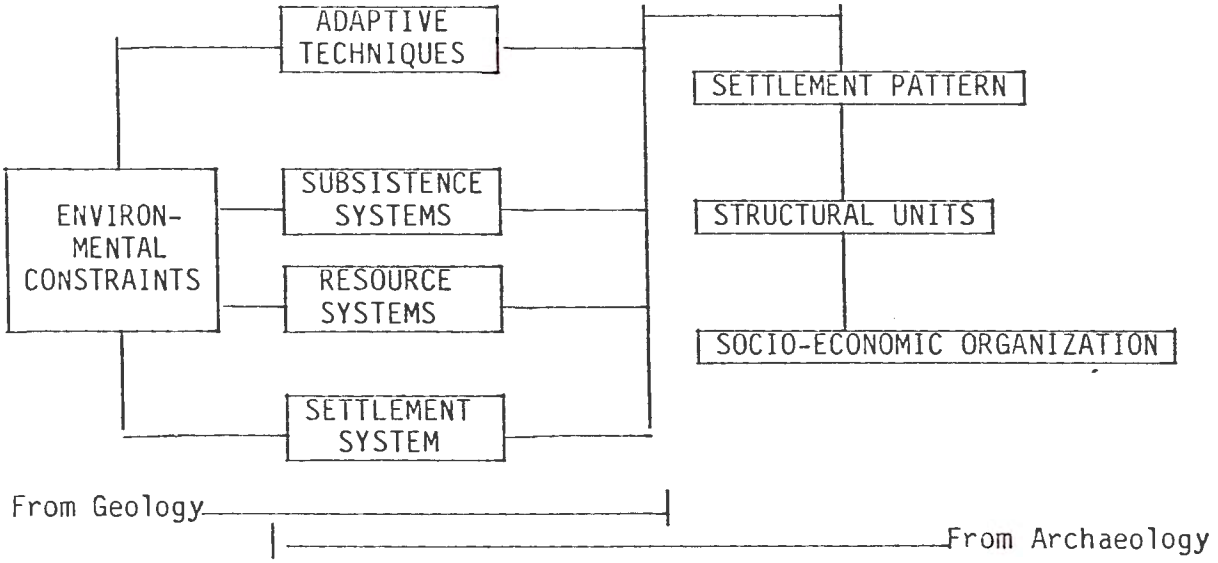
What are the resources?

Where are the resources?



Problem Domain 3: Social Organization and Settlement Pattern

The settlement pattern is inferred from the distribution of structural units (social groups) of different sizes according to the distribution of landforms, resources, and other factors considered in previous problem domains.



Question I - What is economic organization of the community?

Problem Domain 4: Foreign Relations

Question 1 - What D.A.P. data reflect exchange outside the project region?

From the geology - Identification of exotic materials.

Question 3 - What mechanisms of cultural exchange can be inferred to have operated in the project area?

From the physical geography - 1. On the basis of topography what are reasonable routes of travel and communication?

2. Are there physical barriers which would impede travel or communication in any direction?

3. Are any trails actually discernable? If so, where do they originate and where do they go?

Problem Domain 5: Culture Process

Question 2a- Given diachronic variability, what cultural mechanisms or processes can be inferred?

2b- What rhythms in settlement pattern occurred?

From the geology - Are there any data in depositional, erosional, or weathering history which suggest changes in the physical environment which would be of sufficient magnitude to have altered the physical basis of the settlement pattern?

Question 5a- What caused the Anasazi to move out of the area?

5b- What environmental factors might be involved?

From the geology - 1. What is the baseline physical environment to which the Anasazi were adapted?

2. What are significant parameters in the physical environment?

3. Are there any discernable variations in the parameters? What is the kind, chronology, and magnitude of variation in environmental parameters?

APPENDIX B

GEOLOGY

BEDROCK GEOLOGY

Introduction

Bedrock geologic units in the D.A.P. area and immediate environs are all Mesozoic sedimentary rocks of the Jurassic and Cretaceous periods. Locally the units have been deformed and eroded and in nearby areas they are intruded by later igneous rocks. The local bedrock is exposed as a weathering surface or is mantled by a thin veneer of eolian or alluvial sediments. The sedimentary geology is important for the archaeological interpretation because local rocks provide an immediate source for local building materials and tool stone. The sediments overlying the bedrock strata and weathered bedrock products constitute the parent materials for local soils.

A Preliminary Geologic Map (Figures 9.1 and 9.2) of the D.A.P. area was made using U.S.G.S. maps and descriptions for control. The map, compiled from air photos and ground inspection, shows the occurrence of recognized stratigraphic mapping units in the project area in conjunction with major structural features, such as the House Creek Fault and the Dolores River canyon. The map is called "preliminary" because it is presently a working document which can be refined. Refinements would include mapping lithologic variations within the formations or members which would not be of great stratigraphic significance but which might well be of cultural importance. Descriptions of local geologic units are also required.

The major stratigraphy in the D.A.P. area is only a part of the complex Mesozoic sedimentary systems present in the Four Corners area of the Colorado Plateau. The later sediments of the Mesa Verde Group, which

dominate the geology only a few miles southeast, have been completely eroded away in the project area. Earlier units, which dominate the geology further west, are not exposed in the project area. The following formations are those recognized and mapped in the project area.

Summerville Formation (J_s)

This unit is exposed downstream from the McPhee Damsite as a red-brown thinly bedded siltstone with minor inclusions of thinly bedded white sandstone (Bush and Taylor [4]). This is a slope-forming unit.

Junction Creek Sandstone (J_{jc})[2]

The unit is a brown to buff, moderately well-sorted to well-sorted, well-bedded terrestrial sandstone (Shawe et al. [5]). In the project area, two members can be distinguished. The dominant unit is white to yellow-orange, thick to massively bedded, fine to medium-grain, cross-bedded, eolian quartz sandstone. The unit erodes to rounded cliffs with distinct polygonal or checkerboard weathering patterns.

Archaeologically, the Junction Creek Sandstone is of particular interest only in that it forms the bedrock foundation at Grass Mesa. The unit does not contain any rock of special cultural importance. It is too massive and too friable to be a good building stone, although it was used occasionally, and it is not exposed widely enough to contribute significantly to local soil parent materials.

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[2]Preliminary copies of the Bedrock Geology Map identified this formation as Entrada Sandstone.

The Morrison Formation (J_m)

The Morrison Formation consists of flood plain, fluvial, and lacustrine deposits and contains red, green, and orange sandstone, siltstone, mudstone, and conglomerate (Criag [6]). Minor thinly-bedded, erosion-resistant sandstones are a prominent slope-forming unit. The upper Brushy Basin Member resembles the overlying Burro Canyon Formation, and the two may intertongue. The Brushy Basin Member includes white to pale brown siltstone, mudstone, and claystone with minor inclusions of orthoquartzite, tuff, and arkosic materials. The Salt Wash Member includes light, red-brown to buff sandstone, red-brown mudstone, and a light gray to buff sandstone.

The rocks of the Morrison Formation are of considerable archaeological interest because they are a high quality, locally available tool stone. Many of the finer textured rocks have been consolidated through silica cementation and, consequently, have characteristics of fracture suitable for manufacturing flaked stone implements.

The Burro Canyon Formation (K_{bc})

Rocks of the Burro Canyon Formation are extremely variable flood plain, fluvial, and lacustrine deposits. They are light gray to buff conglomeritic sandstone, green-gray shale and siltstone, and green gray to gray limestone and chert (Ekren and Houser [7]). The sandstone grades into orthoquartzites formed by secondary silica overgrowths. The chert in the Burro Canyon Formation tends to occur along bedding planes in the upper part of the formation. The Karly Kay Member is a resistant ridge forming unit in the lower part of the formation, which forms a distinct break in slope along the canyon walls in the project area.

Like the underlying Morrison Formation the Burro Canyon Formation is of archaeological interest because it contains good tool stone. The cherts and opalitic orthoquartzites are especially good quality stone for flaked stone implements.

The Dakota Sandstone (K_d)

The Dakota Sandstone is composed of an extremely variable assemblage of discontinuous, lenticular, flood plain, alluvial, lagoonal, littoral, and paludal deposits characteristic of a transgressive marine environment (Shawe et al. [5]). Typical Dakota outcrops in the project area include an upper tan to gray sandstone, an interbedded gray to black carbonaceous mudstone and coal bed, and a lower yellow-brown to yellow-gray sandstone or conglomerate. The upper standstone is tabular and sometimes heavily indurated with silica. These units are erosion resistant and cap the steep canyon walls. The indurated units are frequently underlain by weakly cemented or uncemented, poorly consolidated sandstone which weathers and erodes easily.

The Dakota Sandstone is of considerable archaeological interest for a number of reasons. It is the surface rock over most of the project area and controls most of the local geomorphology. Weathered Dakota residuum constitutes one of the two most widespread soils parent materials. The tabular cemented sandstone is easily quarried and was the major building stone used during Pueblo times. The unit contains coarse-gained sandstone and fine conglomerates for grinding tools, and a white orthoquartzite or opalite frequently used for flaked stone tools may be from this unit.

The Mancos Shale (K_m)

The Mancos Shale is a shallow marine deposit composed principally of gray, carbonaceous, calcareous shale, silty and sandy mudstone, and bentonitic shale or claystone (Shawe et al. [5]). Invertebrate fossils are common. The Mancos Shale is almost completely eroded away in the project area. Where it occurs, it forms prominent hillocks.

The Mancos Shale contains a weakly silicified siltstone which is a knappable tool stone, but the most significant archaeological interest is probably a negative one. The weathered shale, whether it occurs as residuum or as alluvium, is the parent material for three locally prominent soils; the Renohill, Belmear, and Midway Series. These soils have agricultural limitations due to characteristics inherited from the parent rock. The high montmorillonitic clay content in these soils inhibits water penetration and, consequently, the soils are droughty, regardless of depth.

QUATERNARY STRATIGRAPHY

Although one of the primary objectives for the first year's geology program was a map of Quaternary stratigraphy in the project area, the task was only started. Completion of the Reconnaissance Soils Map, the bedrock geology and geomorphology, and site stratigraphy took higher priority when time became a limiting factor. Even so, first order mapping units, such as loess, flood plain deposits, slopewash deposits, and colluvium were determined. Working manuscript maps were made for the Sagehen Flats and House Creek localities and pertinent information about the distribution of loess deposits was recorded on the soils manuscript maps. The origins and chronology of virtually all the Quaternary units are still open questions and a great deal of fieldwork is still required.

Three prominent Quaternary deposits are of archaeological interest. First is a loess of uncertain age and origin. Where it is not severely eroded, this deposit is over 1 m thick and is the parent material for agriculturally important soils. Similar deposits are described for Mesa Verde (Arrhenius and Bonatti [8]). The second major unit is a complex of alluvial deposits of varying age in the Dolores River canyon (Shawe et al. [5]). These are partially included in the area mapped Q_a on the Preliminary Geologic Map. The third is a complex of alluvial and colluvial deposits which form low gradient fans or terrace-like benches. These and other less prominent deposits are of archaeological significance (Figure 9.3). First, the unconsolidated deposits constitute the parent materials for most of the agriculturally important soils, and differences in deposits are reflected in soils differences which may be significant to understanding the distributions of prehistoric sites.

Second, some of the deposits must be considered as "building material" --they are the major constituent in pithouse construction. Third, gravels included in the alluvial deposits are the likely source for dense igneous and metamorphic rock used for tools.

MAJOR LANDFORMS

The basic landforms of the D.A.P. area (Figure 9.3) are first a result of the soft, poorly consolidated, easily eroded bedrock strata. Second, the landforms are a result of structures produced by uplift, deformation, and subsequent erosion of the bedrock units. The project area is situated on the southern dip slope of a southeasterly plunging fold. The northwest-southeast trending Dolores Anticline is to the north, and the parallel McElmo Syncline is to the south. The dip slope has been extensively modified by erosion controlled by structural weaknesses and by erosion resistant beds within the bedrock.

By all rights, the Dolores River should be flowing through the bottom of the McElmo Syncline, generally following the channel of McElmo Creek. Instead, the river is perched upslope where it has cut a canyon following what must be a major tension joint in the anticlinal fold. Downstream the river cuts through the divide created by the crest of the Dolores Anticline. How the river came to be perched in this unusual position is not certain, but stream piracy is the most reasonable possibility. However, headward erosion in the arroyo system downslope from the river is within a fraction of a mile laterally and within a few tens of feet vertically from recapturing the Dolores River and diverting it to its proper place in the landscape--down the base of the McElmo syncline.

