Department of Energy
Washington, DC 20585

NOV 30 1993

Mr. Joseph J. Holonich, Director
Repository Licensing & Quality Assurance
Project Directorate
Division of High-Level Waste Management
Office of Nuclear Material Safety
and Safeguards
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Reference: Ltr, Holonich to Shelor, dtd 10/15/93

Dear Mr. Holonich:

A letter dated October 15, 1993 (Reference), requested materials for the U.S. Nuclear Regulatory Commission's (NRC) review of the U.S. Department of Energy's (DOE) topical report titled, "Evidence of Extreme Erosion During the Quaternary Period." NRC requested four items prior to initiating their review: (1) additional original copies; (2) data packages from the Yucca Mountain Site Characterization Project Office (YMPO) Technical Data Base; (3) resumes of the data qualification Technical Assessment Team; and (4) a copy of an "in press" reference cited in the report. With respect to Item 1, two additional original copies of the subject topical report are enclosed (enclosure 1). The data packages requested are included in Enclosure 2.

With respect to resumes, this request cannot be fulfilled directly. The record package for the data qualification technical assessment was audited as part of YMPO's April 5-9, 1993, audit (YMP-93-09). William Belke observed the audit of the technical assessment documentation and made no request to view the assessment team's qualifications at that time. A future audit is the appropriate opportunity for an NRC staff member(s) to view the qualification records of the assessment team. As you know, these records are privileged information under the Privacy Act of 1974 and are not available for external dissemination.

Enclosure 3 consists of a pre-publication copy of work listed as "in press" in the topical report. Although this U.S. Geological Survey (USGS) Open-File Report (OFR) by Partick Glancy is stamped "Preliminary Draft", it is approved by the USGS, and DOE. The designation only pertains to the fact that the report is not yet published in the final OFR format. The figures in the plates contain some handwritten notations and require final drafting, but the text of the report will not change. We trust that the version herein is adequate to begin the NRC's review. The published version will be distributed to the usual recipients of

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WM-11
NH03

YMPO technical reports when it is available.

If you have any questions, please contact Chris Einberg of my staff at (202) 586-8869.

Sincerely,

John P Roberts

Dwight E. Shelor for
Associate Director
Office of Systems and Compliance
Office of Civilian Radioactive
Waste Management

on the shelf

Enclosures:
1. Topical Reports (2)
2. Data Packages
3. "In-Press" Reference

cc: w/ enclosures
T. J. Hickey, Nevada Legislative Committee

cc: w/enclosure 2 & 3 only
(enclosure 1 previously transmitted)
R. Loux, State of Nevada
D. Bechtel, Las Vegas, NV
Eureka County, NV
Lander County, Battle Mountain, NV
L. Bradshaw, Nye County, NV
P. Niedzielski-Eichner, Nye County, NV
W. Offutt, Nye County, NV
C. Schank, Churchill County, NV
F. Mariani, White Pine County, NV
V. Poe, Mineral County, NV
J. Pitts, Lincoln County, NV
J. Hayes, Esmeralda County, NV
B. Mettam, Inyo County, CA

cc: w/o enclosures
R. Nelson, YMPO

rec'd with [illegible] 11/30/93

LA000000000026.002

INFORMATION ONLY

NNA.930308.0035

RECORD PACKAGE TRAVELER

DATE 1-15-93	TWS NUMBER TWS-EES-13-01-93-028	WBS NUMBER 1.2.5.3.5
TITLE OR SUBJECT Technical Database Submission for the Erosion Topical Report: LANL Work on Rock Varnish Calibration Sites.		☒ QUALITY-RELATED PACKAGE ☐ RECORDS TURNOVER PACKAGE
☒ QA ☐ N/A	TOTAL NUMBER OF PAGES (INCLUDING THIS FORM) ~~38~~ 40 LLL 2-17-93	

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I HAVE REVIEWED THIS PACKAGE, AND TO THE BEST OF MY KNOWLEDGE AND UNDERSTANDING, THE CONTENTS OF THIS PACKAGE ARE ACCURATE, COMPLETE, AND APPROPRIATE RECORD TO THE WORK ACCOMPLISHED. ALL RECORDS IN THIS PACKAGE ARE THE BEST AVAILABLE COPY. ALL BLANKS ARE INTENTIONAL.

AUTHENTICATED BY Loretta L. Lopez

RPC REC'D
SMC 1/19/93
Signature Date

DATE January 15, 1993

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RPC ACCEPTED
2/17/93 dm
DATE INITIALS

Distribution:
RPC (2)
L.L. Lopez (1)
EES-13 - (1)

LANL-YMP-QP-17.4

Los Alamos
Yucca Mountain Site
Characterization Project

Encl. 2

WBS 1.2.5.3.5
QA

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

January 15, 1993

TWS-EES-13-01-93-023

Mr. Jim Beckett
GENISES Technical Database Administrator
RSL YMP Support Office
EG&G/Energy Measurements
P. O. Box 1912, MS V-02
Las Vegas, NM 89125

Dear Jim,

SUBJECT: TECHNICAL DATABASE SUBMISSION FOR THE EROSION TOPICAL REPORT: LANL WORK ON ROCK VARNISH

Enclosed is the technical database submission and a floppy disk for "Rock-Varnish Cation Ratio Data" and "Rock-Varnish Dating Curve Calibration Sites." Please enter the attached information into the GENISES database:

1) Journal article entitled "Scanning Electron Microscope Method for Rock-Varnish Dating";

2) Cation ratio data for calibration of rock-varnish dating curve for Yucca Mountain area
    a. Crater Flat alluvial surface,
    b. Fortymile Wash lower alluvial terrace (Q2B), and
    c. Fortymile Wash upper alluvial terrace (Q2C);

3) Table of disk VCRS to be used to calculate cation ratio for deposit (red cone lava flows); and

4) Table of disk VCRS to be used to calculate cation ratio for deposit (black cone lava flow).

If you have any questions regarding this transmittal, please call me at (505) 665-1033.

Sincerely,

Loretta L. Lopez

LLL/SHK/elm

Enclosure: a/s

Cy w/attach.:
L. L. Lopez, EES-13, MS J521

Cy w/o attach.:
J. A. Canepa, EES-13, MS J521
C. D. Harrington, EES-1, MS D462
A. M. Simmons, DOE/YMP, Las Vegas, NV
H. Moomey, T&MSS, Las Vegas, NV
TWS-EES-13 File, MS J521
CRM-4, MS A150

YMP-023-R1
3/20/92

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
TECHNICAL DATA INFORMATION FORM

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300807

(Check one or more):

☐ DATA RESULTING FROM DATA ACQUISITION *(complete Parts I and II)*
Data Tracking Number (DTN): __________

☑ DEVELOPED DATA *(complete Parts I, II, and III)*
Data Tracking Number: LB000000000026.001

☐ DATA TRANSFER *(complete Parts III and IV)*

PART I Identification of Data and Source

Submittal Date: 11-24-93 92 mar 3/5/93 (MM/DD/YY) WBS Number: 1.2.3.2.5.5.1 Is Data Qualified? Y

Preparer: Long (Last Name) Lourta (First) L (Initial) PDA Org.: LANL

Principal Investigator: Harrington (Last Name) Charles (First) D. (Initial) PI Org.: LANL

Participating Organization Generating Data: USGS

Automated Recording System Data Source: N/A

Parameter: N/A Parameter No.: N/A

Parameter Category: N/A Parameter Category No.: N/A

Report Number: N/A

Title/Description of Data: Scanning electron microscope method for rock-varnish dating (Rock Varnish Calibration Cation-Ratio Data)

Activity Number: 8.3.1.6.1.1.3 Governing Plan: SCPB (Acronym)

Comments: N/A

YMP-023-R1
3/20/92

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
TECHNICAL DATA INFORMATION FORM

PART II Data Acquisition and Development Information

Acquisition/Development Method: Field Sampling, SEM Analysis

Identification Number of Test: N/A

Sample Number: N/A

Acquisition/Development Location: LANL

Period of Data Acquisition/Development: 6/30/84 (MM/DD/YY) 6/30/86 (MM/DD/YY)

PART III Source Data

A. If ALL data identified by a previous TDIF(s) was transferred or used to generate developed data, identify the DTN(s) assigned to the TDIF(s):

N/A

B. If only a portion of the data identified by a previous TDIF(s) were transferred or used to generate developed data, identify the DTN(s) assigned to to the TDIF(s):

N/A

YMP-023-R1
3/20/92

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
TECHNICAL DATA INFORMATION FORM

Page 3 of 4

PART IV Transfer of Data ***(Use this page only if data were transferred.)***

Date of Transfer: ____________________
MM / DD / YY

A. Complete one of the following:

TDB Component: ____________________

Other Recipient: ____________________
Last Name First Name Initial

Recipient Organization: ____________________

B. Technical Data Base Submittal Supplementary Information:

1. Format of document containing submitted data (e.g., magnet tape, floppy disc, etc.). Attach any remarks regarding special storage format or data organization that might be required.

____

____

2. Number of attached pages containing data: ____________________

3. Identification number(s) (other than DTNs) on each submitted document:

____

4. Are submitted data published? ☐ Yes ☐ No

Published reference: ____________________

____

5. If submittal includes a modification (addition, correction, etc.) to a previous submittal, indicate reference to previous submittal. Also indicate which data is to be removed or superceded, the data and information as it should be in the TDB, and the reason for the modification (include attachments if necessary).

____

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6. The attached data was collected for the Yucca Mountain Site Characterization Project and it is hereby authorized for inclusion in the TDB. All appropriate reviews and quality assurance requirements have been met.

The signature below constitutes procedural compliance. I have read, understood, and complied with Procedure ________, Rev. ____, ICN # ____, in accomplishing my responsibilities in this procedure.

____________________ ____________________
TPO Signature/Organization MM / DD / YY

7. For TDB Administrator Use:

Acceptance Date: ____________________
MM / DD / YY

Rejection Date: ____________________
MM / DD / YY

AP5.1Q

DATA SUPPLEMENT

Page 4 of 4

This form is used to provide traceability of the data to its supporting documentation

Date 11/23/90 DTN# LA0000000CC0126.001
(to be assigned by technical data coordinator)

Prepared by Loretta L. Lopez

Title/Subject Rock Varnish Calibration Cation-Ratio Data

The following items contain supporting documentation for the attached data submittal. Fill in the blanks with as much information as possible, and if it does not apply to a particular submission mark "N/A."