Erosion of joint structure has created one of the most prominent landforms, the Dolores River canyon. A second prominent feature was created by erosion of House Creek Fault, a transverse fault oriented at an approximate right angle to the axis of the anticline. Erosion has produced a resequent fault scarp which is a prominent geomorphic feature.

The Dolores River has cut through the fault without any evident displacement, which indicates that the fault is antecedent to the river. The valley system along the fault through the Sagehen Flats would seem to have been a part of the Dolores canyon system and a former channel of the Dolores River. If so, there is no direct evidence that a major river ever had a main channel west or southwest of the canyon. The elevations along the fault scarp relative to the canyon suggest that the river should have flowed through the Sagehen Flats. This impression, however, is probably mistaken, a result of comparatively recent erosion of the divide between the Dolores River and the Dawson Creek.

The Preliminary Landform Map (Figure 9.3) for the D.A.P. shows the major landforms in the project area. The map indicates the major bedrock features or structural features. However, many minor features of archaeological significance were not included. Since the map was completed, an obvious association with small relief geomorphic features, such as small ridges beween intermittent drainages, alluvial fans, or alluvial slopes, has become apparent. Such features are not included on the landform map for two reasons. First, the major features which are indicated dominate the lesser features, and second, many of the lesser features are too small to indicate effectively on the 1:24,000 scale base map. Consequently, larger scale site-specific or locality-specific landform maps will have to be done to show the relationship between achaeological sites and smaller geomorphic features. In addition, there are many small features, such as arroyos and eroded joint fractures, which are of possible archaeological significance. Many of these lesser features have been noted in the site descriptions, but a more detailed landform map is necessary.

The Preliminary Landform Map delineates the major topographic features in the project area. The dip slope, canyon wall, the resequent fault scarp, the bedrock terrace system, and the Dolores River flood plain are the most prominent features. Lesser features such as hillocks, beaches, and alluvial fans are also shown.

Beach (B)

The only beach in the D.A.P. area is the gently sloping shore of Narraguinnep Reservoir. The beach is developed on an alluvial slope composed of silts derived from the Mancos Shale. It has been formed by erosion between the high and low water marks. Because the beach is a consequence of the reservoir, it is a modern feature and cannot be of archaeological consideration. The antecedent alluvial slope is similar to other landforms mapped as a pediment.

Canyon Wall (C)

The canyon-wall unit is composed of cliffs, ledges, and colluvial slopes in the Dolores River canyon, in the canyons of streams tributary to the Dolores, in the larger arroyo systems, and along parts of the House Creek Fault. The major archaeological significance of the canyon-wall unit is that all the stratigraphic units underlying the Dakota Sandstone are exposed only in the canyon walls. Convenient access to resources contained in these strata is limited to the canyon walls. This factor provides a strong constraint for models of prehistoric resource procurement. In general, relief in this unit is too steep for habitation, but there are ledges, relatively gentle slopes, and rockshelters within

the area mapped as canyon walls which were used for habitation. These features cannot be mapped at basemap scale.

The Dip Slope (D)

The dip slope is the surface of low relief controlled by the dip of the Dakota Sandstone. The slope has been cut by the Dolores River canyon system and by the arroyo system tributary to McElmo Creek. Less extensive erosion has sculpted the surface of the dip slope into a series of broad, parallel trending, low relief, convex ridges separated by shallow drainage ways. In some areas there are narrow, linear, low-gradient, arroyo-like features created by erosion of the joint structure in the deformed Dakota Sandstone.

In terms of area, the dip slope is the largest and most prominent geomorphic feature. The dip slope is the feature upon which most contemporary agriculture is done, providing there is a veneer of suitable soils. The extent to which the dip slope might have been a controlling feature for prehistoric settlement or agriculture is not presently apparent. It is more likely that controls over prehistoric settlement-subsistence systems associated with the dip slope are less prominent features such as ridge form, vegetation, soil depth, or access to building materials.

Alluvial Fans (F_a)

Alluvial fans are broad, flattened, connate deposits usually associated with the mouth of an intermittent drainage at the base of a steep slope or cliff. There are some relatively large fans mapped within

the Dolores River canyon, and at least one major archaeological site, the Periman Site (Site 5MT4671), is associated with an alluvial fan.

Flood Plain (Fp)

A flood plain consists of the deposits adjacent to a river constructed by the present river regime and innundated at normal flood stage. The Dolores River flood plain is one of the prominent geomorphic features in the project area. The flat, deep, well-drained soil associated with the flood plain would seem to make it a productive area. The present sediments in the floodplain are quite young and probably post-date the Anasazi occupation of the area.

Hillocks (H)

The hillocks are small hills, prominences rising above the surrounding terrain. In the D.A.P. area, the units mapped as hillocks are all erosional remnants of Mancos Shale. They are especially prominent features along the western half of the House Creek Fault in the Sagehen Flats area.

Pediment (P)

A pediment is a low gradient structural feature truncating bedrock structures and commonly steepening upslope. The area mapped as a pediment in the project area is a complex alluvial slope built from two directions, form the dip slope to the north and from the resequent fault scarp to the south. The pediment is, in fact, most of Sagehen Flats, and is probably an important feature for archaeological interpretation.

Resequent Fault Line Scarp (Rf)

The unit mapped Rf is the result of differential erosion along the House Creek Fault. This geomorphic unit is essentially identical to the canyon wall and was formed by a similar process, but the controlling structural features are different. As with the canyon wall, the most significant archaeological aspect of the unit is the exposure of rock units containing lithic resources.

Ridge (Ri)

A ridge is a relatively narrow elevation which is prominent due to the steep angle at which it rises. The units mapped as ridges in the D.A.P. area are large blocks of Mancos Shale that have not been eroded into the smaller hillocks.

The Terrace System (T)

In cutting the canyon through the Dakota Sandstone, the Dolores River cut a series of prominent bedrock terraces with the highest (T4) extending as much as 480 feet above the present river. The terraces are prominent just west of the town of Dolores where the river swings northward. There the entire terrace system, both constructional and erosional, is present.

The system is composed of the flood plain and four terraces (T0 or FP through T4). The flood plain and the first terrace are constructional. The second, third, and fourth terraces are eroded bedrock features capped by alluvial deposits. These units are geomorphically complex and are important because they are records of the Pleistocene erosional history of the Dolores River. Other than basic mapping, however, these units have

been ignored. It should be inserted parenthetically that the elevation of the fourth terrace indicates that a minimum of 300 feet of bedrock has to have been eroded from the south canyon wall of the Dolores River since formation of T4. This is only one of several features which indicate that bedrock erosion in the project area has been extreme in comparatively recent geologic time.

Archaeologically the terraces constitute suitable locations for settlements. The lower terraces, at least, support contemporary agriculture.

Drainage Basins and Stream Order

A second map relating to the geomorphology delimits the drainage basins and depicts a stream-order classification (Figure 9.5). The stream order begins with small, unbranched streams as 1, and proceeds upward with the Dolores River as the largest order stream. The stream pattern is complex due to the dramatic range of elevation and topography within the project area.

The drainage basin and stream order map constitutes the first description of the hydrology of the project area. At present it can be used as one of the many variables to be tested as a determinant in the settlement system. Other aspects of the area's hydrology remain unknown. Aspects of hydrology of extreme significance for agriculture are the moisture-retaining characteristics of different soils, the rates and kinds of discharge and recharge in the soil-vegetation system, and possible cultural manipulation of the natural hydrology.

APPENDIX C

SOILS OF THE DOLORES ARCHAEOLOGICAL PROJECT AREA

INTRODUCTION

Included in this section are the descriptions of the soils series identified in the D.A.P. area. The descriptions are those used in the Cortez Soil Survey Area (8671) by the Soil Conservation Service (S.C.S). The descriptions and some manuscript maps were provided by Mr. J.P. Panel of the Soil Conservation Service Durango Office. Mr. Panel's maps provided the control for identifying the soils in the field. Soil types were identified on the basis of topography, parent material, surface characteristics and, where possible, subsurface horizon characteristics. The reconnaissance soils map (Figure 9.6) for the project area was made on the basis of air photo interpretation and ground reconnaissance. Field checks of profile characteristics were made where exposures were available.

Some mapping units and unit designations currently being used in the Cortez Soil Survey Area are tentative. Series such as Witt, Granath, and related series were defined in other parts of Colorado and their applicability to the soils in the differing environment of southwestern Colorado remains to be documented. This is of no great consequence. Should the designation or classification of any of the mapped units change, it will not alter the units themselves.

The project map differs from S.C.S. mapping conventions in some repects. First, the finest mapping level is the series, not the phase. S.C.S. maps recognize differences in slope, stoniness, erosion, or other factors which are important for land management. Distinctions at this level were not considered to be of immediate interest to the archaeological project. Further, delineating such phase differences would require more time than was available to construct a reconnaissance map. Second,

some areas were mapped as complexes not recognized by the S.C.S. This was a matter of convenience, one which graphically illustrates the occurrence of different soils in some parts of the project area. Finally, there is at least one soil which is of local interest but which is not recognized in the S.C.S. catalog. This soil, the Sagehen Paleosol, is mapped separately in the area where it is found at or near the surface. There are other soils now considered only as inclusions in other units which probably should be distinguished as separate mapping units.

The soils of the project area are highly variable and, judging from contemporary agricultural practices, soils variation has a significant effect on land use. A soils suitability classification can be constructed by observing contemporary practices, but to what extent that classification is applicable to the Anasazi is not known. Presuming soil characteristics of tilth, fertility, and moisture retaining capabilities to be constant, regardless of the kind of food producing technology, the most desirable soils would be the soils developed on deep loess or alluvium. These incude soils in the Witt, Sharps, Pulpit, and Granath series. Soils developed in shale residum or alluvium would be less desirable because they are difficult to work and are droughty. Soils in the Dolores River flood plain, the Cheyenne series, do not seem to have any particular characteristic which would inhibit agriculture but they are used today only for hay crops or pasture. Nonsoils factors such as a high water table or local microclimate may make the flood plain a relatively poor place to grow crops. The soils in the sandstone uplands, the Gladel and Batterson series, tend to be shallow, rocky, and excessively drained. There are, nonetheless, many small areas of Gladel or Ackmen soils which would be perfectly good for gardens.

Because of intensive field cropping and mechanized agriculture, the contemporary agricultural pattern cannot be used as the model for prehistoric agriculture. The measure of soil suitability today is the crop grown. The most suitable soils support the dry farming of beans and wheat. These are those soils developed in deep loess or alluvium. Soils developed in parent material derived from shale and the soils in the flood plain are used for pasture or hay crops. The rocky upland soils are not cultivated, but support native woodlands and are used for grazing. If we assume that size of a soil body is not a limiting factor and that even elemental water controls could be used, then the soil's suitability classification for the past would be quite different from that of the present. Tilth, fertility, and moisture would still be dominant factors, but factors such as area, shape, stoniness, or droughtiness would not be. A formal suitability classification could be constructed on three bases. The first would be on the basis of morphological characteristics. The resulting classification would not be very different from the suitability classification for modern agriculture. The second basis is laboratory measurements of texture, fertility, and moisture retention capabilities. These several characteristics could then be combined with attributes of slope, aspect, depth, and stoniness to construct a model of soils suitability for gardening rather than for field cropping.

The soils map (Figure 9.6) and the accompanying S.C.S. series descriptions provide the first basis for assessing soils as an economic resource. Prehistoric farmers were surely as knowledgeable about soils characteristics and their importance for crop production as are modern farmers. Even though we may assume that different soils characteristics in any area were essentially the same in Anasazi times as they are in the present, we

cannot assume that the relative importance of any characteristic was the same for Anasazi farmers as it is for modern farmers. One way to approximate likely desirable characteristics for prehistoric agriculture is to look at the requirements for kitchen gardens rather than the requirements for field agriculture. The requirements of tilth, fertility, moisture retention, available moisture, exposure, etc., necessary for good gardens today are probably similar to those necessary for good gardens in the past. We cannot assume that soils presently considered unsuitable for food production today were unsuitable in the past. The requirements of mechanized field agriculture and garden horticulture are different. A rational suitability classification for prehistoric agriculture is possible, but it will be difficult to test. The applicability probably would have to be assumed.