Notebook

	TWS #/ID #	Page	TWS #/ID #	Page
① Field NtBK	TWS - ESS-1-5 - 88-37			
	TWS #/ID #	Page	TWS #/ID #	Page
② Sampling Tracking Logbook	TWS - EES-1-7-86-50			
	TWS #/ID #	Page	TWS #/ID #	Page
(3) SEM Book	TWS - EES-1-6/86-41			
	TWS #/ID #	Page	TWS #/ID #	Page
	TWS #/ID #	Page	TWS #/ID #	Page
Log Book				
	TWS #/ID #	Page	TWS #/ID #	Page

Photographs N/A
IDENTIFICATION (If Applicable) IDENTIFICATION (If Applicable)

Maps N/A
IDENTIFICATION (If Applicable)

Computer Files N/A
FILE NAME FILE NAME

Other Comments

PI OR DESIGNEE SIGNATURE Loretta L. Lopez

DATE 11-23-90

To be used only by the Technical Coordinator

Comments:

LANL-YMP-QP-08.3

Los Alamos
Yucca Mountain Site
Characterization Project

HQS.880517.2703

Attachment 1

Scanning electron microscope method for rock-varnish dating

Charles D. Harrington
Earth and Space Sciences Division, MS D462, Los Alamos National Laboratory, Los Alamos, New Mexico 87545

John W. Whitney
U.S. Geological Survey, MS 913, Box 25046, Federal Center, Denver, Colorado 80225

ABSTRACT

Rock-varnish coatings on cobbles from geomorphic surfaces and exposed deposits in arid environments are an effective medium for dating over a time range of several thousand to a few million years. A new analytical method for dating of rock varnish is presented wherein the varnish cation ratio (VCR) is determined by a scanning electron microscope (SEM) equipped with an energy dispersive X-ray analyzer (EDAX).

The experimental SEM method is a nondestructive technique that has several potential advantages over the original method of analysis, described by R. I. Dorn, that uses particle-induced X-ray emission (PIXE) of varnish scraped from rock surfaces. The SEM method can potentially eliminate analytical errors due to contamination from rock substrate because variations in varnish thickness and irregularities on the substrate surface are examined before cation ratios are determined. Because varnish surfaces remain intact, varnish sites that yield anomalous results may be reanalyzed or verified. In addition, the general accessibility of scanning electron microscopes will make rock-varnish dating more widely available for use in Quaternary studies.

Cation ratios were calculated for rock varnish from Española Basin, New Mexico, and the Yucca Mountain region, Nevada, and were used to construct rock-varnish dating curves for these areas.

INTRODUCTION

Rock varnish is a thin (usually <100 μm thick) coating of ferro-manganese oxides, clay minerals, and minor amounts of biologic material derived primarily from airborne material that accretes on rocks (Potter and Rossman, 1977, 1979; Dorn and Oberlander, 1982). Varnish is abundant in semiarid and arid regions and is typically found on exposures of bedrock and on gravel clasts that mark stable geomorphic surfaces. For these reasons, geologists and archaeologists have been interested in establishing age-dependent characteristics of rock varnish. A review of early work on rock varnish is found in Dorn and Oberlander (1981a, 1982).

Dorn (1983) developed the first cation-ratio dating method for rock varnish by using the relative abundance of minor elements to establish differential leaching rates of several cations in the varnish. The ratio of mobile to immobile cations ($([\mathrm{K}+\mathrm{Ca}]:\mathrm{Ti})$) was found to decrease with time and provides a relative-age indicator for rock varnish from a given region.

By Dorn's method, bulk samples of varnish are scraped from rock surfaces using a tungsten-carbide needle under 10× to 45× stereo magnification; these samples are analyzed by particle-induced X-ray emission (PIXE). Cation ratios of varnishes were determined for K-Ar dated volcanic rocks from the Coso volcanic field of eastern California and were used by Dorn (1983) to construct a cation-leaching curve (the relation of cation ratios to log age). Recently, a cation-leaching curve for the eastern Mojave region was calibrated using isotopically dated volcanic rocks and radiocarbon-dated varnish (Dorn et al., 1986). The curves were used to calculate chronometric ages of varnish samples of unknown age in these regions and to establish the minimum time since varnished surfaces became stable. (See Dorn [1983] and Dorn and Whitley [1984] for a discussion of the scraping-PIXE technique, and methodological assumptions.)

The alternative method of cation-ratio dating presented here relies on a scanning electron microscope (SEM) equipped with an energy dispersive X-ray analyzer (EDAX). This method was used to construct empirical cation-leaching curves for the Española Basin, New Mexico, and the Yucca Mountain region in southern Nevada (Fig. 1). The Department of Energy's Nevada Nuclear Waste Storage Investigations (NNWSI) Project is studying the Yucca Mountain area as a candidate site for a high-level nuclear waste repository. Because of variations in climate, rates of dust deposition, and differences in dust chemistry, new cation-leaching curves must be constructed for each region studied. Our calibration curves were constructed by determining varnish cation ratios (VCR) on surfaces that had been previously dated by conventional isotopic techniques. An important assumption in the curve calibration is that the varnish age is the same as the dated underlying deposit. Calibrated VCR curves can be used for the calibrated time interval to estimate the VCR age of unknown-age deposits within the region, including any surficial deposits that are not datable by conventional isotopic techniques.

SAMPLING METHOD

Rock samples with dark, well-developed varnish formed under subaerial conditions are selected for analysis. A suite of eight to ten rock specimens is collected and analyzed for each isotopically dated geomorphic surface used in constructing the calibration curve. To reduce potential variability in varnish thickness and composition, samples are collected from (1) stable, well-drained geomorphic surfaces, (2) similar lithologic substrates, and (3) areas having similar environmental conditions. Samples are not collected in close proximity to lichens and other vegetation, to varnish formed along cracks, or to rock surfaces in contact with soil. Wind-abraded and spalled rocks are also avoided. We collect the best developed (i.e., thickest and darkest) varnish from the smoothest varnished rock surfaces available. When calibrating a curve, samples are collected from, or as close as possible to, isotopically dated localities. Clasts examined in this study are of volcanic origin. Volcanic rocks generally have porous surface textures on which varnish coatings are readily accreted.

SAMPLE PREPARATION

Rock samples are rinsed in deionized water to remove surface detritus and then air dried. Two different areas on each sample are selected where the varnish is darkest, thickest, and/or smoothest. A circular core of the varnish and rock substrate (2 to 2.5 cm in diameter) is drilled from each area. A flat 0.5-cm-thick disk is then made from the core by grinding the rock substrate parallel to the varnish surface. The disk is mounted on a glass slide and carbon coated for SEM analysis.

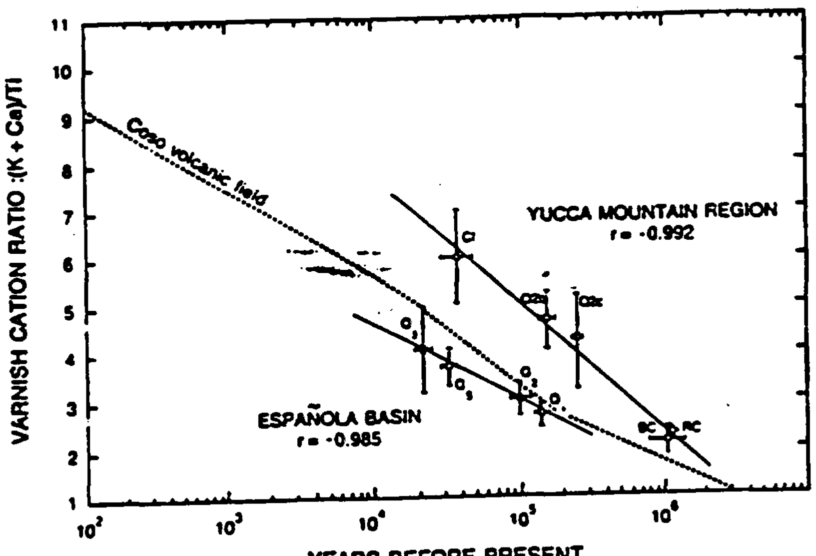
ANALYSIS

Samples are analyzed by using an ISI (Model DS-130) SEM equipped with a Tracor Northern (TN-2000) EDAX. This SEM also has magnification compensation for voltage changes. For each analysis a takeoff angle of 40° and a counting time of 100 s is used, and counting dead time is held between 15% and 20%. A designated sample disk is reanalyzed at the beginning of each day of machine use for purposes of standard comparison: before new analyses are run, variations of less than 1% from original VCR values are necessary. All data are obtained using a standardless program wherein X-ray peak intensities are ZAF (factors for atomic number, absorption, and fluorescence) corrected before elemental weight percentages are calculated. Elemental abundance is recorded in weight percentage for four major (Si, Al, Fe, and Mn) and six minor (Ca, K, Mg, Ti, P, and S) varnish constituents. Relative abundances of elements are based on relative X-ray peak intensities. Hence, ratios of elements have a high degree of accuracy, although absolute concentrations of individual elements may not be determined with great accuracy.

The SEM is commonly used for high-resolution study of small, discrete points. In our method, however, the bulk chemistry of the varnish on each disk, which has a surface area of about 4 cm^2, is obtained by using the EDAX. By initially using a low electron accelerating potential (10 kV) and then progressively increasing the voltage in 5-kV increments while analyzing the same sample area, successively larger sample volumes and greater depth penetration into progressively older varnish are achieved. Several elements in the varnish may be significantly more or less abundant than in the rock substrate. For example, Mn is a major constituent of varnish, and a very minor constituent of substrate, whereas Mg commonly exhibits the opposite relation. Amounts of other elements may increase or decrease with varnish depth and then exhibit a reverse trend when the rock substrate is included in the analysis. In this study, quantities of Ti and Mn gradually increase as varnish is penetrated, reach a maximum when older varnish is included, and decrease as volcanic substrates are penetrated. The quantity of calcium and/or potassium may decrease with depth in the near-surface varnish, gradually increase with greater varnish depth, and rapidly increase as significant substrate penetration occurs. Thus, for varnish developed on volcanic rocks the VCR decreases to a minimum value at some depth in the varnish and then gradually increases with increasing penetration, a result of higher accelerating voltage. The VCR minima occur at, or just below, the voltage at which Mn and Fe maxima are obtained; these are the values we select to calculate a VCR for each rock. In addition, on Mg-bearing substrates these minimum VCR values occur at voltage levels low enough to exclude Mg from the analysis. Microprobe analysis of basalts used as substrate lithologies in this study yielded compositions with approximately 3.4% Mg. VCR minima for varnish on these basalt substrates occur in chemical analyses where Mg concentrations are <0.01% (the lowest EDAX concentration that is recorded). We calculate that the volume of basalt substrate (i.e., substrate contamination) that could be included in the volume of material analyzed without yielding at least 0.01% Mg in the SEM analysis is <0.5%. Thus, we determine the effective accelerating voltage required to analyze the total thickness of varnish but do not include significant quantities of underlying rock substrate in the analysis.

In this study, varnish from Española Basin was found to be thinner than varnish of comparable age from Yucca Mountain. VCR minima for Española Basin varnish were obtained at energy levels of 15–20 kV. For rock varnish older than 40 ka, higher voltage was needed to penetrate samples from Yucca Mountain. VCR minima were typically obtained at 15 kV for varnish from the Crater Flat surface, 20–25 kV for the Forty Mile Wash terraces, and 30 kV for varnish from Red Cone and Black Cone. Densities of varnish from the Yucca Mountain area generally increase with age from 2.70 (Crater Flat surface) to 4.02 (Black Cone).

All samples are analyzed using minimum SEM magnification in order to include the maximum area of varnish in each analysis. Six sites each about 1 cm^2 in area, are analyzed on each disk to produce an integrated analysis of the



each sampled geomorphic surface or deposit is determined by discarding the highest rock VCR value and averaging the remaining values. We currently analyze eight to ten rock samples per geomorphic surface or deposit. Thus, the final cation ratio represents the average of 70 to 90 site SEM/EDAX analyses. Future statistical work may indicate that fewer rock samples and/or analyses will produce a VCR of comparable confidence.

Several factors may cause the chemistry of varnish to vary either across individual rock samples or among a group of samples from a geomorphic surface and result in an anomalous VCR (Dorn and Oberlander, 1981b, 1982; Dorn, 1983). These factors include (1) retardation of initial varnish formation due to unfavorable rock (substrate) lithology, surface smoothness, or the presence of lichens; (2) removal of initial varnish by organic acids derived from organic materials or microorganisms, or by eolian abrasion, with subsequent revarnishing; and (3) incorporation of detrital minerals with high Ca or K concentration in the varnish. The majority of varnishes that result from these varnish-variation processes have higher cation ratios, which produce an apparent younger age than the initial unaltered VCR. An anomalously old age can result when titanomagnetites with abnormally high Ti concentrations are present in the rock varnish, thereby causing low VCR values (Dorn, 1983). These anomalous concentrations can often be recognized during the SEM varnish surface examination or by EDAX chemical analysis, and thus can be avoided for the VCR calculations. Anomalously high values of VCR are more difficult to recognize, and this may result in their inclusion in VCR calculations. Therefore, in our calculation of a rock-varnish age, we exclude the highest VCR site on each disk (1 out of 6) and the highest rock VCR for each deposit or surface.

To determine the reproducibility of VCR values, we analyzed 22 samples from four deposits on two separate occasions and calculated separate ratios for individual samples and for each deposit. The second set of cation ratios for the 22 samples differed by about 4% from the original values. For the four deposits, the average variation of the duplicate analyses was less than 3%. VCR variation across a disk and between disks from the same rock is less than half the variation observed among rock samples from the same geomorphic surface. Thus, we believe that sample selection, not analytical accuracy, is at present the major limiting factor for varnish age determinations. Future analytical work will include refinement of substrate identification by the SEM-EDAX, and comparison of VCR values obtained by the SEM method with those obtained by other laboratory techniques.

ADVANTAGES OF THE SEM-EDAX TECHNIQUE

Use of the SEM-EDAX to determine VCR values has several advantages over the scraping-PIXE method. Sample purity in the scraping-PIXE method is limited by one's ability to differentiate fresh, weathered, and varnish-covered rock fragments from pure varnish, even when substrates are fine-grained, dark volcanic rocks. With use of the SEM, varnish depth can be identified, and this enables analysis of the maximum varnish thickness without significant contamination from the substrate. Changes in chemical composition detected during EDAX analysis determine at what point the substrate is first penetrated; most, if not all, of this contamination can be excluded from the analysis by reducing voltage penetration.

Varnish is not removed from its substrate for SEM analysis, as it must be for PIXE analysis. If an SEM-EDAX analysis yields an anomalous result, then the specific site on the disk may be reexamined to determine the cause of the anomaly. Furthermore, chemical inhomogeneities can be examined across an entire disk. If a PIXE analysis is anomalous, then the original varnish surface cannot be reexamined, and a substitute sample must be studied.

In SEM analysis, VCR values show no significant variation when the analysis is performed over minor irregularities in the varnish surface; significant topographic irregularities can be avoided during SEM examination of the varnish surface under high magnification. Thus, a greater variety and number of specimens can be evaluated at a field locality where smooth-surfaced rocks are not abundant.

CALIBRATION OF CATION-LEACHING CURVES

VCR values for geomorphic surfaces presented here (Table 1) are the average of eight or more individual rock cation ratios per field locality. The standard deviation (1 σ) of VCR values for an individual surface (shown as vertical error bars for sample points in Fig. 1) varies from less than 4% for the oldest deposit to 23% for the youngest. Analyses on individual deposits and geomorphic surfaces will probably have smaller standard deviations when we better understand the nature and significance of various environmental factors that result in spot-to-spot rock-varnish variations. Increased understanding will lead to improvement in selection of sites and methods of sampling, and this will minimize variations in cation ratios for a single geomorphic surface or deposit.

ESPAÑOLA BASIN

Age control for the Española Basin is established from a sequence of four gravel-capped erosional surfaces along the northeast flank of the Jemez Mountains. Dense inner layers of calcium carbonate coatings were extracted from pebbles in near-surface soil K horizons and uranium-series dated at 22 ±3 ka, 31 ±4 ka, 103 ±17 ka, and 144 ±15 ka (Harrington and Aldrich, 1984; M. J. Aldrich, Jr., 1986, unpublished data). Samples of black, well-developed, surface rock varnish were collected from basalt

TABLE 1. SURFACES OR DEPOSITS USED TO CALIBRATE CATION LEACHING CURVES

Deposit*	Radiometric age (ka)	Method of dating	Cation ratio† (K+Ca:Ti)
Española Basin			
Q1 surface	144 ±15§	Uranium series	2.71 ±0.24
Q2 surface	103 ±17	Uranium series	3.14 ±0.43
Q5 scarp	31 ±4	Uranium series	3.72 ±0.39
Q4 surface	22 ±3	Uranium series	4.10 ±0.94
Yucca Mountain Region			
Crater Flat basalt flows			
Black Cone (BC)	1090 ±300**	K-Ar	2.18 ±0.27
Red Cone (RC)	1120 ±70	K-Ar	2.33 ±0.11
Terraces along Forty Mile Wash			
Q2c terrace	255 ±15††	Uranium trend	4.34 ±1.04
Q2b terrace	160 ±20	Uranium trend	4.68 ±0.52
Crater Flat surface (CF)	40 ±10	Uranium trend	6.00 ±1.00

* Symbols used in Figure 1.
† Standard errors for varnish cation ratios listed are 1 standard deviation.
§ Harrington and Aldrich (1984); M. J. Aldrich, Jr. (1986, unpublished data).
**Vaniman et al. (1982); Carr (1984).
††Rosholt et al. (1985); D. R. Muhs (1986, unpublished data).

and andesite gravel on these surfaces. Cation ratios and their standard deviations were calculated for these surfaces and plotted against their independently determined uranium-series ages (Fig. 1) to generate a cation-leaching curve (a least-squares regression line of cation ratio to log of time base 10). This line has a correlation coefficient (r) of −0.985 and is described by the function $VCR_E = 6.093 - 1.529 \log_{10} t$, where t is in thousand years before present (ka) and VCR_E is the varnish cation ratio ([K+Ca]:Ti).

The cation-leaching curve for the Española Basin is similar to that for the Coso volcanic field of eastern California (Dorn, 1983), both in terms of y intercept and slope, for the time interval of 10.5 to 150 ka. However, to explain the Coso data, Dorn used three line segments for his cation-leaching curve with changes in slope at approximately 10 and 150 ka. More data suggest that the hypothesized slope change at 10 ka is not substantiated for the Mojave Desert (Dorn et al., 1986). If the regression line for the Coso data is recalculated without the change in slope at 10 ka, its similarity to the Española Basin curve is enhanced. Such similarity suggests that the Española and Coso regions had similar environmental conditions during the late Pleistocene. These conditions may include type and amount of rainfall, temperature, and long-term rates of dust deposition.

YUCCA MOUNTAIN

Five dated geomorphic surfaces in the area of Yucca Mountain were used to calibrate a cation-leaching curve. Samples of black rock varnish were collected from (1) outcrops and boulders of two basalt flows K/Ar-dated at 1.1 Ma (Vaniman et al., 1982; Carr, 1984); (2) clasts of welded tuff on two alluvial terraces along Forty Mile Wash, which are dated by uranium trend at 160 and 250 ka; and (3) clasts of welded tuff on an alluvial surface in Crater Flat, dated by uranium trend at 40 ka (Rosholt et al., 1985; D. R. Muhs, 1986, unpublished data). Varnish samples were collected from the most stable part of each surface. The uranium-trend method dates the time of sediment deposition, whereas rock varnish dates the time of surface stability. We assume that the time between surface stabilization and the beginning of varnish formation on surface clasts is negligible compared to the age of the Pleistocene deposits.

The Yucca Mountain cation-leaching curve between 40 and 1500 ka has a correlation coefficient of −0.992 (a near linear trend) and is described by the function $VCR_E = 10.466 - 2.667 \log_{10} t$. The apparent reduction in leaching rate for varnish older than 150 ka originally noted by Dorn (1983) does not appear in data for the Yucca Mountain area.

The Yucca Mountain cation-leaching curve is significantly different from curves for both the Española Basin and the Coso volcanic field: Yucca Mountain has both higher VCR values for similar varnish ages and a higher leaching rate. Higher cation ratios for the varnish from Yucca Mountain suggest that greater alkaline eolian fallout occurred here during the Pleistocene than in the Coso or Española regions. Higher accumulation rates and more alkaline composition of dust probably resulted from deflation of dry playas that persisted over great aerial extent and for long time periods. The Yucca Mountain area did not experience significant climatic amelioration, and nearby playas did not become pluvial lakes, during late Pleistocene glacial episodes (Mifflin and Wheat, 1979; Spaulding, 1985).

APPLICATIONS OF THE TECHNIQUE

Cation-ratio dating can be used to determine the time of varnish initiation on clasts from a variety of erosional and depositional surfaces, and, thus, to determine the minimum time since a surface stabilized. In the Yucca Mountain area and the Española Basin we are using the SEM-EDAX method to obtain VCR ages on pediment surfaces, alluvial fan surfaces, fluvial terraces, stabilized hillslope deposits, bedrock surfaces, and surfaces of eolian deposits. These dated surfaces and deposits in the Yucca Mountain area are being used to calculate local and regional erosion and incision rates, to date faulted surfaces for neotectonic studies, and to understand early to late Pleistocene paleoenvironmental conditions by dating deposits and surfaces whose origins were controlled by climatic changes and geomorphic processes not operating under present climatic conditions.