The map, identification legend (Table 9.C.1) and the accompanying descriptions provide the basis for answering the questions: What are the soil types? What are the agricultural soils resources? and, Where are the (soils) resources located? Sites can be correlated with the proximity of differing soils. The information presently available can be greatly refined, however. Continued refinements in the map should be made through field checking and larger scale locality soils maps might be desirable where the 1:24,000 map is too generalized. Descriptions of model profiles for each of the series recognized in the project are necessary, and a project specific classification is desirable. Soils chemistry relevant to soils fertility and nutrient depletion is highly desirable to understand the potential productivity of the project area.

Table 9.C.1 Identification Legend Cortez Soil Survey Area, January 1979 (page 1 of 3)

Symbol	Soil Mapping Unit Name
*AO-B	Billings silty clay loam, 1-3 percent slopes
AO-C	Billings silty clay loam, 3-6 percent slopes
AOA-B	Billings silty clay loam, alkali, 1-3 percent slopes
AOB-B	Billings silty clay loam, seeped, 1-3 percent slopes
*A1-B	Fluvents
*A2-A	Limon silty clay loam, 0-1 percent slopes
A2-B	Limon silty clay loam, 1-3 percent slopes
C2-CD	Midway clay loam, 2-25 percent slopes
*C2-F	Midway clay loam, 25-65 percent slopes
C3-CS	Work silty clay loam, 3-12 percent slopes
C3-E	Work silty clay loam, 12-25 percent slopes
*C4-C	Renohill loam, silty calcareous variant, 3-6 percent slopes
C4-D	Renohill loam, silty calcareous variant, 6-12 percent slopes
DO-CE	Circleville cobbly loam, 3-25 percent slopes
GP	Gravel pit
H1-CD	Lockerby clay loam, 3-12 percent slopes
*H1D-C	Belmear silty clay, 3-12 percent slopes
*J1-B	Cheyenne sandy loam, 0-3 percent slopes
M1-CE	Falcon stony fine sandy loam, 3-25 percent slopes
XM1-F	Falcon - Rock outcrop complex, 25-65 percent slopes

Table 9.C.1 Identification Legend Cortez Soil Survey Area, January 1979 (page 2 of 3)

*M2-CE	Batterson - Gladel - Rock outcrop complex, 3-25 percent slopes
*M2D-D	Gladel stony fine sandy loam, 3-25 percent slopes
*RO-B	Witt loam, 1-3 percent slopes
RO-C	Witt loam, 3-6 percent slopes
RO-D	Witt loam, 6-12 percent slopes
*ROH-C	Pulpit loam, 3-6 percent slopes
ROH-D	Pulpit loam, 6-12 percent slopes
*ROL-C	Sharps loam 3-6 percent slopes
ROL-D	Sharps loam 6-12 percent slopes
*RI-C	Granath loam, 3-6 percent slopes
R1-D	Granath loam, 6-10 percent slopes
R1H-B	Ricot loam, 1-3 percent slopes
R1H-C	Ricot loam, 3-6 percent slopes
*R1H-D	Ricot loam, 6-12 percent slopes
R3-B	Cahona very fine sandy loam, 1-3 percent slopes
R3-C	Cahona very fine sandy loam, 3-6 percent slopes
R3-D	Cahona very fine sandy loam, 6-10 percent slopes
R4-B	Cahona - Bowdish - Witt complex, 1-3 percent slopes
R4-C	Cahona - Bowdish - Witt complex, 3-6 percent slopes
R4-D	Bowdish - Cahona complex 6-12 percent slopes
*R7-C	Bowdish - Pulpit complex, 3-6 percent slopes
*R7-D	Bowdish - Pulpit complex, 6-10 percent slopes

Table 9.C.1 Identification Legend Cortez Soil Survey Area, January 1979 (page 3 of 3)

SL	Rubble land
T1-B	Weber loam, 1-3 percent slopes
T1-C	Weber loam, 3-6 percent slopes
*VO-B	Otero fine sandy loam, 1-3 percent slopes
VO-C	Otero fine sandy loam, 3-6 percent slopes
VOA-B	Otero fine sandy loam, alkali, 1-3 percent slopes
VOB-B	Otero fine sandy loam, seeped, 1-3 percent slopes
VOC-B	Otero clay loam, 1-3 percent slopes
VOC-C	Otero clay loam, 3-6 percent slopes
*V1-B	Hesperus loam, 1-3 percent slopes
V1-C	Hesperus loam, 3-6 percent slopes
V1-D	Hesperus loam, 6-12 percent slopes
*WO-B	Ackmen loam, 1-3 percent slopes
WO-C	Ackmen loam, 3-6 percent slopes
WOB-B	Ackmen loam, seeped, 1-3 percent slopes
W1-B	Zigwied clay loam, 1-3 percent slopes
W1B-B	Zigwied clay loam, seeped, 1-3 percent slopes
W1C-B	Zigwied clay loam, very wet and saline, 1-3 percent slopes
*XTO-E	Ustic Torriorthents
Z	Gullies

*Indicates units recognized in D.A.P. area. Descriptions of these units follow.

The B2t horizon has hue of 7.5YR through 10R, value of 5 through 7 dry, 3 through 6 moist, and chroma of 2 through 6. It is typically clay loam or silty clay loam but clay ranges from 18-35 percent, silt from 10-70 percent and sand from 10-70 percent with less than 15 percent being fine or coarser sand.

The C horizon has hue of 7.5YR through 10YR. It is loam, clay loam, or very fine sandy clay loam.

Bowdish Series - R4

The Bowdish series consists of soils that are fine-loamy, mixed, mesic Ustollic Calciorthids. They are moderately deep, well-drained soils on nearly level to sloping uplands and mesa tops. These soils formed in calcareous reddish loess. Slope is 1-12 percent. The average annual precipitation is 12-16 inches and the average annual soil temperature is 47-52° F.

Bowdish soils are similar to Pulpit and Sharps soils. Pulpit soils have developed subsoils and have hard bedrock at depths of 20-40 inches. Sharps soils have developed subsoils.

Typical pedon of Bowdish loam along the north side of U.S. Highway 160 in the northeast quarter of Sec 19, T19W, R41N:

Ap - 0-7 inches; reddish brown (5YR 5/4) loam, dark reddish brown (5YR 3/4) moist; weak medium subangular blocky structure that parts to moderate fine granular structure; soft, very friable, slighty plastic, and slightly sticky; 5 percent sandstone fragments; calcareous; moderately alkaline (pH 8.2); clear smooth boundary (4-10 inches thick).

AC - 7-10 inches; reddish brown (5YR 5/4) loam, reddish brown (5YR 4/4) moist; weak medium subangular blocky structure that parts to moderate

S.C.S. SOILS DESCRIPTIONS

Billings Series - AO

The Billings series consists of soils that are fine-silty, mixed (calcareous), mesic Typic Torrifluvents. They are deep, well-drained soils on flood plains, fans, and terraces. These soils formed in alluvium from shale. Slope is 1-6 percent. The average annual precipitation is 10-16 inches, and the average annual soil temperature is 48-52° F.

Billings soils are similar to Limon, Otero, and Ackmen soils. Limon soils have more than 35 percent clay in the control section. Otero soils have less than 18 percent clay in the control section. Ackmen soils have dark colored surface layers.

Typical pedon of Billings silty clay loam, is located along U.S. Highway 160 about 1600 feet east of the west quarter corner of Sec 26, T36N, R15W:

A11 - 0-2 inches; gray (10YR 6/1) silty clay loam, dark gray (10YR 4/1) moist; weak medium platy structure that parts to moderate fine granular structure; soft, very friable, slightly sticky, and slightly plastic; calcareous; strongly alkaline (pH 8.8); clear smooth boundary (2-6 inches thick).

A12 - 2-5 inches; light brownish gray (10YR 6/2) silty clay loam, dark grayish brown (10YR 4/2) moist; weak coarse subangular blocky structure; hard, friable, slightly sticky, and slightly plastic, calcareous; strongly alkaline (pH 8.8); gradual smooth boundary (0-8 inches thick).

AC - 5-15 inches; gray (10YR 6/1) silty clay loam, dark gray (10YR 4/1) moist; weak medium subangular blocky stucture; hard, firm, sticky,

and plastic; calcareons; moderately alkaline (pH 8.4); gradual smooth boundary (0-12 inches thick).

C1ca - 15-28 inches; gray (10YR 6/1) silty clay loam, dark gray (10YR 4/1) moist; weak medium subangular blocky structure; hard, firm, sticky, and plastic; highly calcareous; moderately alkaline (pH 8.4); gradual smooth boundary.

C2ca - 28-60 inches; light brownish gray (10YR 6/2) silty clay loam, dark grayish brown (10YR 4/2) moist; weak medium subangular blocky structure; slightly hard, friable, slightly sticky, and slightly plastic; highly calcareous; moderately alkaline (pH 8.4).

Salinity and alkalinity range from slight to strong. The profile is moderately or strongly alkaline.

The A horizon has hue of 10YR through 5Y, value of 5 through 7 dry, 4 through 6 moist, and chroma of 1 through 4. The 10-40 inch control section has 27-35 percent clay and less than 15 percent fine or coarser sand. It is silty clay loam, or clay loam. It has hues of 10YR through 5Y, value of 5 through 7 dry, 4 through 6 moist, and chroma of 1 through 4.

Limon Series - A2

The Limon series consists of fine, montomorillonitic (calcareous), mesic Ustertic Torriorthents. They are deep, well-drained soils that formed in fine textured alluvium weathered from shale. Limon soils are on alluvial fans, flood plains, and valley bottoms and have slopes of 0-3 percent. Average annual precipitation is 14-18 inches. Average annual soil temperature ranges from 47-52° F.

Limon soils are similar to Billings and Lockerby soils. Billings soils have less clay in the control section. (Lockerby soils do not have cracks that remain open from 175-240 days.)

A typical pedon of Limon silty clay loam is located 600 feet north of the southwest corner of Sec 35, T36N, R14W:

A11 - 0-4 inches; gray (2.5Y 5/1) heavy silty clay loam, very dark gray (2.5Y 3/1) moist; moderate, fine granular structure, soft, very friable, very sticky, and plastic; calcareous; mildly alkaline (pH 7.6); clear smooth boundary (2-8 inches thick).

A12 - 4-7 inches; gray (2.5Y 5/1) silty clay, dark grayish brown (2.5Y 4/2) moist; moderate, medium platy structure that parts to moderate, fine granular structure; very hard, firm, very sticky, and plastic; calcareous; mildly alkaline (pH 7.6); clear smooth boundary (2-6 inches thick).

AC - 7-18 inches; grayish brown (2.5Y 5/2) silty clay, dark grayish brown (2.5Y 4/2) moist; weak, coarse, subangular blocky structure that parts to weak, medium subangular blocky structure; extremely hard, very firm, very sticky, and plastic; calcareous; mildly alkaline (pH 7.6); gradual smooth boundary (9-14 inches thick).

C1 - 18-31 inches; light brownish gray (2.5Y 6/2) silty clay, grayish brown (2.5Y 5/2) moist; massive; extremely hard, very firm, very sticky, and plastic; calcareous; moderately alkaline (pH 8.0); gradual smooth boundary (10-15 inches thick).

C2ca - 31-40 inches; light brownish gray (2.5Y 6/2) silty clay, grayish brown (2.5Y 5/2) moist; massive; extremely hard, very firm, very sticky, and plastic; calcareous; moderately alkaline (pH 8.4); gradual smooth boundary (5-12 inches thick).

C3ca - 40-60 inches; light brownish gray (2.5Y 6/2) heavy silty clay loam, grayish brown (2.5Y 5/2) moist; massive; extremely hard, firm, sticky, and plastic; calcareous; moderately alkaline (pH 8.4).

Depth to uniformly calcareous material ranges from 0-10 inches. Rock fragments range from 0-10 percent but are typically less than 2 percent.

The A horizon has hue of 2.5Y or 10YR, value of 5 through 7 dry, 3 through 5 moist, and chroma of 1 to 3. This horizon is moderately to strongly alkaline. The control section has more than 35 percent clay. Cracks up to three-fourths of an inch wide occur in most years.