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YMP-023-R1
3/20/92

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
TECHNICAL DATA INFORMATION FORM

Page 1 of 3

(Check one or more):

300933

☐ DATA RESULTING FROM DATA ACQUISITION *(complete Parts I and II)*
Data Tracking Number (DTN): ______________

☑ DEVELOPED DATA *(complete Parts I, II, and III)*
Data Tracking Number: LA000000000026.002

☐ DATA TRANSFER *(complete Parts III and IV)*

PART I Identification of Data and Source

Submittal Date: 1-15-93 (MM/DD/YY) WBS Number: 1.2.3.2.5.5.1 Is Data Qualified? Y

Preparer: Lopez (Last Name) Loretta (First) L (Initial) PDA Org.: LANL

Principal Investigator: Harrington (Last Name) Charles (First) D. (Initial) PI Org.: LANL

Participating Organization Generating Data: USGS

Automated Recording System Data Source: N/A

Parameter: N/A Parameter No.: N/A

Parameter Category: N/A Parameter Category No.: N/A

Report Number: N/A

Title/Description of Data: Rock-Varnish Cation Ratio Data and Rock-Varnish Dating Curve Calibration Sites Data

Activity Number: 8.3.1.6.1.1.3 Governing Plan: SCPB (Acronym)

Comments: N/A

APS.1Q

YMP-023-R1
3/20/92

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
TECHNICAL DATA INFORMATION FORM

Page 2 of 3

PART II Data Acquisition and Development Information

Acquisition/Development Method: Field Sampling, SEM Analisis

Identification Number of Test: N/A

Sample Number: N/A

Acquisition/Development Location: LANL

Period of Data Acquisition/Development: MM/DD/YY MM/DD/YY

PART III Source Data

A. If ALL data identified by a previous TDIF(s) was transferred or used to generate developed data, identify the DTN(s) assigned to the TDIF(s):

LA000000000026.001

B. If only a portion of the data identified by a previous TDIF(s) were transferred or used to generate developed data, identify the DTN(s) assigned to to the TDIF(s):

N/A

YMP-023-R1
3/20/92

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
TECHNICAL DATA INFORMATION FORM

Page 3 of 3

PART IV Transfer of Data *(Use this page only if data were transferred.)*

Date of Transfer: January 15, 1992
MM / DD / YY

A. Complete one of the following:

TDB Component: GENISES

Other Recipient: N/A
Last Name First Name Initial

Recipient Organization: EG&G

B. Technical Data Base Submittal Supplementary Information:

1. Format of document containing submitted data (e.g., magnet tape, floppy disc, etc.). Attach any remarks regarding special storage format or data organization that might be required.

Hard copy, floppy disk (ASCII).

2. Number of attached pages containing data: 1

3. Identification number(s) (other than DTNs) on each submitted document:

TWS-EES-13-01-93-023

4. Are submitted data published? ☐ Yes ☑ No

Published reference:

5. If submittal includes a modification (addition, correction, etc.) to a previous submittal, indicate reference to previous submittal. Also indicate which data is to be removed or superceded, the data and information as it should be in the TDB, and the reason for the modification (include attachments if necessary).

N/A

6. The attached data was collected for the Yucca Mountain Site Characterization Project and it is hereby authorized for inclusion in the TDB. All appropriate reviews and quality assurance requirements have been met.

AP 5.1Q R2

LLC 2-16-93

The signature below constitutes procedural compliance. I have read, understood, and complied with Procedure AP 5.2Q, R3 Rev. [illegible], ICN # 0 in accomplishing my responsibilities in this procedure.*

JC 1/15/93

JAN 15, 1993

TPO Signature/Organization MM / DD / YY

7. For TDB Administrator Use:

Acceptance Date:
MM / DD / YY

Rejection Date:
MM / DD / YY

AP5.1Q

Attachment 2a

CATION RATIO DATA FOR CALIBRATION OF ROCK VARNISH DATING CURVE FOR YUCCA MOUNTAIN AREA

FIELD SITE:CRATER FLAT ALLUVIAL SURFACE
FIELD ID NUMBER: 23068503-A LAB ID NUMBER: CF3A

	DISK 1			DISK 2		
KEV	10	15	20	10	15	20
VCR SITE 1		8.576*OM	8.690	7.106*	9.588	10.577
2		7.152*		17.269	10.221*OM	12.518
3	6.408*	8.750		7.439*	11.133	
4	7.518	6.141*		7.333*		
5	5.639*	8.196		8.250*	9.720	
6	5.806*			8.510*	12.900	

DISK 1 MEAN VCR 6.229 DISK 2 MEAN VCR 7.728

* = ANALYSIS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

FIELD SITE: CRATER FLAT ALLUVIAL SURFACE
FIELD ID NUMBER: 23068503-B LAB ID NUMBER: CF3B

	DISK 1			DISK 2		
KEV	10	15	20	10	15	20
VCR SITE 1	7.070	6.891*		11.724	7.802*	
2		6.672*			9.588*	
3	10.117	8.691*OM	9.216		6.293*	
4		6.254*			10.781*OM	
5	5.460*	9.355			8.923*	
6	5.536*				8.109*	

DISK 1 MEAN VCR 6.163 DISK 2 MEAN VCR 8.143

* = ANALYSIS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

FIELD SITE:CRATER FLAT ALLUVIAL SURFACE

```
FIELD ID NUMBER: 23068503-C   LAB ID NUMBER: CF3C


                    DISK 1                              DISK 2
KEV          10        15        20          15        20        25

VCR
SITE  1  3.886     3.564*   3.891       6.039     5.803     5.732*
      2            3.218*                                   6.378*OM
     3             3.668*OM                       5.408*    6.503
      4            3.172*                         5.023*
      5            3.621*                         5.276*
      6            2.834*   2.894                 3.995*

      DISK 1 MEAN VCR  3.282            DISK 2 MEAN VCR  5.087

* = ANALYSIS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
         VCRS
```

```
FIELD SITE:CRATER FLAT ALLUVIAL SURFACE
FIELD ID NUMBER: 23068503-D    LAB ID NUMBER: CF3D


                    DISK 1                              DISK 2
KEV          15        20        25          15        20        25

VCR
SITE  1 12.351     6.835*   7.550       6.901     6.125*    6.712
      2            6.180*                         6.982     6.441*
     3             7.369*                         6.543*    7.813
      4  9.419     8.902*OM11.250                 5.055*
      5            7.278*                         5.255*
      6  8.300*   13.027    9.553          ONLY 5 SITES ANALYZED


DISK 1 MEAN VCR  7.192                  DISK 2 MEAN VCR  5.884

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS
```

```
FIELD SITE:CRATER FLAT ALLUVIAL SURFACE
FIELD ID NUMBER: 23068503-E    LAB ID NUMBER: CF3E


                DISK 1                           DISK 2
KEV          15       20        25          15        20        25

VCR
SITE  1  8.728    8.229*  10.581       5.813*   7.114
      2  8.434*  12.802   11.753       6.098*
     3   6.433*                        5.149*
      4  9.077*OM                      6.185*OM
      5  6.888*                        5.479*
      6  7.640*                        5.115*

DISK 1 MEAN VCR  7.525                 DISK 2 MEAN VCR  5.531

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS




FIELD SITE:CRATER FLAT ALLUVIAL SURFACE
FIELD ID NUMBER: 23068503-F     LAB ID NUMBER: CF3F


             DISK 1                              DISK 2
KEV          15       20          10        15        20        25

VCR
SITE  1  3.189*   3.540                    9.580    7.935*
      2  3.387*                            9.738    8.940*OM 13.792
     3   3.012*                            7.[illegible]79*  1[illegible].011
      4  3.565*OM                          8.765    6.859*
      5  2.968*                                     6.949*
      6  2.885*                6.775*  8[illegible]35    [illegible].563

DISK 1 MEAN VCR  3.088                 DISK 2 MEAN VCR  7.239

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS
```

```
FIELD SITE:CRATER FLAT ALLUVIAL SURFACE
FIELD ID NUMBER: 23068503-G       LAB ID NUMBER: CF3G


                DISK 1                        DISK 2
KEV        10       15       20         10       15       20

VCR
SITE  1           3.422*   4.167      7.554    6.126*   9.220
      2           3.469*                       6.200*
     3            3.971*   4.010               6.713*
      4           4.340*OM 4.161               6.621*   7.630
      5           3.796*             12.591    8.411*OM16.407
      6           3.962*                       8.295

DISK 1 MEAN VCR  3.724                 DISK 2 MEAN VCR  6.791

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS



FIELD SITE:CRATER FLAT ALLUVIAL SURFACE
FIELD ID NUMBER: 23068503-H     LAB ID NUMBER: CF3H


                DISK 1                        DISK 2
KEV        10       15       20         10       15       20

VCR
SITE  1 10.970    7.104*   7.159      8.070*OM10.623   11.762
      2           8.614    6.991*     9.169    7.195*
     3            8.989    8.657*OM            9.081    6.438*
      4                    8.330*                       6.777*
      5           6.664*   8.979               7.114*   7.982
      6           6.972*              4.644*   9.368

DISK 1 MEAN VCR  7.212                 DISK 2 MEAN VCR  6.434

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS
```

FIELD SITE:CRATER FLAT ALLUVIAL SURFACE
FIELD ID NUMBER: 23068503-I   LAB ID NUMBER: CF3I

		DISK 1		DISK 2		
KEV		15	20	10	15	20
VCR SITE	1	5.471*	5.881	7.903*	9.467	11.083
	2	5.875*OM		10.028	9.640	8.374*
	3	4.794*				8.674*
	4	5.053*			8.892	8.724*OM
	5	5.179*		8.467	8.229*	11.410
	6	5.065*			6.723*	

DISK 1 MEAN VCR 5.112   DISK 2 MEAN VCR 7.981

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

TABLE OF DISK VCRS USED TO CALCULATE CATION RATIO FOR DEPOSIT: CRATER FLAT ALLUVIAL SURFACE (CF3) CALIBRATION POINT (PUBLISHED IN TABLE 1, HARRINGTON AND WHITNEY, 1987, SCANNING ELECTRON MICROSCOPE METHOD FOR ROCK-VARNISH DATING: GEOLOGY, V. 15, p. 967-970).

DEPOSIT	DISK 1 VCR	DISK 2 VCR
CF3A	6.229	7.728
CF3B	6.163	8.143
CF3C	3.282	5.087
CF3D	7.192	5.884
CF3E	7.525	5.531
CF3F	3.088	7.239
CF3G	3.724	6.791
CF3H	7.212	6.434
CF3I	5.112	7.981

MEAN VCR FOR CRATER FLAT ALLUVIAL SURFACE (CF3) 6.00+/-1.00

CATION RATIO DATA FOR CALIBRATION OF ROCK VARNISH DATING CURVE FOR YUCCA MOUNTAIN AREA

FIELD SITE: FORTYMILE WASH LOWER ALLUVIAL TERRACE (Q2B)
FIELD ID NUMBER: 22068501-A LAB ID NUMBER: 40LA

```
                DISK 1                        DISK 2
KEV  10     15      20       25    10       15     20        25

VCR
SITE
1                  8.330*OM11.384  9.494  8.171* 9.196
2          7.483*  9.962    9.306         8.698* 9.223                    3
           8.204*                 34.217 10.868 10.247*OM 10.990      4
6.325*     9.421  11.494                        11.057*OM
5  5.336*  8.152                   9.488*10.671 11.152    10.491          6
   7.478*                                 9.304            8.905*         7
                                          8.009*
```

DISK 1 MEAN VCR 6.965 DISK 2 MEAN VCR 8.964

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

FIELD SITE: FORTYMILE WASH LOWER ALLUVIAL TERRACE (Q2B)
FIELD ID NUMBER: 22068501-B LAB ID NUMBER: 40LB

```
                DISK 1                        DISK 2
KEV        20       25       30          20       25

VCR
SITE  1  6.744    6.392*OM 6.478     4.953*   5.789
      2           5.890*             6.252    5.728*
     3            5.565*             5.741*   6.411
      4           5.932*             5.937*   6.289
      5           5.469*             5.427*
      6  6.097    6.041*             8.000    6.919*OM
```

DISK 1 MEAN VCR 5.779 DISK 2 MEAN VCR 5.557

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

FIELD SITE: FORTYMILE WASH LOWER ALLUVIAL TERRACE (Q2B)

```
FIELD ID NUMBER: 22068501-C      LAB ID NUMBER: 40LC


                   DISK 1                               DISK 2
KEV          15         20         25          20         25


VCR
SITE  1               4.419      4.349*      4.423*     4.717
      2                          4.578*      5.465      4.872*OM
     3   4.150*     4.570      5.043                   4.466*
      4   4.823     4.630      4.500*      4.803*     4.960
      5   5.016*OM  5.087      5.226       4.582*
      6   4.724     4.956      4.579*      4.752      4.370*

DISK 1 MEAN VCR  4.431                    DISK 2 MEAN VCR 4.529

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS



FIELD SITE: FORTYMILE WASH LOWER ALLUVIAL TERRACE (Q2B)
FIELD ID NUMBER: 22068501-D    LAB ID NUMBER: 40LD

                   DISK 1                               DISK 2
KEV          15         20            15        20         25         30


VCR
SITE  1   4.660*     5.189       11.177     10.911      9.342*
      2   4.179*                  9.860      9.757*    12.744
     3   4.932*OM                14.379     15.015     10.714      9.946*
      4   4.393*                                       11.710*OM13.596
      5   4.096*                            19.792     12.382     10.972*
      6   4.338*                                                   9.180*

DISK 1 MEAN VCR  4.334                  DISK 2 MEAN VCR  9.839

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS



FIELD SITE: FORTYMILE WASH LOWER ALLUVIAL TERRACE (Q2B)
FIELD ID NUMBER: 22068501-E   LAB ID NUMBER: 40LE
```

	DISK 1				DISK 2		
KEV	10	15	20	25	15	20	25
VCR SITE 1		5.752*	7.197	6.815	6.009*		
2	4.468*	6.307	6.748		6.287	5.341*	
3	6.400	4.944*			6.339*OM	8.068	6.661
4	3.671*	6.274	6.688			4.909*	5.871
5	4.890*					4.082*	
6	5.957*OM	6.452				5.231*	

DISK 1 MEAN VCR 4.745 DISK 2 MEAN VCR 5.114

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

FIELD SITE: FORTYMILE WASH LOWER ALLUVIAL TERRACE (Q2B)
FIELD ID NUMBER: 22068501-F LAB ID NUMBER: 40LF

	DISK 1	DISK 2			
KEV	20	10	15	20	25
VCR SITE 1	2.721*		5.794*	6.880	
2	4.047*	4.392*	6.319		
3	4.377*OM	7.155	6.466*OM	6.695	6.549
4	3.678*		6.886	5.950*	
5	3.734*		6.464		5.690*
6	3.187*				6.431*

DISK 1 MEAN VCR 3.473 DISK 2 MEAN VCR 5.651

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

FIELD SITE: FORTYMILE WASH LOWER ALLUVIAL TERRACE (Q2B)
FIELD ID NUMBER: 22068501-G LAB ID NUMBER: 40LG

	DISK 1			DISK 2		
KEV	15	20	25	20	25	30
VCR						
SITE 1	5.543	4.933*OM		5.052	5.056*OM	5.311
2		4.913	4.766*	4.878*	5.207	
3			4.565*	5.321	4.683*	
4			4.595*		4.541*	
5		4.589*	5.061	5.536	5.039*	5.070
6		4.856	4.500*		5.133	4.768*

DISK 1 MEAN VCR 4.603 DISK 2 MEAN VCR 4.728

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

FIELD SITE: FORTYMILE WASH LOWER ALLUVIAL TERRACE (Q2B)
FIELD ID NUMBER: H100285-14 LAB ID NUMBER: 40LM

	DISK 1			DISK 2		
KEV	15	20	25	10	15	20
VCR						
SITE 1	4.756*	5.140	6.416	9.143*	10.628	11.256
2	4.598*			11.694	10.841*	
3	4.903	4.644*		7.713*	11.645	
4	4.489*	5.771	7.041	14.982	13.104	12.013*OM
5	4.640*			10.644*	19.885	13.859
6	4.871*OM		6.243	6.659*		

DISK 1 MEAN VCR 4.625 DISK 2 MEAN VCR 9.000

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

FIELD SITE: FORTYMILE WASH LOWER ALLUVIAL TERRACE (Q2B)
FIELD ID NUMBER: H100285-15 LAB ID NUMBER: 40LN

```
                DISK 1                        DISK 2
KEV              15      20      25      10         15       20

VCR
SITE  1        3.784   3.674*  4.065   9.790      6.557*   8.008
      2        3.926*  4.221   4.474              6.220*
     3         3.576*                  6.831*OM   8.755    7.541
     4         4.231*OM                                    6.259*
      5        4.160*  4.433                      6.624*
      6        3.768*                             6.493*

DISK 1 MEAN VCR  3.821                DISK 2 MEAN VCR  6.430

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS


FIELD SITE: FORTYMILE WASH LOWER ALLUVIAL TERRACE (Q2B)
FIELD ID NUMBER: H100285-16      LAB ID NUMBER: 40LO

                DISK 1                        DISK 2
KEV              20      25      30      10         15       20

VCR
SITE  1        5.632   5.391*                     10.862   8.296*
      2        4.937*  5.412   5.609                       8.007*
     3         6.118   5.743*          6.336*     13.368  10.427
     4         7.071   5.908*OM        5.987       8.750*OM
      5        5.583   5.471*         17.277       8.5663*
      6  5.362 5.103*                  7.584*

DISK 1 MEAN VCR  5.329                DISK 2 MEAN VCR  7.757

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS


FIELD SITE: FORTYMILE WASH LOWER ALLUVIAL TERRACE (Q2B)
FIELD ID NUMBER: H100285-17   LAB ID NUMBER:  40LP
```

```
                    DISK 1                            DISK 2
KEV           10     15        20            20          25

VCR
SITE  1 11.167*OM12.989                    4.445*      5.397
       2  8.087    12.371                  3.696*
      3 12.520   10.624*  13.371           4.566*
       4            8.488*                 4.822*OM    5.735
       5            7.795*                 4.737*
       6            6.738*                 4.280*

DISK 1 MEAN VCR  8.346                   DISK 2 MEAN VCR  4.344

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS
```

TABLE OF DISK VCRS TO BE USED TO CALCULATE CATION RATIO FOR DEPOSIT: FORTYMILE WASH LOWER ALLUVIAL TERRACE (Q2B) CALIBRATION POINT (PUBLISHED IN TABLE 1, HARRINGTON AND WHITNEY, 1987, SCANNING ELECTRON MICROSCOPE METHOD FOR ROCK-VARNISH DATING: GEOLOGY, V. 15,

p. 967-970).

DEPOSIT	DISK 1 VCR	DISK 2 VCR
40LA	6.965**	8.964**
40LB	5.779	5.557
40LC	4.431	9.839**
40LD	4.334	5.114
40LE	4.745	5.114
40LF	3.473	5.651
40LG	4.603	4.782
40LM	4.625	9.000**
40LN	3.821	6.430**
40LO	5.329	7.757**
40LP	8.346**	4.344

MEAN VCR FOR FORTYMILE WASH
LOWER ALLUVIAL TERRACE (Q2B) 4.68+/-0.53

In the samples collected from the Fortymile Wash lower alluvial terrace (Q2B), several of the samples appeared to show abrasion of the varnish and revarnishing (40LA and disk 2 from 40LC). A second collection of clasts were made that clearly possessed a stripped varnish from part of the clast with what appeared to be unmodified varnish on the opposite side of the clast (40LM-40LP).
In calculating the mean VCR for the terrace (Q2B), neither 40LA, nor disk 2 from 40LC, nor the stripped and revarnished disks from 40LM-40LP were used (all disks omitted from the VCR calculation are noted by **).