The C horizon has hue of 2.5Y or 10YR, value 5 through 7 dry, 3 through 5 moist, and chroma of 2 or 3. Texture is silty clay loam or silty clay. This horizon is moderately to strongly alkaline.

Midway Series - C2

The Midway series consists of soils that are clayey, montmorillonitic (calcareous) mesic shallow Ustic Torriorthents. They are shallow, well-drained soils that formed in residuum from Mancos Shale. Midway soils are on shale hills. Slope is 3-65 percent. Average annual precipitation is 13-18 inches. Average annual soil temperature is 47-52° F.

Midway soils are similar to Batterson, Gladel, and Valto soils. Batterson and Gladel soils have less than 35 percent clay in the control section. Valto soils have a colder mean annual temperature.

A typical pedon of Midway clay loam is located about 225 feet south and 250 feet east of the bridge located in the northeast corner of Sec 3, T35N, R14W:

A1 - 0-7 inches; pale brown (2.5Y 6/2) clay loam, dark grayish brown (2.5Y 4/2) moist; weak, fine crumb structure; loose, friable, sticky, and plastic; calcareous; clear smooth boundary (2-9 inches thick).

C1 - 7-11 inches; light brownish gray (2.5Y 6/2) clay, very dark grayish brown (2.5Y 4/2) moist; massive; hard, firm, sticky, and plastic; few, fine faint mottles; calcareous; abrupt smooth boundary (1-5 inches thick).

C2r - 11 inch; weathered Mancos Shale.

Depth to weathered bedrock ranges from 6-20 inches. Bedrock is Mancos Shale with thin strata of interbedded sandstone. The soils are calcareous throughout.

The A horizon has hue of 2.5Y or 10YR, value of 5 or 6 dry, 3 or 4 moist, and chroma of 2 or 3. It is a clay or silty clay loam.

The C horizon has hue of 2.5Y or 10YR, value of 5 or 6 dry, 3 or 4 moist, and chroma of 2 or 3. It is clay or silty clay loam.

Renohill Series - C4

The Renohill series consists of soils that are fine, montmorillonitic, mesic Ustollic Haplargids. They are moderately deep, well-drained soils that formed in alluvium from shale mixed with eolian material. Renohill soils are on upland hills and ridges and have slopes of 3-12 percent. Averge annual precipitation is 14-18 inches. Average annual soil temperature ranges from 47-52° F.

Renohill soils are similar to Pulpit and Sharps soils. Pulpit soils overlie sandstone at depths of 20-40 inches. Sharps soils have less than 15 percent sand coarser than very fine sand.

A typical pedon of Renohill loam is located 1245 feet north and 1285 feet east of the southwest corner of Sec 22, T40N, R19W.

A1 - 0-5 inches; light brown (7.5YR 6/3) loam, brown (7.5YR 4/2) moist; moderate, medium granular structure; soft, very friable, slightly sticky, and slightly plastic; calcareous, mildly alkaline; clear smooth boundary (3-7 inches thick).

B1 - 5-9 inches; light brown (7.5 YR 6/3) silty clay loam, brown (7.5YR 4/3) moist; weak, medium subangular blocky structure, slightly hard, friable, sticky, and slightly plastic, thin patchy clay films on faces of peds; calcareous; moderately alkaline; clear smooth boundary (3-5 inches thick).

B21t - 9-14 inches; light brown (7.5YR 6/3) heavy silty clay loam, brown (7.5YR 5/3) moist; weak, coarse prismatic structure that parts to moderate, medium angular blocky structure; hard, firm, sticky, and plastic; thin continuous clay films on faces of peds; calcareous; moderately alkaline; clear smooth boundary (5-7 inches thick).

B22t - 14-20 inches; pale brown (10YR 6/3) heavy silty clay loam, brown (10YR 5/3) moist; medium, fine angular blocky structure; hard, firm, sticky, and plastic; thin, nearly continuous clay films on faces of peds; calcareous; moderately alkaline; gradual smooth boundary (4-8 inches thick).

C1ca - 20-32 inches; pale yellow (2.5YR 7/3) silty clay loam, light olive brown (2.5Y 5/4) moist; massive; very hard, firm, sticky, and plastic; calcareous; visible lime in spots and seams; moderately alkaline; abrupt smooth boundary (10-15 inches thick).

C2r - 32 inches; weathered Mancos Shale.

Depth to paralithic contact ranges from 20-40 inches. Thickness of the solum ranges from 15-30 inches. Depth to uniformly calcareous material ranges from 6-20 inches. Coarse fragments range from 0-10 percent and are mostly sandstone and shale fragments.

The A horizon has hue of 7.5YR-10YR, value of 5 or 6 dry, 4 or 5 moist, and chroma of 2 or 3. This horizon is neutral to mildly alkaline. The B2t horizon has hue of 2.5Y-7.5YR, value of 5 or 6 dry, 4 or 5 moist, and chroma of 2 or 3. This horizon is typically silty clay loam but clay content ranges from 35-50 percent. The B2t horizon is mildly to moderately alkaline.

The C horizon has hue of 2.5Y through 10YR. It is moderately or strongly alkaline.

Belmear Series - HID

The Belmear series consists of soils that are fine, montmorillonitic Torriorthentic Haploborolls. They are moderately deep, well-drained soils that formed in calcareous, fine-textured materials weathered in place or locally transported from shale hills. Belmear soils are on hillsides, ridges, and narrow valleys among shale hills. Slope is 3-12 percent. Average annual precipitation is 12-18 inches. Average annual soil temperature is 42-47° F.

Belmear soils are similar to Renohill soils. Renohill soils have a B2t horizon and have a warmer mean annual soil temperature.

A typical pedon of Belmear silty clay is located along the west side of the northwest quarter of Sec 2, T36N, R14W:

A1 - 0-10 inches; grayish brown (10YR 5/2) silty clay, very dark grayish brown (10YR 3/2) moist; strong, fine granular structure; soft,

very friable, slightly sticky, and slightly plastic; calcareous, moderately alkaline (pH 8.2); clear smooth boundary (6-15 inches thick).

C1 - 10-30 inches; grayish brown (2.5Y 5/2) silty clay, dark grayish brown (2.5Y 4/2) moist; massive, extremely hard, firm, plastic, and sticky; few slickenslides; calcareous; moderately alkaline (pH 8.4); gradual wavy boundary (5-34 inches thick).

C2r - 30-40 inches; calcareous clayey shale.

Depth to uniformly calcareous material ranges from 0-6 inches. Depth to the paralithic contact ranges from 20-40 inches. Content of coarse fragments ranges from 0-5 percent.

The A horizon has hue of 5Y through 7.5YR, value of 4 to 5 dry, 2 or 3 moist, and chroma of 1 to 3. Reaction ranges from mildly to moderately alkaline.

The C horizon has hue of 5Y through 7.5YR. Reaction ranges from moderately to strongly alkaline. It is typically a heavy silty clay loam or silty clay.

Cheyenne Series - J1

The Cheyenne series consists of soils that are fine-loamy, over sandy, or sandy-skeletal, mixed, mesic Aridic Haplustolls. They are deep, well-drained soils that formed in loamy alluvium overlying river deposited cobble and gravel. Cheyenne soils are on terraces of major drainages and have slopes of 0-3 percent. The average annual precipitation ranges from 15-19 inches. The average annual soil temperature ranges from 48-52 degrees F., and the average summer soil temperature ranges from 65-68 degrees F.

Cheyenne soils are similar to Connerton, Harlan, Satanta, and Unaweep soils. Connerton, Harlan, Satanta, and Unaweep soils all lack river cobble and gravel within 40 inches.

A typical pedon of Cheyenne fine sandy loam is located in the northwest quarter of the northwest quarter of Sec 26, T34N, SUL, R7W.

A1 - 0-3 inches; dark grayish brown (10YR 4/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist; moderate fine platy structure; slightly hard, friable, slightly sticky, and slightly plastic; clear wavy boundary (1-6 inches thick).

B2 - 3-12 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; weak fine prismatic structure that parts to weak fine subangular blocky; hard, friable, slightly sticky, and slightly plastic, gradual wavy boundary (7-12 inches thick).

C1 - 12-20 inches; grayish brown (10YR 5/2) loam, dark brown (10YR 3/3) moist; weak fine and medium subangular blocky structure; hard, friable, sticky, and plastic; strongly calcareous; gradual wavy boundary (6-10 inches thick).

C2 - 20-30 inches; light brownish gray (10YR 6/2) loam, very dark grayish brown (10YR 3/2) moist; weak medium subangular blocky structure; hard, friable, sticky, and plastic; strongly calcareous; clear wavy boundary (6-14 inches thick).

IIC_3 - 30-60 inches; river cobble and gravel.

Depth to contrasting IIC horizon ranges from 20-40 inches. Thickness of the mollic epipedon ranges from 7-15 inches. Depth to carbonates ranges from 20-30 inches but may be calcareous to the surface in some pedons. Depth to sand and gravel ranges from 20-40 inches.

The A horizon has hue of 10YR, value of 4 or 5 dry, 2 or 3 moist, and chroma of 1 through 3. It is a loam, or fine sandy loam.

The B horizon has hue of 10YR, value of 5 dry and 3 moist, with chroma of 3 or 4. It is loam or light clay loam.

The C horizon has hue of 10YR, value of 5 or 6 dry, and 3 or 4 moist, and chroma of 1 through 3. It is loam, sandy loam, or loamy sand.

The IIC horizon is calcareous mixed river sand, cobble, and gravel.

Gladel Series - M2

The Gladel series consists of loamy, mixed (calcareous), mesic Lithic Ustic Torriorthents. They are shallow to somewhat excessively drained soils. The soils were formed in calcareous residuum from sedimentary bedrock. They occupy gently sloping to moderately steep hills and ridges. Slope is 3-25 percent. Average annual precipitation is 12-18 inches. Average annual soil temperature is 47-50° F.

Gladel soils are similar to Batterson, Valto, and Pulpit soils. Batterson soils are sandy. Valto soils are frigid. Pulpit soils have more than 18 percent clay in the control section and overlie sandstone at depths of 20-40 inches.

A typical pedon of Gladel stony fine sandy loam is located* feet south and* feet west of the northeast corner of Sec 18, T41N, R19W:

A1 - 0-5 inches; light reddish brown (5YR 6/3) stony fine sandy loam, reddish brown (5YR 4/3) moist; moderate fine granular structure; soft, very friable, nonplastic, and nonsticky; 20 percent sandstone fragments; calcareous; moderately alkaline (pH 8.0); clear smooth boundary (4-8 inches thick).

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* Number not present in original.

Ac - 5-10 inches; light reddish brown (5YR 6/3) fine sandy loam reddish brown (5YR 4/3) moist; weak coarse subangular blocky structure; slightly hard, very friable, nonplastic, and nonsticky; 30 percent sandstone fragments; calcareous; moderately alkaline (pH 8.2); gradual wavy boundary (0-6 inches thick).

Cca - 10-15 inches; pinkish gray (5YR 7/2) stony fine sandy loam, pinkish gray (5YR 6/2) moist; massive; slightly hard, very friable, nonplastic, and nonsticky; 30 percent sandstone fragments; visible secondary calcium carbonate concretions; calcareous; moderately alkaline (pH 8.4); abrupt wavy boundary (4-16 inches thick).

R - 15 inches; hard reddish brown Dakota Sandstone.

Depth to lithic contact ranges from 10-20 inches. Rock fragments range from 0-35 percent in the control section.

The A horizon has hue of 2.5YR-10YR value of 5 to 7 dry, 3 to 6 moist, and chroma from 1 to 4. It is mildly alkaline to moderately alkaline.

The C horizon has hue of 7.5YR-10R, value of 5 to 7 dry, 3 to 6 moist, and chroma of 1 to 4. It is moderately to strongly alkaline. Calcium carbonate equivalent ranges from 2-14 percent. Texture is usually a stony fine sandy loam but clay may range from 5-18 percent, silt from 5-40 percent, and sand from 45-82 percent with more than 35 percent fine or coarse sand.