Attachment 2a

CATION-RATIO DATA FOR CALIBRATION OF ROCK VARNISH DATING CURVE FOR YUCCA MOUNTAIN AREA

FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: 22068502-A LAB ID NUMBER: 40MA

		DISK 1			DISK 2		
KEV		20	25	30	20	25	30
VCR SITE	1	3.932	3.854	3.833*		3.936	3.580*
	2		3.692	3.656*		3.969	3.732*OM
	3		3.921	3.719*			3.672*
	4			3.534*			3.493*
	5		4.238	3.915*OM			3.678*
	6		3.612*	3.785			3.593*

DISK 1 MEAN VCR 3.671 DISK 2 MEAN VCR 3.603

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: 22068502-B LAB ID NUMBER: 40MB

		DISK 1			DISK 2			
KEV		20	25	30	15	20	25	30
VCR SITE	1		5.978*	6.725	4.792*	5.1[illegible]	5.885	
	2		5.430*		6.627*	6.731		
	3	6.358*OM	7.231	7.532	5.120*	7.600	7.557	8.207
	4	4.612*			7.375	6.805*OM	7.008	
	5	5.046*			5.015*	6.295	6.611	
	6	5.521*			4.556*			

DISK 1 MEAN VCR 5.318 DISK 2 MEAN VCR 5.222

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

```
FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: 22068502-C     LAB ID NUMBER: 40MC


                     DISK 1                            DISK 2
KEV          10        15        20        10        15        20

VCR
SITE  1  6.422*    7.526     9.867       6.972*    9.400
      2  5.933*    8.746                 7.769*    8.569
     3   6.036*    7.983                 7.807*    9.031
      4  6.939*    9.416                14.361     8.026*
      5  7.407*OM  7.597                           6.543*
      6  7.042*    8.168                           6.008*

DISK 1 MEAN VCR  6.474                 DISK 2 MEAN VCR  7.020

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING-MEAN
VCRS




FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: 22068502-D      LAB ID NUMBER: 40MD


                     DISK 1                            DISK 2
KEV          15        20                  15        20        25

VCR
SITE  1  1.987*    1.973                 2.995*OM 4.159     5.030
      2            1.921*                1.771*
     3             1.6[illegible]*       1.67[illegible]*
      4            1.688*                1.685*
      5            2.070*OM              1.739*
      6            1.720*                2.211*   2.776

DISK 1 MEAN VCR  1.783                 DISK 2 MEAN VCR  1.816

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS
```

FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: 22068502-E LAB ID NUMBER: 40ME

		DISK 1			DISK 2		
KEV		15	20	25	10	15	20
VCR SITE	1	3.949*	4.907	5.826	4.238*	6.239	7.347
	2	6.621	6.065*OM		3.803*		
	3	5.860*	7.302		3.826*		
	4	4.656*			4.681*	6.288	
	5	4.044*			4.006*	6.689	
	6	3.902*			5.078*OM		

DISK 1 MEAN VCR 4.482 DISK 2 MEAN VCR 4.111

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: 22068502-F LAB ID NUMBER: 40MF

		DISK 1			DISK 2		
KEV		10	15	20	15	20	25
VCR SITE	1	2.973	2.815*	3.050	4.645*OM	4.906	5.330
	2			3.063*	3.904*		
	3			3.111*	3.561*		
	4			3.061*	4.184*		
	5			2.881*	3.519*		
	6			3.181*OM	3.059*		

DISK 1 MEAN VCR 2.986 DISK 2 MEAN VCR 3.645

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: 22068502-G LAB ID NUMBER: 40MG

		DISK 1				DISK 2		
KEV		10	15	20	25	15	20	25
VCR SITE	1	9.439	6.718*OM	6.873	7.058	7.257	6.176*	6.271
	2		6.827	6.504	6.378*		5.852*	6.015
	3				5.864*		5.923	5.886*
	4		--		5.462			5.144*
	5		6.812	5.738*	6.520			5.141*
	6			5.865*	5.923		5.407*	6.158

DISK 1 MEAN VCR 5.861 DISK 2 MEAN VCR 5.486

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: 22068502-H LAB ID NUMBER: 40MH

		DISK 1				DISK 2		
KEV		15	20	25	30	20	25	30
VCR SITE	1	6.110	5.214	5.148*		7.179	6.269	6.230*OM
	2		5.159*	5.300	5.259		5.767*	5.911
	3			5.815	5.208*	6.237	6.052	5.575*
	4			5.896	5.381*			5.866*
	5				5.178*	6.406	6.512	6.187*
	6			5.760	5.375*		5.770*	5.790

DISK 1 MEAN VCR 5.214 DISK 2 MEAN VCR 5.833

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

```
FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: 22068502-I    LAB ID NUMBER: 40MI


                       DISK 1                          DISK 2
KEV          10        15       20       15       20       25

VCR
SITE   1   5.529*    9.011   9.860    5.281*   5.948
       2   6.470*    9.975            6.350    6.198*   7.947
       3  11.013*OM11.064                      7.356*OM 7.781
       4   5.783*    9.824                     5.436*   6.658
       5   5.955*                     5.217*   6.134
       6   8.913*   10.617            5.991*   6.536

DISK 1 MEAN VCR  6.530                     DISK 2 MEAN VCR  5.625

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS



FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: 22068502-J    LAB ID NUMBER: 40MJ


                       DISK 1                           DISK 2
KEV          20        25       30       15       20       25

VCR
SITE   1   5.555     5.396*  5.603    5.295    4.885*  5.163
       2   6.418     5.933   5.453*   5.808    5.122*
       3             5.289*           4.895*
       4   6.058     5.922   5.901*OM          5.893   5.272*OM
       5   5.949     5.693*                    5.048*
       6             5.781*                    5.186*

DISK 1 MEAN VCR  5.522                     DISK 2 MEAN VCR  5.027

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS




FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
```

```
FIELD ID NUMBER: H100285-20   LAB ID NUMBER: 40MM


                DISK 1                        DISK 2
KEV        20      25      30       15     20      25      30
VCR
SITE  1  3.624   3.365   3.217*          5.676*  6.009   5.892
      2                 3.408*  7.699   6.483*OM6.491   6.671
      3         3.588   3.558*OM        6.687   6.286*  6.312
      4         3.411   3.279*                  5.281   5.174*
      5                 3.347*                  5.696   5.066*
      6                 3.428*                  4.904*  5.379

DISK 1 MEAN VCR  3.336                  DISK 2 MEAN VCR  5.421

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS



FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE  (Q2C)
FIELD ID NUMBER: H100285-21    LAB ID NUMBER: 40MN


                DISK 1                        DISK 2
KEV        20      25      30      20      25      30

VCR
SITE  1  7.317*  7.7665  7.464           5.090*  5.866
      2  7.280*  7.378                   6.754   6.454*OM
      3 12.651   9.435*OM                        5.500*  5.808
      4         6.790*                  5.006*
      5         7.096*                  5.019*
      6         6.623*                  6.014*

DISK 1 MEAN VCR  7.021                   DISK 2 MEAN VCR  5.326

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS




FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: H100285-22      LAB ID NUMBER: 40MO
```

```
                    DISK 1                                DISK 2
KEV          20        25        30         15         20        25        30
VCR
SITE   1  4.903     4.326*   4.686                  4.082*   4.764
       2  4.593*    4.829    5.236      5.122       4.867*   5.066
       3            5.113*                          5.966    5.889*OM  6.829
       4            4.671*              5.313       5.133*   5.646
       5            4.601*                          5.150    4.915*
       6  5.342*OM6.371     6.374                            4.430*

DISK 1 MEAN VCR  4.661                    DISK 2 MEAN VCR  4.685

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS




FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: H100285-23      LAB ID NUMBER: 40MP


                    DISK 1                                DISK 2
KEV
              20        25               20        25
VCR
SITE   1  3.702*    3.812            3.904     3.786*
       2  3.840     3.753*           3.378*
       3            3.787*           4.031     3.780*
       4            3.701*                     3.856*OM
       5            3.844*OM                   3.818*
       6            3.372*                     3.482*

DISK 1 MEAN VCR  3.663                     DISK 2 MEAN VCR  3.649

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS






FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: H100285-24       LAB ID NUMBER: 40MR

                    DISK 1                                DISK 2
```

```
KEV         25       30                 25       30

VCR
SITE  1  4.439    4.122*            3.496    3.300*
      2  4.583*OM4.596              3.799*   3.856
      3           4.218*            3.901*   4.055
      4  4.803    4.536*            4.553    4.467*OM
      5  4.747    4.524*                     3.445
      6           4.431*                     3.459*

DISK 1 MEAN VCR  4.366                DISK 2 MEAN VCR  3.581

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS
```

```
FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: H100285-25     LAB ID NUMBER: 40MS


                   DISK 1                          DISK 2
KEV         15       20      25        15        20       25      30

VCR
SITE  1  3.744*  4.027              8.974   7.576*OM8.792    9.372
      2  3.883*  4.087                      5.469    5.466
      3  4.381*  4.749    4.569             4.616*
      4  5.509*  5.678    6.331     5.066*  5.267
      5  4.942   4.525*             8.135   7.451*OM7.877
      6  7.111   6.072*OM6.082      7.374   5.530*   5.786   6.701
      7                                     6.297*   6.461

DISK 1 MEAN VCR  4.408               DISK 2 MEAN VCR 5.395

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS
```

```
FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: H100285-26   LAB ID NUMBER: 40MT


                   DISK 1                          DISK 2
```

```
KEV          15      20      25        15      20      25

VCR
SITE  1  3.185*  3.210   3.312             3.820*  3.831
      2  3.261*  3.286                             3.513*
      3  4.579   3.691*OM                  3.758*  3.821
      4  3.447   3.279*            3.914*  4.233
      5          2.941*            4.091*  4.184
      6          3.164*            4.341   3.933*

DISK 1 MEAN VCR  3.166                   DISK 2 MEAN VCR 3.788

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS



FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: H100285-27    LAB ID NUMBER:  40MU


                DISK 1                         DISK 2
KEV          20      25      30        15      20      25      30

VCR
SITE  1  4.264   4.248*OM                  3.644*  3.759
      2  4.008   3.826*            3.130*  3.436
      3  4.395   4.186*            3.856   3.759   3.740*OM
      4  4.248   3.937*            3.904   3.719*OM3.746
      5  4.557   4.327   4.153*                    3.454*  3.580
      6          3.989   3.858*            4.023   3.702   3.656*
      7                                            3.791   3.686*

DISK 1 MEAN VCR  3.992                DISK 2 MEAN VCR  3.514

* = VCRS USED IN CALCULATING MEAN VCR
OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN
VCRS



FIELD SITE: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C)
FIELD ID NUMBER: H100285-28      LAB ID NUMBER: 40MV


                DISK 1                         DISK 2
```

KEV		10	15	20	25	15	20	25
VCR SITE	1		3.411*	4.147	3.890	3.610	3.524*	
	2		3.481*	3.575	3.993	3.923	3.828	3.531*
	3		3.987	3.948*OM				3.594OM
	4	3.821	3.795*	3.857				3.265*
	5		3.419	3.316*			3.557	3.512
	6		3.594*	3.932				3.452*

DISK 1 MEAN VCR 3.519

DISK 2 MEAN VCR 3.457

* = VCRS USED IN CALCULATING MEAN VCR

OM = OMIT = HIGHEST VCR OF * VCRS; OMITTED WHEN CALCULATING MEAN VCRS

TABLE OF DISK VCRS TO BE USED TO CALCULATE CATION RATIO FOR DEPOSIT: FORTYMILE WASH UPPER ALLUVIAL TERRACE (Q2C) CALIBRATION POINT (PUBLISHED IN TABLE 1. HARRINGTON AND WHITNEY, 1987, SCANNING ELECTRON MICROSCOPE METHOD FOR ROCK-VARNISH DATING: GEOLOGY, V. 15, p. 967-970).

DEPOSIT	DISK 1 VCR	DISK 2 VCR
40MA	3.671	3.603
40MB	5.318	5.222
40MC	6.474**	7.020**
40MD	1.783	1.816
40ME	4.482	4.111
40MF	2.986	3.645
40MG	5.861	5.486
40MH	5.214	5.833
40MI	6.530**	5.625
40MJ	5.522	5.027
40MM	3.336	5.421
40MN	7.021**	5.326
40MO	4.661	4.685
0MP	3.663	3.649
40MR	4.366	3.581
40MS	4.408	5.395
40MT	3.166	3.788
40MU	3.992	3.514
40MV	3.519	3.457

MEAN VCR FOR FORTYMILE WASH
UPPER ALLUVIAL TERRACE (Q2C) 4.34+/-1.04

In the samples collected from the Q2C terrace, several samples appeared to show abrasion of the varnish and revarnishing. A larger group of samples were collected to provide a calibration VCR of greater reliability. Samples showing anomalous VCRs (high) and evidence of partial or total stripping of varnish from the clast by abrasion (Samples marked **; 40MC and disk 1 from 40MI and 40MN) were not used to calculate the mean VCR for the Q2C terrace.

Attachment 3

TABLE OF DISK VCRS TO BE USED TO CALCULATE CATION RATIO FOR DEPOSIT: RED CONE LAVA FLOWS (RC) CALIBRATION POINT (PUBLISHED IN TABLE 1, HARRINGTON AND WHITNEY, 1987, SCANNING ELECTRON MICROSCOPE METHOD FOR ROCK-VARNISH DATING: GEOLOGY, V. 15, p. 967-970).

DEPOSIT		DISK 1 VCR	DISK 2 VCR
FIELD ID#	LAB ID#		
H100385-20	RCM	3.056**	3.211**
H100385-21	RCN	2.331	2.210
H100385-22	RCO	2.247	2.127
H100385-23	RCP	3.101**	2.266
H100385-24	RCT	2.236	2.426
H100385-25	RCU	2.457	2.435
23068505-Z	RCZ	2.466	2.404

MEAN VCR FOR RED CONE LAVA FLOW (RC) 2.33+/-0.11

ALL SAMPLES WERE RUN AT 30KEV, THEREFORE ONLY ONE VCR WAS CALCULATED FOR A SINGLE ANALYTIC SITE. THE DISK VCR IN THE TABLE REPRESENTS THE MEAN VCR FOR SIX ANALYTIC SITES ON THAT DISK.

SAMPLE RCM AND DISK 1 FROM SAMPLE RCP WERE NOT USED TO CALCULATE THE MEAN VCR BECAUSE OF THE SIGNIFICANTLY HIGHER CATION RATIOS OBTAINED FOR THESE DISKS.

TABLE OF DISK VCRS TO BE USED TO CALCULATE CATION RATIO FOR DEPOSIT: BLACK CONE LAVA FLOW (BC) CALIBRATION POINT (PUBLISHED IN TABLE 1, HARRINGTON AND WHITNEY, 1987, SCANNING ELECTRON MICROSCOPE METHOD FOR ROCK-VARNISH DATING: GEOLOGY, V. 15, p. 967-970).

DEPOSIT FIELD ID#	LAB ID#	DISK 1 VCR	DISK 2 VCR
23068501-A	BCA	1.977	2.033
23068501-B	BCB	2.012	2.304
23068501-C	BCC	2.018	1.493
23068501-D	BCD	2.561	2.433
23068501-E1	BCE1	2.435	2.169
23068501-E2	BCE2	2.238	2.448
23068501-F	BCF	[illegible]935	1.662
23068[illegible]-H	BCH	[illegible]90	2.1[illegible]
23068501-J	BCJ	[illegible]40	1.8[illegible]

MEAN VCR FOR BLACK CONE LAVA FLOW (BC) 2.[illegible]3+/-0.27

ALL SAMPLES WERE RUN AT 30KEV, THEREFORE ONLY ONE VCR WAS CALCULATED FOR A SINGLE ANALYTIC SITE. THE DISK VCR IN THE TABLE REPRESENTS THE MEAN VCR FOR SIX ANALYTIC SITES ON THAT DISK.

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Volumetric analysis and interpretation of debris eroded from a hillslope during convective rainstorms near Yucca Mountain, Nevada

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ABSTRACT

On July 21 or 22, 1984, debris flows occurred on the south hillslope of Jake Ridge, about 6 km east of the crest of Yucca Mountain. Precipitation gages near Jake Ridge recorded 65 mm and 69 mm on July 21, and 20 mm and 17 mm on July 22, respectively. Rainfall rates ranged up to 73 mm/hour on the 21st and 15 mm/hour on the 22nd. Digital elevation models (DEMs) with 2.0 m spatial resolution, measured from pre-storm and post-storm aerial stereo photographs using an analytical stereo plotter, were used to map hillslope erosion and the downslope distribution of debris. Volumes were calculated by numerical integration of a difference DEM created by subtracting the pre-storm DEM from the post-storm DEM. Volumetric calculations show that about 3640 m^3 (5 percent) of the available hillslope debris was eroded during the two-day storm period. The maximum and mean depths of erosion were 1.2 m and 0.092 m, respectively. Modern debris flows such as these are infrequent events at Yucca Mountain, as evidenced by the preservation of middle-Pleistocene hillslope deposits and the lack of erosional scars on hillslopes.

INTRODUCTION

Yucca Mountain, Nevada (fig.1) is the site the U.S. Congress selected for characterization as a potential underground, high-level, nuclear-waste repository (U.S. Department of Energy, 1988). Two elements of the site characterization plan are: 1) determination of flood and debris-flow hazards to surface facilities and transportation routes that would be built in support of the repository, and 2) analysis of modern hillslope erosion. Glancy (in press) has documented multiple debris-flow deposits of Quaternary age exposed by trenches excavated near the location for two exploratory shafts (DOE, 1988; fig. 6-59) that were planned prior to the relocation and reconfiguration of the underground exploratory studies facility for ramp access. These paleoflood deposits indicate that debris flows have occurred in the general area of the site in the past and should therefore be expected in the future. As part of the site characterization process, our study examines modern debris flows that occurred on July 21 or 22, 1984, following intense rainfall on the south-facing hillslope of Jake Ridge (geographic name from Scott and Bonk, 1984), a flat-topped ridge about 6 km east of the crest of Yucca Mountain (fig. 1). These debris flows stripped a portion of the upper hillslope of colluvium, deepened and widened existing hillslope channels, created new channels on the lower hillslope, and deposited debris up to 1.2 m deep on a dirt road at the base of the hillslope. Our investigation provides the first known data for the Yucca Mountain area that documents the occurrence of modern debris flows, and gives a sense of the amount and intensity of precipitation that triggered the flows.

An important aspect of analyzing modern hillslope erosion, as well as potential flood and debris-flow hazards, is correlating individual storm events with the corresponding volumes of sediment eroded by runoff. Field measurements of sediment eroded from hillslopes by runoff in arid-to-semiarid climates are difficult because precipitation events capable of causing noticeable erosion are infrequent and geographically localized. Measurement techniques range from repeated measurements of painted surface clasts or lines of stakes, to sediment traps on slopes or in channels (Goudie, 1981, p. 156-180). Measurements of debris eroded during single large storms are uncommon, and the above-mentioned traditional techniques of measurement are not well suited for recording large volumes of sediment eroded during sudden events. Typically, after large storms, the volume of eroded sediment is calculated by estimating or surveying the thickness and areal extent of debris deposited at the base of slopes or in channels (Beaty, 1970, Williams and Costa, 1988, Wohl and Pearthree, 1991). In this report we use a photogrammetric method to quantify the volume and redistribution of unconsolidated colluvium eroded from Jake Ridge during an unusually large storm. This volumetric analysis, combined with an understanding of the geologic and climatic setting, and a hydrologic analysis of the precipitation event that caused the hillslope erosion, help to establish the bases to characterize potential debris flow hazards and modern hillslope erosion in the Yucca Mountain area.

SETTING

Geology

The Yucca Mountain area is underlain by a thick, volcanic sequence of silicic ash-flow and air-fall tuffs, rhyolite lava flows, and tuffaceous sedimentary rocks of Tertiary age. Yucca Mountain itself is made up of the Topopah Spring, Pah Canyon, Yucca Mountain, and Tiva Canyon Members of the Paintbrush Tuff (Scott and Bonk, 1989). The Topopah Spring member also caps Jake Ridge. The Jake Ridge hillslope, however, is underlain by light colored, interlayered rhyolite flows and non-welded tuffaceous beds that outcrop in the Calico Hills area (Christiansen and Lipman, 1965, Frizzell and Shulters, 1990). The volcanic rocks of Calico Hills are part of a sequence of rocks of Tertiary age that form a regional tuff aquitard. Whereas, the Paintbrush Tuff, and the volcanic sequence above it, form aquifers with coefficients of transmissibility ranging from 100 to 100,000 gallons per day per ft. (Winograd and Thordarson, 1975, p. 10). Jake Ridge, therefore, is capped by a member of the aquifer, but underlain by a member of the aquitard.

Hillslopes in the Yucca Mountain area are mantled by coarse-grained bouldery colluvium and fine-grained eolian deposits that are generally less than 2.5 m thick. Cation-ratio age estimates of varnished relict colluvial-boulder deposits in the Yucca Mountain area range from about 150 ka to 1.2 Ma (Whitney and Harrington, in press). The presence of these relict deposits indicates a condition of long-term slope stability during multiple climatic cycles of Quaternary age. Slope degradation marginal to these dated deposits ranges from 0.2 to 7 mm/ka (Harrington and Whitney, 1991; Coe et al., 1993). These long-term erosion rates are similar to those calculated in the nearby western Mojave Desert (Oberlander, 1974).

Jake Ridge, the southern end of Joey Ridge (geographic name from Scott and Bonk, 1984) directly to the west, and the northwest-facing side of Skull Mountain about 20 km east of Yucca Mountain, are anomalous to the Yucca Mountain area because fresh erosional scars are visible on their hillslopes. The most prominent of these scars are found at Jake Ridge and Skull Mountain, both of which resulted from debris flows caused by rainstorms in the summer of 1984. The hillslope at Jake Ridge is mantled by less than 2 m of bouldery colluvium and has a gradient that ranges from about 31° just below the caprock, to about 5° at the base of the slope (fig. 2). The top surface of the ridge, a dip slope on the resistant caprock, grades slightly (4°) to the southeast and is covered by a thin mantle of cobbly colluvium. The hillslope drains into a tributary of Fortymile Wash; the main drainage channel on the east side of Yucca Mountain.