Batterson Series - M2

The Batterson series consists of soils that are sandy, mixed, mesic Lithic Ustic Torriorthents. They are shallow, well to somewhat excessively-drained soils on gently sloping to moderately steep hills and

ridges. These soils formed in residuum from sedimentary rock. Slope is 3-25 percent. The average annual precipitation is 12-18 inches, and the average annual soil temperature is 47-50° F.

Batterson soils are similar to Gladel, Valto, and Pulpit soils. Gladel soils are less sandy. Valto soils are frigid. Pulpit soils have more than 18 percent clay in the control section and overlie sandstone at depths of 20-40 inches.

Typical pedon of Batterson loamy sand in the northeast quarter of Sec 28, T38N, R19W:

A1 - 0-5 inches; light reddish brown (5YR 6/4) channery loamy sand, reddish brown (5YR 5/4) moist; loose, nonsticky, and nonplastic; 20 percent channery; calcareous; moderately alkaline; clear smooth boundary (3-6 inches thick).

AC - 5-13 inches; reddish yellow (5YR 6/6) channery sandy loam, yellowish red (5YR 5/6) moist; soft, very friable, nonsticky, and nonplastic; 25 percent channery; calcareous; moderately alkaline; clear smooth boundary (0-9 inches thick).

Cr - 13 inches; reddish brown calcareous sandstone.

Depth to lithic contact is 10-20 inches. Depth to uniformly calcareous material is 0-2 inches. The control section is predominately loamy sand or sand, but textures finer than loamy fine sand occur in the control section. The content of coarse fragments is 0-35 percent.

The A horizon has hue of 7.5YR-2.5YR, value of 5 or 6 dry, 3 through 5 moist, and chroma of 2 through 4. Surface horizons having value as dark 5 dry and 3 moist are too thin or lack sufficient organic matter to qualify as mollic epipedons.

The C horizon has hue of 5YR through 10YR.

Witt Series - RO

The Witt soils are fine-silty, mixed, mesic, Ustollic Haplargids. They are deep, well-drained soils that formed in silty calcareous loess derived from redbeds to the west and southwest. Witt soils are on mesa tops. Slope is 1-12 percent. Average annual precipitation is 14-17 inches. Average annual soil temperature ranges from 47-52° F.

Witt soils are similar to Pulpit, Cahona, and Sharps. Pulpit and Sharps soils have bedrock at depths of 20-40 inches. The Cahona soil has a solum less than 30 inches deep.

A typical pedon of Witt loam is located 200 feet east of the north-south corner of Sec 2, T38N, R18W, Montezuma County, Colorado, about 2 miles west of Pleasant View.

Ap - 0-8 inches; reddish brown (5YR 5/4) loam, dark reddish brown (5YR 3/4) moist; moderate fine granular structure; soft, very friable, slightly sticky, and slightly plastic; neutral (pH 7.0); clear smooth boundary (4-9 inches thick).

B1 - 8-12 inches; reddish brown (5YR 5/4) silty clay loam, dark reddish brown (5YR 3/4) moist; weak medium subangular blocky structure; slightly hard, very friable, slightly sticky, and slightly plastic; thin patchy clay films on ped faces; neutral (pH 7.0); clear smooth boundary (3-5 inches thick).

B2t - 12-30 inches; reddish brown (5YR 5/4) silty clay loam, reddish brown (5YR 4/4) moist; moderate medium prismatic structure parting to moderate medium subangular blocky; hard, friable, sticky, and plastic; thin nearly continuos clay films on ped faces; mildly alkaline (pH 7.4); clear smooth boundary (15-30 inches thick).

B3ca - 30-40 inches; light reddish brown (5YR 6/4) light clay loam, reddish brown (5YR 4/4) moist; moderate medium subangular blocky structure; hard, friable, sticky, and plastic; thin patchy clay films on ped faces; highly calcareous; moderately alkaline (pH 7.9); gradual smooth boundary (10-18 inches thick).

Cca - 40-60 inches; light reddish brown (5YR 6/4) loam, reddish brown (5YR 5/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; highly calcareous with visible mycelial streaks of calcium carbonate; moderately alkaline (pH 8.0).

The thickness of the solum is 30 inches or more. Depth to lime is 18 inches or deeper. Depth to a calcic horizon is 30 inches or more.

The A horizon has a hue of 5YR through 10YR, value of 5 through 7 dry, 3 through 5 moist, and chroma of 2 through 4. It is typically a loam or can be a silt loam, or very fine sandy loam.

The B2t horizon has a hue of 5YR or 7.5YR, value of 5 through 7 dry, 3 through 5 moist, and chroma of 2 through 4. It is typically clay loam or silty clay loam with clay ranging from 18-35 percent and sand coarser than very fine less than 15 percent.

The C horizon has a hue of 5YR or 7.5YR, value of 5 through 7 dry, 3 through 5 moist, chroma of 3 through 6. It is typically loam or silt loam.

Buried soils of similar color and texture are common and often the present B is developing down into the buried soil.

Pulpit Series - ROH

The Pulpit series consists of soils that are fine-silty, mixed

mesic Ustollic Haplargids. They are moderately deep, well-drained soils on gently sloping to sloping uplands. These soils formed in eolian material overlying sandstone. Slope is 3-12 percent. The average annual precipitation is 14-16 inches, and the average annual soil temperature is 47-52° F.

Typical pedon of Pulpit loam is about 6 miles northwest of Dove Creek in the northeast quarter of Sec 24, T41N, R20W:

Ap - 0-7 inches; reddish brown (5YR 5/4) loam, dark reddish brown (5YR 3/4) moist; moderate medium granular structure; soft, very friable, nonsticky, and nonplastic; neutral (pH 7.2); clear smooth boundary (3-8 inches thick).

B1 - 7-10 inches; reddish brown (5YR 5/4) loam, reddish brown (5YR 4/4) moist; weak medium subangular blocky structure that parts to moderate fine granular structure; slightly hard, very friable, slightly sticky, and slightly plastic; few thin clay films on some faces of peds and in root channels; few fine root pores; mildly alkaline (pH 7.4); clear smooth boundary (0-4 inches thick).

B2t - 10-20 inches; reddish brown (5YR 5/4) light clay loam, reddish brown (5YR 4/4) moist; weak medium prismatic structure that parts to moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, and slightly plastic; thin clay films on faces of peds and in root channels; few root pores; mildly alkaline (pH 7.6); clear wavy boundary (7-30 inches thick).

B3ca - 20-25 inches; reddish brown (5YR 5/4) loam, reddish brown (5YR 4/4) moist; weak medium subangular blocky structure; hard, friable, slightly sticky, and slightly plastic; few thin patchy clay films on faces of peds and in root channels; visible secondary calcium carbonate as

concretions and as thin seams and streaks; calcareous; moderately alkaline (pH 8.2); gradual wavy boundary (3-8 inches thick).

C1ca - 25-30 inches; reddish brown (5YR 5/4) loam, reddish brown (5YR 4/4) moist; massive; hard, firm, slightly sticky, and slightly plastic; visible secondary calcium carbonate as concretions and as thin seams and streaks; calcareous; moderately alkaline (pH 8.2); clear smooth boundary (0-9 inches thick).

C2ca - 30-36 inches; pink (7.5YR 8/4) fine sandy loam, pink (7.5YR 7/4) moist; massive; slightly hard, friable, nonsticky, and nonplastic, visible secondary calcium carbonate as concretions and as thin seams and streaks; calcareous; moderately alkaline (pH 8.2); abrupt wavy boundary (0-10 inches thick).

R - 36+ inches hard calcareous sandstone.

Depth to uniformly calcareous material is 6-20 inches. Depth to lithic contact is 20-40 inches. Rock fragments range from 0-10 percent in the major part of the solum.

The A horizon has hue of 7.5YR through 2.5YR, value of 5 through 7 dry, 3 through 6 moist, and chroma of 2 through 4. It is loam, silt loam, or very fine sandy loam.

The B2t has hue of 5YR through 10R value of 5 through 7 dry, 3 through 5 moist, and chroma of 3 through 6. It is clay loam, silty clay loam, loam, silt loam, or very fine sandy clay loam and has 18-35 percent clay, 10-60 percent silt, and 15-70 percent sand, with less than 15 percent being fine sand or coarser.

The C horizon has hue of 7.5YR through 2.5 YR and is loam, fine sandy loam, or clay loam.

Sharps Series - ROL

The Sharps series consists of soils that are fine silty, mixed, mesic, Ustollic Haplargids. They are moderately deep, well-drained soils that formed in moderately thin, calcareous eolian material overlying shale and soft sandstone. Sharps soils are on upland mesas and hills and have slopes of 3-12 percent. The average annual precipitation is about 13-16 inches and the average annual soil temperature is about 51° F.

Sharps soils are similar to Cahona, Pulpit, and Witt, and near Renohill. Cahona and Witt soils are deep. Pulpit soils have a lithic contact. Renohill soils have more than 35 percent clay in the control section and are yellower.

A typical pedon of Sharps loam is located in the northwest quarter of Sec 18, T41N, R19N, Dolores County, Colorado:

Ap - 0-6 inches; light reddish brown (5YR 6/4) light loam, reddish brown (5YR 4/4) moist; moderate medium granular structure; slightly hard, very friable, slightly plastic, and slightly sticky; neutral (pH 7.2); clear smooth boundary (4-8 inches thick).

B1 - 6-9 inches; light reddish brown (5YR 6/4) heavy loam, reddish brown (5YR 4/4) moist; weak medium subangular blocky structure that parts to moderate medium granules; slightly hard, very friable, slightly plastic, and slightly sticky; thin clay films on the inside of some root channels; mildly alkaline (pH 7.4); clear smooth boundary (0-6 inches thick).

B2t - 9-19 inches; reddish brown (5YR 5/4) light clay loam, reddish brown (5YR 4/4) moist; moderate medium prismatic structure that parts to moderate medium subangular blocks; hard, friable, slightly plastic, and slightly sticky, thin continuous clay films on ped faces and on the inside

of root channels; mildly alkaline (pH 7.4); clear wavy boundary (4-32 inches thick).

B3ca - 19-25 inches; light reddish brown (5YR 6/4) heavy loam, reddish brown (5YR 5/4) moist; weak medium subangular blocky structure; hard, friable, slightly plastic, and slightly sticky; thin patchy clay films on some ped faces and on the inside of root channels; visible secondary calcium carbonate occurring as concretions and in thin seams and streaks; calcareous; moderately alkaline (pH 8.2); gradual wavy boundary (4-8 inches thick).

Cca - 25-30 inches; pink (5YR 8/4) loam, pink (5YR 7/4) moist; massive; hard, friable, slightly plastic, and slightly sticky; visible secondary calcium carbonate occurring in finely divided form; calcareous; moderately alkaline (pH 8.2); gradual wavy boundary (0-28 inches thick).

Cr - 30-40 inches; shale and soft sandstone.

Depth to uniformly calcareous material normally ranges from 6-30 inches but should not be shallower than the upper 3 inches of the B2t horizon. Depth to the paralithic contact ranges from 20-40 inches. Depth to the base of the argillic horizon ranges from 12-40 inches.

The A horizon ranges in hue from 10YR-2.5YR, in value from 5 to 7 dry, and 3 to 6 moist, and in chroma from 2 to 6. It is typically a loam, silt loam, or very fine sandy loam.

The B2t horizon ranges in hue from 7.5YR-10R, in value from 5 to 7 dry, or 4 to 6 moist, and in chroma from 2 to 6. Texture is typically a loam or clay loam but may range in clay from 18-35 percent, in silt from 5-55 percent, and in sand from 15-70 percent, 15 percent or less which is very fine sand.

The C horizon may range in hue from 10YR-2.5YR. Texture is typically a loam or clay loam.

Granath Series - R1

The Granath series consists of soils that are fine-silty, mixed Aridic Argiborolls. They are deep, well-drained soils on mesas, high terraces, fans, and valley sideslopes. These soils formed in reddish calcareous eolian material weathered from reddish brown sedimentary rock. Slope is 3-10 percent. The average annual precipitation is 16-20 inches, and the average annual soil temperature is 44-46° F.

Granath soils are similar to Hesperus and Witt soils. Hesperus soils have a thick, dark colored surface layer. Witt soils do not have a dark colored surface layer and they are warmer.

Typical pedon of Granath loam in the southeast quarter of the southeast quarter of Sec 10, T36N, R13W:

O1 - 1 inch to 0; undecomposed organic materials consisting of leaves, twigs, bark, and grasses.

A1 - 0-8 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; strong, fine granular, and crumb structure; soft, very friable, slightly sticky, and slightly plastic; neutral (pH 7.0); clear smooth boundary (4-12 inches thick).

B1 - 8-13 inches; brown (7.5YR 5/3) loam, dark brown (7.5YR 3/3) moist; moderate, fine subangular blocky structure that parts to strong, fine, and very fine granular structure; slightly hard, very friable, slightly sticky, and slightly plastic; neutral (pH 6.8); clear smooth boundary (4-12 inches thick).

B21t - 13-35 inches; reddish brown (5YR 5/3) clay loam, reddish brown (5YR 4/3) moist; moderate, medium prismatic structure that parts to strong, fine, and medium angular blocky structure; friable, slightly hard, slightly sticky, and slightly plastic; thin continuous clay films on faces of peds and on the inside of root channels; neutral (pH 7.0); gradual smooth boundary (14-34 inches thick).

B22 - 35-52 inches; light reddish brown (5YR 6/4) light clay loam, reddish brown (5YR 4/4) moist; moderate, coarse, and medium prismatic structure that parts to strong, medium angular blocky structure; hard, very friable, slightly sticky, and slightly plastic; thin continuous clay films on faces of peds and on the inside of root channels; mildly alkaline (pH 7.4); gradual smooth boundary (4-15 inches thick).

B3 - 52-60 inches; light reddish brown (5YR 6/4) light clay loam, reddish brown (5YR 4/4) moist; weak, medium subangular blocky structure, hard, firm, slightly sticky, and slightly plastic; thin patchy clay films on faces of peds and on the inside of root channels; mildly alkaline (pH 7.6); clear wavy boundary (4-10 inches thick).

Cca - 60-80 inches; light reddish brown (5YR 6/4) loam, reddish brown (5YR 4/4) moist; massive, hard, firm, slightly sticky, and slightly plastic, visible secondary calcium carbonate occurring as concretions and in thin seams and streaks; calcareous; moderately alkaline (pH 8.2).

Depth to uniformly calcareous material ranges from 30 to about 70 inches. Depth to the base of the argillic horizon ranges from 40-70 inches.

The A horizon has hue of 10YR through 5YR, value of 4.5-5.5 dry, 2 or 3 moist, and chroma of 1 to 3.

The B2t horizon has hue of 7.5YR through 10R, value of 5 through 7 dry, 3 through 6 moist, and chroma of 2 through 6. It is typically clay loam or silty clay loam but clay ranges from 18-35 percent, silt from 10-70 percent and sand from 10-70 percent with less than 15 percent being fine or coarser sand.

The C horizon has hue of 7.5YR through 10YR. It is loam, clay loam, or very fine sandy clay loam.

Bowdish Series - R4

The Bowdish series consists of soils that are fine-loamy, mixed, mesic Ustollic Calciorthids. They are moderately deep, well-drained soils on nearly level to sloping uplands and mesa tops. These soils formed in calcareous reddish loess. Slope is 1-12 percent. The average annual precipitation is 12-16 inches and the average annual soil temperature is 47-52° F.

Bowdish soils are similar to Pulpit and Sharps soils. Pulpit soils have developed subsoils and have hard bedrock at depths of 20-40 inches. Sharps soils have developed subsoils.

Typical pedon of Bowdish loam along the north side of U.S. Highway 160 in the northeast quarter of Sec 19, T19W, R41N:

Ap - 0-7 inches; reddish brown (5YR 5/4) loam, dark reddish brown (5YR 3/4) moist; weak medium subangular blocky structure that parts to moderate fine granular structure; soft, very friable, slighty plastic, and slightly sticky; 5 percent sandstone fragments; calcareous; moderately alkaline (pH 8.2); clear smooth boundary (4-10 inches thick).

AC - 7-10 inches; reddish brown (5YR 5/4) loam, reddish brown (5YR 4/4) moist; weak medium subangular blocky structure that parts to moderate

coarse granular structure; slightly hard, friable, slightly plastic, and slightly sticky; 10 percent sandstone fragments; calcareous; moderately alkaline (pH 8.4); clear wavy boundary (0-12 inches thick).

C1ca - 10-30 inches; pinkish white (5YR 8/2) loam, pink (5YR 8/3) moist; massive; hard, friable, slightly plastic, and slightly sticky; 10 percent sandstone fragments; visible calcium carbonate occurs as concretions, seams, and streaks; very strongly calcareous; moderately alkaline (pH 8.4); diffuse wavy boundary (10-25 inches thick).

C2r - 30-36 inches; yellow and gray soft shale and soft sandstone.

Depth to uniformly calcareous material is 0-4 inches. Depth to the calcic horizon is 5-33 inches. Depth to paralithic contact is 20-40 inches.

The A horizon has hue of 7.5YR to 2.5YR, value of 5 to 7 dry, and 3 to 6 moist, and chroma of 2 to 6.

The C horizon has hue of 7.5YR to 2.5YR. Calcium carbonate equivalent is 15-40 percent. It is loam or clay loam. It has 18-35 percent clay.

Otero Series - VO

The Otero series is a member of the coarse loamy, mixed (calcareous) mesic family of Ustic Torriorthents. It is a deep, well-drained soil on alluvial fans and valley filling slopes below escarpments of sandstone and shale. Slope is 1-6 percent. Average annual precipitation is 12-17 inches. Average annual soil temperature is 47-55° F.

Otero soils are similar to Billings, Ackmen, Mespun, and Cheyenne soils. Billings soils have less than 15 percent fine sand or coarser in the control section. Ackmen soils have more than 18 percent clay in the

control section and a dark surface layer. Mespun soils have less than 5 percent clay and are noncalcareous. Cheyenne soils have a gravelly substratum, and a dark surface layer.

A typical pedon of Otero fine sandy loam is located near the north quarter corner of Sec 29, T36N, R16W:

A1 - 0-3 inches; light brownish gray (10YR 6/2) fine sandy loam, dark grayish brown (10YR 4/2) moist; moderate, medium platy structure parting to weak fine granular; soft, very friable, nonsticky, and nonplastic; mildly alkaline (pH 7.4); clear smooth boundary (0-5 inches thick).

A12 - 3-8 inches; pale brown (10YR 6/3) fine sandy loam, brown (10YR 4/3) moist; weak coarse subangular blocky structure parting to weak fine granular; slightly hard, friable, nonsticky, and nonplastic; moderately calcareous; mildly alkaline (pH 7.6); clear smooth boundary (3-8 inches thick).

AC - 8-15 inches; pale brown (10YR 6/3) light fine sandy clay loam, brown (10YR 4/3) moist; weak medium and coarse subangular blocky structure parting to weak, fine granular; hard, friable, slightly sticky, and slightly plastic; moderately calcareous; mildly alkaline (pH 7.6); clear smooth boundary (6-9 inches thick).

C1ca - 15-22 inches; pale brown (10YR 6/3) fine sandy loam, brown (10YR 4/3) moist; very weak coarse subangular blocky structure; hard, friable, nonsticky, and nonplastic; strongly calcareous with few nodules of calcium carbonate; moderately alkaline (pH 8.0); clear smooth boundary (0-10 inches thick).

C2 - 22-60 inches; pale brown (10YR 6/3) fine sandy loam, brown (10YR 4/3) moist; massive; hard, very friable, nonsticky, and nonplastic; strongly calcareous; moderately alkaline (pH 8.0).

These soils are typically calcareous to within 2-4 inches of the surface.

The A horizon has hue of 5Y through 7.5YR, value of 5 through 7 dry, 3 through 6 moist, and chroma of 2 through 4. It is fine sandy loam or clay loam.

The C horizon has hue of 5Y through 7.5YR, value of 5 through 7 dry, 3 through 6 moist, and chroma of 2 through 4. It is typically sandy loam, or fine sandy loam.

Hesperus Series - V1

The Hesperus series is a member of the fine-loamy, mixed family of Pachic Argiborolls. They are deep, well-drained soils that formed in mixed alluvium. Hesperus soils occur on alluvial fans, valleys, and valley filling sideslopes. Average annual precipitation is 16-22 inches, average annual soil temperature is 44-46° F.

Hesperus soils are similar to Ackmen, Granath, Ricot, and Zigweid soils. Ackmen and Zigweid soils are warmer and lack the deep dark surface layer. Ricot soils have more than 35 percent clay in the control section. Granath soils have less than 15 percent fine sand or coarser in the control section.

A typical pedon of Hesperus loam is located 10 feet south of the southwest corner of the corral at the abandoned railroad station of Glencoe, Colorado, in the southwest quarter of Sec 22, T37N, R11W:

A1 - 0-6 inches; dark gray (10YR 4/1) loam, black (10YR 2/1) moist; moderate, fine granular structure; soft, very friable, slightly plastic, and slightly sticky; neutral (pH 6.8); clear smooth boundary (4-10 inches thick).

B1 - 6-11 inches; dark gray (10YR 4/1) heavy loam, black (10YR 2/1) moist; weak, medium prismatic structure that parts to moderate fine subangular blocks; slightly hard, very friable, slightly plastic, and slightly sticky; some clay films; neutral (pH 6.8); clear smooth boundary (3-8 inches thick).

B21t - 11-29 inches; dark brown (10YR 4/2) light clay loam, very dark brown (10YR 2/2) moist; moderate, medium prismatic structure that parts to moderate, fine subangular blocks; slightly hard, very friable, slightly plastic, and slightly sticky; nearly continuous clay films on ped faces and in root channels; neutral (pH 7.0); clear smooth boundary (10-24 inches thick).

B22t - 29-38 inches; grayish brown (10YR 5/2) light clay loam, very dark grayish brown (10YR 3/2) moist; moderate, medium prismatic structure that parts to moderate, fine subangular blocks; slightly hard, very friable, slightly plastic, and slightly sticky; nearly continuous clay films on ped faces and in root channels; neutral (pH 7.0); clear smooth boundary (6-30 inches thick).

B3 - 38-44 inches; brown (10YR 5/3) light clay loam, dark brown (10YR 4/3) moist; weak, medium subangular blocky structure; hard, friable, slightly plastic, and slightly sticky; a few clay films; neutral (pH 7.2); gradual smooth boundary (4-8 inches thick).

C - 44-60 inches; brown (10YR 5/3) loam, dark brown (10YR 4/3) moist; a few small faint pale brown (10YR 6/3) moist mottles; massive; hard, friable, slightly plastic, and slightly sticky, neutral (pH 7.2).

Depth to uniformly calcareous material is 40 inches or more. Thickness of the mollic epipedon is 20-50 inches.

The A horizon has hue of 5Y-7.5YR, value of 4 or 5 dry, 2 or 3 moist; and chroma of 1 to 3. It is a loam or light clay loam.

The B2t horizon has hue of 5Y-7.5YR, value from 4 to 7 dry, 2 to 6 moist, and chroma from 1 to 4. It is typically a loam or light clay loam but clay may range from 18-35 percent, silt from 15-55 percent, and sand from 20-60 percent.

Hue of the C horizon may range from 5Y-7.5YR. Texture is typically a loam or light clay loam.

Ackmen Series - WO

The Ackmen series consists of soils that are fine-silty, mixed, mesic Cumulic Haplustolls. They are deep, well-drained soils in upland swales and drainageways. These soils formed in alluvium that eroded from loess deposits on nearby uplands. Slope is 1-6 percent. The average annual precipitation is 13-18 inches, and the average annual soil temperature is 48-54° F.

Ackmen soils are similar to Billings and Cheyenne soils. Billings soils do not have a thick, dark surface layer and are calcareous. Cheyenne soils have a sandy or sandy-skeletal substratum and do not have a thick, dark surface layer.

A typical pedon of Ackmen loam, about a quarter mile north of the town of Lewis, * feet east and 1,320 feet north of the southwest corner of Sec 31, T38N, R16W:

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* Number not present in original.

A11 - 0-4 inches; dark grayish brown (10YR 4/2) loam, block (10YR 2/1) moist; weak to moderate fine platy structure parting to weak, fine granular; slightly hard, very friable, nonsticky, and nonplastic; neutral (pH 6.8); gradual smooth boundary.

A12 - 4-20 inches; dark brown (7.5YR 4/2) loam, very dark brown (7.5YR 2/2) moist; weak coarse prismatic structure parting to weak coarse subangular blocky structure; hard, very friable, nonsticky, and nonplastic, neutral (pH 7.0); gradual smooth boundary.

C - 20-41 inches; brown (7.5YR 5/2) loam, dark brown (7.5YR 3/2) moist; weak coarse prismatic structure parting to weak medium and fine subangular blocky structure; hard, very friable, nonsticky, and nonplastic; soil mass is noncalcareous but small calcareous spots occur throughout the horizon; neutral (pH 7.2); clear smooth boundary.

A1b - 41-60 inches; dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) moist; massive; hard, very friable, nonsticky, and nonplastic, neutral (pH 7.2).

Thickness of mollic epipedon is more than 40 inches. Organic matter ranges from 2-5 percent. Organic matter decreases irregularly with increasing depth.

The A horizon has hue of 7.5YR or 10YR, value of 2 or 3 moist, 4 or 5 dry, and chroma of 2 or 3. It is a loam, silt loam, or silty clay loam.

The C horizon has hue of 7.5YR or 10YR, value of 2 through 4 moist, 3 through 5 dry, and chroma of 2 through 6. It is fine sandy loam, light clay loam or light sandy clay loam. The 10-40 inch control section is usually a loam containing 18-27 percent clay.

Xto-e Ustic Torriorthents, Moderately Steep to Steep

This mapping unit consists of deep, excessively-drained soils on moderately steep to steep terrace edges and on steep slopes. They are formed in gravelly and cobbly alluvium and colluvium. The average annual precipitation is 14-19 inches. The average annual air temperatures are 45-50° F. The average frost-free season is 100-130 days.

Typically, these soils have surface layers consisting of gravelly or cobbly loam or fine sandy loam. These layers overlie very gravelly or cobbly outwash material. In some places the soil overlies sandstone or shale within a depth of 40 inches.

Included in this unit are small areas of soils that are on the more stable portion of the terrace edge or steep slope.

Permeability varies depending upon the texture of the parent material. Effective rooting depth is more than 40 inches. Surface runoff is rapid and erosion hazard is severe. Available water capacity is low.

The mapping units is used primarily for rangeland or wildlife habitat.

Rangeland vegetation on these soils consists primarily of western wheatgrass, Indian rice grass, needle and thread, blue grama, mutton grass, fendlers three awn, junegrass, big sagebrush, rabbitbrush, pinyon pine, Rocky Mountain juniper, ponderosa pine, serviceberry, snowberry, and gambel oak.

Wildlife, such as elk, mule deer, wild turkeys, and various birds utilize these soils. These animals obtain their food from nearby cropland and rangeland. Forested areas provide shelter.

Steep slopes are the primary limiting soil features when planning for

the construction of homes and other community developments. The construction of sanitary facilities may pose a potential pollution problem to nearby water.

The Sagehen Paleosol (SH)

The Sagehen Paleosol is a deep soil developed in old alluvium. It has a very strongly developed A-Bt-Btca-Cca horizon sequence. There is evidence of illuvial humus deep in the B horizon, so the soil would probably be classed as a Mollisol. The B horizon is frequently more than two meters deep and is sometimes developed into coarse fluvial sands underlying the alluvial parent material. The soil is exhumed in Sagehen Flats and is exposed as a buried soil in an arroyo tributary to House Creek.

Witt, Pulpits, or Sharps (Undifferentiated) (UH)

Areas of loess in which specific series were not determined are designated by the symbol UH. These areas are probably predominately Witt soils with lesser areas of Pulpit or Sharps soils. Areas mapped UH could also contain Granath or Bowdish soils.

Midway-Belmear Complex (C2/H1)

Areas mapped C2/H1 contain Midway and Belmear soils which occur in a pattern too complex to be delineated at the base map scale. This association may also include small areas of Renohill soils.

Gladel-Ackmen Complex (M2/WO)

Areas mapped M2/WO are broad drainageways with irregular topograpy. Gladel soils occur on low sandstone knobs or ridges and Ackmen soils occur in the intervening low areas. The pattern of occurrence is too complex to delineate at the base map scale.

Gladel-Witt Complex (M2/UH)

Areas mapped M2/UH are areas in which Witt or Sharps soils occur on low ridges and Gladel soils occur in the intervening swales. The areas of different soils are too small to delineate at the base map scale. The areas between the ridges contain relatively deep, stone-free soil developed in weathered sandstone which in other areas is included within the Gladel mapping unit.

All these mapping units except the Sagehen Paleosol are complexes of soils recognized in the S.C.S. list. No other soils were recognized. However, there are some areas of distinctive soils included within the Gladel mapping unit which might well be separated as an independent mapping unit. These are deep, stone-free soils developed in weathered Dakota Sandstone which does not contain indurated rock.

RANKING OF SOILS FOR AGRICULTURE

The several kinds of soils recognized in the D.A.P. area vary considerably in their suitability for agriculture. A formal soils suitability classification would consider several interrelated factors such as nutrient and moisture regimes, erosion potential, and particular chemical or physical characteristics in evaluating soils for particular agricultural uses. We presently lack sufficient information to create a formal soils suitability classification. Regardless, it is possible to rank the soils according to present day use and assume, albeit weakly, that the presently productive soils were equally productive in the past.

Series	Comments
Witt Bowdish Pulpit Sharps	These are the major agricultural soils in the project area. They are used both for irrigated and dryland crops. They have good tilth and good moisture retention characteristics. Nutrient retention characteristics are not known but fertility is probably quite high. Because of continuous heavy cropping they are heavily fertilized. A best guess is that nitrogen and phosphorus are limiting macronutrients.
Granath	The Granath soils are less extensive than the Witt and related soils but locally they are very important. Except for higher organic matter content in the upper horizons of Granath soils have essentially the same characteristics as Witt soils and are equally productive.

Gladel Batterson	Gladel and Batterson soils occur in complex association with other soils. In terms of area, these are the dominant soils in the region but they are shallow and too rocky to cultivate and are presently used for rangeland. Small areas where the solum is relatively deep would probably be suitable for gardening. Moisture retention is the limiting characteristic.
Renohill Midway Belmear	The soils developed form shale residuum are presently used for pasture or hay crops or for rangeland. Because of the high montmorillonitic clays, water does not penetrate deeply into the solum and these soils are droughty. Ironically, the same clays bind nutrients and the soils are very fertile. The texture also makes the soils hard to work, but, given adequate water they are probably good garden soils.
Cheyenne and Fluvents	Soils in the flood plain or canyon bottoms are sometimes flooded. These should be good garden soils given adequate moisture but they occur in areas where temperature rather than any soils characteristic may be a limiting factor.

Other soils in the area are minor in terms of their occurrence. Some, such as Ackmen, are very good agricultural soils but do not occur in areas large enough to be of importance for contemporary agriculture.

PRELIMINARY BEDROCK MAP

-Q_a-

Alluvial Deposits

Located along the Dolores River and tributaries. Consists of rounded to sub-rounded boulder to sand size particles. Upper terrace gravels are not mapped as Qa. Most particles are gravel of igneous and metamorphic origin. The igneous and metamorphic rocks are from the Rico, San Miguel, La Plata, and San Juan Ranges.

-K_m-

Mancos Shale

Shallow marine deposit of chiefly gray carbonaceous, calcareous shale, commonly silty and sandy mudstone, and bentonitic shale or claystone. Fossils of invertebrataes are common with calcareous pelecypods most noted in the D.A.P. area. Forms noticeable hillocks along the House Creek Fault.

-K_{bc}-

Dakota Sandstone

Extremely variable assemblage of floodplain, lagoonal, littoral, and paludal deposits representative of a transgressive marine environment. The beds are lenticular and discontinuous in nature. Typical Dakota outcrops on the D.A.P. include an upper tan to gray sandstone, an interbedded gray to black carbonaceous mudstone and coal bed, and a lower yellow-brown to yellow-gray sandstone or conglomerate. The upper sandstone is tabular with common ripple marks and worn trails in the Sagehen Flats Locality. Thickness is variable over the project.

UNCONFORMITY

-K_{bc}-

Burro Canyon Formation

Extremely variable deposits of floodplain, fluvial, and lacustrine environments. Light gray to light buff conglomeritic sandstone, green-gray shale, and siltstone, green-gray to gray limestone and cherts. The light sandstone is gradational into a white/buff/orange/green quartzite formed by many silica overgrowths. Chert of the Burro Canyon Formation tends to occur along upper bedding plains in the green-gray mudstone pebbles, and other assorted rock fragments in a sandy matrix. The Karla Kay Member is a resistant ridge-forming conglomerate in the lower part of the unit. Forms a distinct break in slope along D.A.P. canyon walls.

Morrison Formation

Floodplain, fluvial, and lacustrine deposits consisting primarily of red, green, and orange sandstone, siltstone, mudstone, and conglomerate. Slope forming unit with minor thin bedded resistant sandstone units. The Brushy Basin Member may intertongue and resemble the overlying Burro Canyon and includes white to pale brown siltstone, mudstone, and claystone, with minor orthoquartzite, tuff, and arkosic material. The Salt Wash Member includes light red brown to buff sandstone, red brown mudstone, and a light gray to buff sandstone.

$-J_c-$

Junction Creek Sandstone

The Junction Creek Sandstone is a brown to buff moderately to well sorted, bedded sandstone unit. It occurs on the D.A.P. as a white to yellow-orange, thick to massive, fine to medium grained, eolian, cross-bedded, quartz sandstone. This unit erodes to rounded cliffs with distinct polygonal or checkerboard patterns.

$-J_s-$

Summerville Formation

Similar to the Morrison, consisting of slope forming red and green siltstone to silty sandstone, and mudstone. Minor thin-bedded white sandstone is also present. This unit outcrops in the Dolores Valley bottom downstream from the McPhee Dam site.

$-J_e-$

Entrada Sandstone

Aeolian sandstone of dark reddish brown to reddish brown color. Coarse to medium fine grained quartzose sand with high and low angle cross-bedding. No strong reaction with HCl, Recorded in dam site drill records. No outcrops within the Project area.

NOTES

Maps made from orthophoto quadrangles Trimble Point, Dolores East, Dolores West, and Boggy Draw with minimal field checking by V. Clay, J. Hampson, and R. Glaser at the 1:24,000 scale.

Description references include:

Ekren, E.B., and Houser, F.N. (1965)
Geology and Petrology of the Ute Mountains Area, Colorado. U.S. Geology Survey prof. Paper 481.

Shawe, D., Simmons, C.6., Archbold, N. (1968)
Stratigraphy of the Slick Rock District and vincinity, San Miguel and Dolores Counties, Colorado. U.S. Golology Survey Prof. Paper. 576 A.

U.S. Department of the Interior, Water and Power Resources Service (1980)
Records of Subsurface Investigations and Construction and Foundation Materials Test Data for McPhee Dam (Appendices A and B to specifications No DC-7420).

DESCRIPTIONS OF LANDFORM MAP UNITS

-B-

Beach

The gently sloping shore of a body of water which is washed by waves or tides, especially the parts covered by sand and pebbles.

-C-

Canyon Wall

The side of a steep chasm, gorge, or ravine; the side of a channel cut by running water in the surface of the earth. It can be composed of ledges, cliff, and/or colluvial slope.

Cliff

A high steep face of rock.

Colluvial Slope

A slope containing weathered debris including soil which has been moved downslope under the force of gravity.

-D-

Dip Slope

A slope of the land surface which conforms approximately to the dip of the underlying bedrock. The Dakota Sandstone is controlling the dip slope. It is dissected by a southerly, parallel drainage system.

-F-

Fan (Alluvial)

A broad, flattened connate alluvial deposit, usually situated at the base of a steep slope or cliff.

Flood Plain

That portion of a river valley, adjacent to the river channel, which is built of sediments during the present regimen of the river and which is covered with water when the river overflows its bank at flood stage.

-H-

Hill

This term is properly restricted to more or less abrupt elevation of less than 1000 ft.; a mass of material rising above the level of the surrounding country culminating in a well marked crest or summit.

Hillock

A small hill.

-P-

Pediment/Open Basin

A low inclination, planar landform truncating bedrock structure commonly steepening upslope where developed on drainage net profile. A basin with one outlet.

-Rf-

Resequent Fault (Line Scarp)

A scarp that is the result of differential erosion along a fault line rather than the direct result of the movement of the fault and the downthrown block is topographically lower than the upthrown block.

-Ri-

Ridge

A relatively narrow elevation which is prominent, attributed to the steep angle at which it rises.

-T-

Terrace

Elevated portions of alluvial fills, bedrock cut benches and other planar features along a stream valley.

-T_1-

Recent terraces sitting on the present floodplain.

-T_2-

This terrace has its uppermost limits from 100-160 feet above the present floodplain.

-T_3-

Has its uppermost limits from 280-320 feet above the present floodplain.

-T_4-

Has its uppermost limits from 440-480 feet above the present floodplain.

_..._..._..._... Major Stream

Definitions taken from Dictionary of Geological Terms (1976).

Map produced from a combination of U.S.G.S. 7.5 Minute Quadrangles, Trimble Point, Boggy Draw, Dolores East, Dolores West, and aerial photographic coverage by U.S.G.S. 1973.

RECONNAISSANCE SOILS MAP OF THE DOLORES ARCHAEOLOGICAL PROJECT AREA

-AOA-

Billings Silty Clay Loam, Alkali

Entisol: fine silty, mixed (calcareous), mesic Typic Torrifluvent. A strongly alkaline soil with an A-C horizon sequence developed in alluvium derived from shale. In the D.A.P. area Billings soils are found only at the toe of an alluvial slope in the Sagehen Flats Locality.

-A1-B-

Fluvents

Entisol: no further classification
Weakly developed soils with an A-C horizon sequence developed in shallow, sandy alluvium overlying gravel in the active floodplain of the Dolores River and is tributaries.

-A2-

Limon Silty Clay Loam 0-3 percent slope

-C2-

Midway Clay Loam

Entisol: clayey, montmorillonitic (calcareous) mesic shallow Ustic Torriorthent
Shallow, well-drained soils with an A-C horizon sequence formed in residuum from Mancos Shale. In the D.A.P. area Midway soils are coincident with the Km geologic unit. In the southwest part of the mapped area the units mapped C2 may be developed in an exposure of shale interbedded in the Dakota Sandstone.

-C4-

Renohill Loam, silty calcareous variant

Aridsol: fine, montmorillonitic, mesic Ustolic Haplargid
Moderately deep, well-drained soils with an A-BA-Bt-BC-Cca horizon sequence developed in alluvium derived from Mancos shale. In the D.A.P. area Renohill soils are associated with alluvial slopes adjacent to exposures of Mancos shale.

-GP-

Gravel Pit

-H1D-

Belmear Silty Clay

Mollisol: fine, montmorillonitic Torriorthentic Haploboroll

Deep, well-drained soils with an A-C horizon sequence formed in weathered shale or alluvium locally transported from shale hills. The solum ranges from 15-80 cm deep. Belmear soils are found on hillsides, narrow ridges, and narrow valleys, among shale hills. In the D.A.P. area Belmear soils were commonly mapped in association with Midway sois (C2/H1).

-J1-

Cheyenne Sandy Loam

Mollisol: fine-loamy over sandy or sandy-skeletal, mixed, mesic Haplustoll

Deep, well-drained soils with an A-B-C horizon sequence 60 cm to 1 m deep. The soils are developed in sandy alluvium overlying fluvial sands and gravels in the Dolores River floodplain.

-M2-CE-

Batterson-Gladel-Rock and Bedrock Outcrop Complex

This complex of soils occurs on steep slopes and canyon sides throughout the D.A.P. area. The Batterson soils are shallow, excessively-drained soils with an A-C horizon sequence 10-30 cm thick developed in weathered sandstone. In the D.A.P. area they are mapped only as part of this complex, but they also occur as an inclusion in the Gladel series mapping unit (M2D).

-M2D-

Gladel Stony Fine Sandy Loam

Entisol: loamy, mixed (calcareous), mesic, lithic Ustic Torriorthent

Most of the soils mapped as Gladel series are shallow, somewhat excessively-drained soils with an A-C horizon sequence developed in calcareous residium from Dakota sandstone. However, many areas south and west of the Dolores River mapped M2 are deep, rock-free soils developed in deeply weathered sandstone. Such soil is a usual inclusion within this mapping unit.

-RO-

Witt Loam

Aridisol: fine-silty, mixed, mesic, Ustolic Haplargid

Deep, well-drained soils developed n calcareious loess and in alluvium probably derived form loess. The Witt profile has an Ap-Bu-Bt-Bca-Cca horizon sequence at least 1 m deep. Witt soils are distinguished fom similar soils by the depth of the solum and absence of a paralithic contact. Depth to the calcic horizon, if one is present, is at least 80 cm. Witt profiles occasionally contain buried horizons.

-ROH-

Pulpit Loam

Aridisol: fine silty, mixed mesic Ustolic Haplargid

Pulpit soils are very similar to Witt soils. Both have the same horizon sequence developed in the same parent materials. The Pulpit profile has a lithic contact between 60 cm and 1 m. In the D.A.P. area this soil is frequently developed in deep slope wash deposits derived from loess.

-ROL-

Sharps Loam

Aridisol: fine silty, mixed mesic Ustolic Haplargid

Sharps soils are very close to Pulpit and Witt soils. They have the same horizon sequence developed in similar parent materials. Sharps soils are shallower than Witt soils and have a more strongly developed Calcic horizon than do Sharps soils.

-R1-

Granath Loam

Mollisol: fine silty, mixed aridic Argiboroll

Deep, well-drained soils with an A-Bt-Cca horizon sequence developed in loess or alluvium derived from loess. In the D.A.P. area most Granath soils are associated with the alluvium of the first and second terraces. Granath soils are very similar to Witt soils but have a darker colored paper profile (mollic epipedon) than do Witt soils.

-R7-

Bowdish-Pulpit Complex

This mapping unit delineates areas which may be either Bowdish or Pulpit soils or an association of both. Bowdish soils are mapped only in this complex in the D.A.P. area. Bowdish soils are shallow soils with an A-C horizon sequence developed in shallow leoss or slopewash overlying bedrock. The surface characteristics of the 2 soils are identical.

-VO-

Otero Fine Sandy Loam

Entisol: coarse loamy, mixed (calcareous), mesic Ustic Torriorthent

Deep, well-drained soils with an A-C horizon sequence developed in sandy deposits on valley filling alluvial and colluvial slopes in the Dolores River Canyon. Otero soils also occur on sandy alluvial fans and on high point bars in tributary canyons. The area of Otero soils in the Dolores canyon is greater than indicated on the map because the valley fill is too narrow to delineate on the 1:24,000 scale base map.

-V1-

Hesperus Loam

Mollisol: fine loamy, mixed Pachic Argiboroll

Deep, well-drained soils with an A-BA-Bt-BC-C horizon sequence developed in alluvium derived from sandstone. In the D.A.P. area Hesperus soils are associated with alluvial slopes adjacent to the Dakota Sandstone.

-WO-

Ackmen Loam

Mollisol: fine silty, mixed, mesic Cumulic Haplustoll

Deep, well-drained soils with an A-C horizon sequence. The profile is characterized by a deep (50 cm) accumlation of organic matter which forms a mollic epipedon. Ackmen soils are developed in loamy alluvium deposited in swales, arroyos, draws, and drainage ways. Buried soils with a similar but more strongly developed A-B-C profile are frequently encountered. Some areas in the uplands mapped WO are sandier than the model Ackmen profile and lack the mollic epipedon. Many small areas not mapped have the same characteristics. These areas probably could be mapped as a fluventic soil.

-XTO-

No defined series

Entisol: Ustic Torriorthent

The Ustic Torriorthent soils are found on steep terrace edges and steep colluvial slopes adjacent to canyon walls. They are developed in gravely and cobbly alluvium and colluvium. These soils are usually found in the same topographic position as Otero soils but the parent material is stonier and the surface slopes are much steeper. Like Otero soils in the D.A.P. area, the Torriorthentic soils are more extensive than the map indicates because the areas in which they occur cannot be delineated at the base map scale.

-SH-

The Sagehen Paleosol

No classification but possibly a Mollisol

The Sagehen Paleosol is a deep soil developed in old alluvium (or loess). It has a very strongly developed A-Bt-Btca-Cca horizon sequence. There is evidence of illuvial humus deep in the B horizon. The B horizon is frequently more than 2 m deep and is sometimes developed in coarse fluvial sands underlying the alluvial parent material. In the area mapped SH the paleosol is covered by 10-50 cm of slopewash in which a Pulpit like profile is developed.

-UH-

Witt, Pulpit, or Sharps (undifferentiated)

Areas of loess in which specific series were not determined. These areas are probably predominantly Witt soils with lesser areas of Pulpit or Sharps soils. Area mapped UH could also contain Granath and Bowdish soils.

-C2/H1-

Midway-Belmear Complex

Areas mapped C2/H1 contain midway and Belmear soils which occur in a pattern too complex to be delineated at the base map scale. This association may also include small areas of Renohill soils.

-M2/WO-

Areas mapped M2/WO are broad drainage ways with irregular topography. Gladel soils occur on low sandstone knobs or ridges and Ackmen soils occur in the intervening low areas. The pattern of occurrence is too complex to delineate at the base map scale.

-UH/M2-

Areas mapped UH/M2 are areas in which Witt or Sharps soils occur on low ridges and Gladel soils occur in the intervening swales. The areas of different soils are too small to delineate at the base map scale. The areas between the ridges contain relatively deep, stone-free soil developed in weathered sandstone here included in the Gladel mapping unit.

NOTES

Mapped from aerial photogarphs and ground reconnaissance. Planimetric accuracy is limited by distortion in the 1:24,000 quadrangle centered air photos used for the base map.

Series mapping units do not represent homogeneous bodies of soil. The predominant soil in an area should be the series indicated, but it will contain variants and inclussions.

Series names are tentative and subject to change. Any changes in series designation or classification will not alter the areas delineated.

Mapping units were identified on the basis of soils series descriptions for the Cortez Soil Survey Area provide by the Soil Conservation Service, Durango, Colorado. Parts of Sections 25 and 26, T38N, R16W; Sections 29, 30, and 32, T38N, R15W; Section 1, T37N, R16W; and Section 6, T37N, R15W were mapped by Mr. J.P. Panel of the Soil Conservation Service. The SCS manuscript map was used as a control for this map.

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Soil Survey Staff

1975 Revised Soil Survey Manual. Agricultural Handbook 18, Revised. U.S. Department of Agriculture Soil Conservation Service. 1975 Manuscript Copy.

1975 Soil Taxonomy. U.S. Department of Agriculture Soil Conservation Service.

No Change Comments

Volume VI, Chapter 9, Geology of the Project Area

Page	Para.	Sent.	
9			ANSI Guidelines specify that "whenever practicable, number all pages throughout a report consecutively" (p.13).
9	2	1	This is the classic definition of ecology and should not be changed.
9-13			These pages are part of the design memo and should be left where they are.
9	3		The suggested changes in phrasing do nothing to clarify the paragraph, and in fact, they change the meaning and emphasis somewhat. They have not been implemented.
29	2	1	The phrase "by all rights" is perfectly acceptable. "Logic" would not be a better word.
29	3	3	"resequent" has a technical geological meaning which is the meaning intended here. Deletion of the word would be a deletion of information.
30	1		This paragraph serves as an introduction for the specific discussions which follow. It should not be deleted.
34	2	2	The term "cut" has a specific geological meaning which is not conveyed by the term "carved." The substitution is not appropriate.
39	1	2	While it is true that what we are interested in is the "ability of the soil to support crops," what is observed (the measure of that ability) is the crop.
40	1	1	The questions contained within the sentence should not be enclosed in quotation marks. See A Manual of Style, University of Chicago, 12th edition, p.107, paragraph 5.12.
46	2	2	This sentence provides information on the difference between Limon Series soils and Lockenby soils.
83	1	4	In scientific writing the term "assumption" has a specific meaning. What the author has done is to identify an assumption, not a presumption. Furthermore, the term "presume" has conotations not intended in this context.

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Page	Para.	Sent.	
84	2	3	This comment is not clear. The sentence in question clearly states that "the soils are very fertile." What did the reviewer intend here?

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