Vegetation

Vegetation consists of a mixture of desert shrubs that prominently include creosote bush, a variety of saltbushes (atriplex genus), and several species of cacti and Yuccas; grasses are scarce, and trees (pinon-juniper forest assemblage) are found only in neighboring high-altitude areas. This vegetation assemblage provides only weak land-surface protection during intense precipitation events.

Climate

The Yucca Mountain area is in a transitional climatic zone between the mid-latitude, southern-Great-Basin desert, and the low-latitude, northern-Mojave desert (Houghton, et al, 1975). As such, the area has a dry, semi-arid, continental climate that is characterized by cool-to-cold winters and hot-to-very-hot summers. Analysis of two years of temperature records (1988-1989) shows mean-monthly temperatures that range from 3.9°C in January to 28.9°C in July (Whitney and Harrington, in press). Extreme temperatures from the same time period range from -3.9°C in January to 40.6°C in July.

Mean-annual precipitation at and near Yucca Mountain ranges from about 125 to 150 mm (Quiring, 1983). Annual precipitation data from 13 U.S. Weather Service stations (Water Years 1965-81) indicate a bimodal distribution of precipitation, with one maxima in the cool season (Oct.-April) and the other in the warm season (May-Sept.). About 70 percent of the annual precipitation falls during the cool season and 30 percent during the warm season (Quiring, 1983).

Severe Weather Systems That Affect The Region

There are four predominant types of severe weather systems that affect the Yucca Mountain area; cold-winter storms, warm-winter storms, tropical cyclones, and convective summer storms. All of these systems have the potential to produce precipitation at a rate that exceeds the infiltration rate of the land surface, and therefore cause flooding. The Pacific ocean is the source of nearly all moisture for these storms (Hirschboeck, 1991).

Cold-winter storms typically bring polar maritime moisture from the northwest. These storms usually bring snowfall and rarely cause flooding. Occasional warm-winter storms from the west and southwest can cause persistent heavy rainfall that results in major streamflows and flooding throughout the region. These warm-winter storms can also spawn localized cells of intense precipitation that cause severe runoff within localized areas. Tropical cyclones during late summer and early autumn occasionally bring large amounts of moist, warm air over southern Nevada (Hirschboeck, 1991). These cyclones can also affect large or localized areas with heavy rainfall amounts and intensities. Tropical cyclones and warm-winter storms are relatively infrequent but probably generate the largest volumes of streamflow and floodwater throughout southern Nevada.

A monsoonal flow of atmospheric moisture usually occurs each summer in southern Nevada for at least several days, although some years it is recurrent and quite persistent. This moisture is important to the formation of summer convective storms. Severe-localized convective, summer storms, or thunderstorms, are the major cause of flash floods in small drainages throughout the region. These local thunderstorms can yield rainfall in excess of the expected seasonal amount (about 50 mm) in less than an hour. Precipitation from these storms can be compounded when convection occurs in conjunction with frontal convergence and orographic uplifting (Hirschboeck, 1991). The largest of these storms in regard to areal coverage and storm-yield potential are characterized as mesoscale, convective-complex storms (Hirschboeck, 1991). These major convective storms can be especially intense and violent when warm, moist air masses are intercepted by through-moving frontal systems. A particularly devastating example of this type of storm in southern Nevada during 1981 was described by Randerson (1986).

Precipitation during 1984

The 1984 Water Year (Oct. 83 - Sept. 84) was one of anomalous precipitation conditions throughout southern Nevada. The temporal distribution of precipitation in 1984 was out of phase with the normal long-term annual average of about 70 percent falling during the cool season and 30 percent falling during the warm season. Precipitation averaged about 1.3 times normal during the early cool season (Oct.-Dec.) and less than 10 percent of normal during the late cool season (Jan.-Apr.) and early warm season (May-June). July and August were extremely wet with overall rainfall on the order of 600 percent of normal (U.S. National Weather Service, unpublished Nevada Test Site data). On an annual basis, 1984 precipitation averaged about 128 percent of normal.

Reasons for these unusual precipitation conditions during 1984 are not clearly understood, but one possible cause could be the temporal proximity of the summer of 1984 to the recessional phase of the 1982-83 El Nino. The 1982-83 El Nino has been rated as the largest in a century (Keen, 1987). This El Nino caused abnormally heavy precipitation across broad areas of the western U.S. during both the 1981-82 and 1982-83 winters. The weather related effects of this El Nino seem to have peaked during the winter of 1983-83. During the winter of 1983-84, effects of the El Nino lingered (Keen, 1987), but were not as areally extensive as the previous winter. The subsequent, exceptional-wet period of July and August, 1984, follows too closely to the three previous wet winters to not be suspected as the waning gasp of this El Nino.

July, 1984 rainfall near Yucca Mountain and Jake Ridge prior to July 19 was minimal (U.S. National Weather Service, unpublished data). Two precipitation gages, one at the east base of Yucca Mountain, about 5.4 km southwest of Jake Ridge (gage YA, fig. 1), and the other (gage YR, fig. 1) near the crest of Yucca Mountain 7.5 km southwest of Jake Ridge, registered 0.25 mm and 4.8 mm, respectively, on July 19 (Hugh Church, Sandia National

Laboratory, 1985, written communication). Neither these gages, or National Weather Service gage (gage 4JA, fig. 1) registered any precipitation on July 20. Therefore, rainfall antecedent to July 21 at Jake Ridge appears to have been minimal, and a dry-colluvial mantle probably prevailed throughout the Yucca Mountain area.

THE JULY 21 AND 22, 1984 STORMS

The storms that caused the July 21 or 22, 1984, debris flows at Jake Ridge were localized convective storms that occurred during the early part of the summer's monsoonal storm period.. Daily satellite images from mid-June thru August, 1984, show that this storm system was part of a regional atmospheric flow system that brought moisture over a large area of the southern Great Basin.

Rainfall at Yucca Mountain began during the early-morning hours of July 21 (fig. 3). About 4 mm of rain fell at the eastern base of the mountain between 0544 hours (Pacific Standard Time) and 0644 hours. About 11 mm fell at the crest between 0519 and 0719 hours. The next ten hours were dry. Heavy rainfall commenced during the late afternoon (about 1739 hrs.) and continued until about 1959 hours. Rainfall intensities reached 73 mm/hr. at gage YA and 46 mm/hr. at gage YR. Cumulative precipitation amounts for the afternoon-evening storm were about 60 mm and 58 mm at the YA and YR gages, respectively. The heavy rainfall was apparently fairly localized because gage 4JA (fig. 1), about 14 km east-southeast of the Yucca Mountain gages, only recorded about 8 mm of rain during the entire day (U.S. National Weather Service Nuclear Support Office, written communication, 1984).

Rainfall began again on July 22 during the early-morning (0624-0644 hrs.) at gage YA and during mid-morning (1019-1039 hrs.) at gage YR (fig. 3). Rain continued until the mid-afternoon (1424 hrs.) at gage YA and until late-afternoon (1659 hrs.) at gage YR. Cumulative rainfall amounts and maximum intensities for the day were 20 mm and 15 mm/hr. at gage YA, and 17 mm and 12 mm/hr. at gage YR.

Some of the runoff from the storms was recorded by a stream gage (SG, fig 1) in Fortymile Wash, about 1.2 km east and slightly upstream of Jake Ridge. Flow began at this gage on July 21 at about 1900 hours (fig. 4). This flow peaked at 21 m^3/sec. within about 1 1/2 hours and then began to rapidly recede. The flow receded to less than 1 m^3/sec. by 2200 hours (total flow-time of about 3 hrs.) which further substantiates that this storm was quite areally localized (total drainage basin area upstream from gage SG is about 650 km^2). A second smaller runoff pulse (peakflow of about 15 m^3/sec.), recorded by the gage at about 2230 hours, indicates more storm activity upstream. The precise location, timing, and magnitude of the rainfall that caused the second runoff pulse at the stream gage is uncertain. The second pulse may have been the result of a different storm cell, or from the same storm cell as it moved further upstream along Fortymile Wash; in either case, the runoff-pulse arrival could have been delayed by its greater distance of origin from the gage. A third major streamflow pulse began on July 22 about 1130 hours and peaked at about 1 m^3/sec. at 1300 hours; this flow continued for 13 hours, ending about 0030 hours on July 23.

THE DEBRIS FLOWS - FIELD OBSERVATIONS

We discovered fresh debris-flow scars and deposits at Jake Ridge on August 16, 1984. Later inspection of July and early August precipitation data from gages YA and YR revealed the July 21 and 22 rainfall as the sole candidate for initiating the debris flows. Visual examination of other hillslopes to the southwest at Yucca Mountain during the middle of August indicated no other discoveries of debris flows or mass-movement failures attributable to the July 21 and 22 rainfall, although there was abundant evidence of water-dominated sediment transport in many ephemeral stream channels. The anomalous occurrence of debris flows at Jake Ridge implies that (1) Jake Ridge received greater or more intensive rainfall than to the southwest at Yucca Mountain, and/or (2) the hillslope characteristics at Jake Ridge made it more susceptible to debris flows.

Post-storm field observations revealed no evidence for intense runoff from the Jake Ridge hilltop, which is thinly mantled by unconsolidated sediment. Some water may have percolated down through the cobble mantle on the hilltop into the underlying fractured caprock and then exited the fractures at the cliff above the colluvial mantled hillslope. This mechanism may have been an initiating or contributing factor to debris movement by helping to saturate the colluvium on the upper slope or by acting as a point source for water flow. Debris movement was probably triggered by soil-slip failures (Campbell, 1975, Ellen and Fleming, 1987) and channel scour.

The source area for much of the eroded debris at Jake Ridge was between 25 and 80 m below the top of the ridge. Water and debris widened and deepened existing channels on the upper and middle slope (fig. 5a), and cut new channels predominantly on the lower slope (fig. 5b). Boulder-laced levees formed marginally to channels on the middle and lower hillslope. These levees, as well as bouldery lobe deposits that contained a fine-grained matrix (described in the next paragraph), were the criteria (from Costa, 1984) used to classify the runoff as debris flows, rather than Newtonian, or water-dominated flows.

Three main deposits from the debris flows were noted: (1) a debris lobe located about halfway down the large tributary channel that feeds into Fortymile Wash (fig. 6), (2) a debris lobe on the road at the base of the main hillslope channel (fig. 7a and 7b), and (3) an elongated area of debris deposits along the southern most, east-west trending channel that drains the hillslope (fig. 7a). Debris in the tributary depositional lobe is poorly sorted and contains boulders (up to 0.5 m in diameter) from the Jake Ridge hillslope as well as from Fortymile Wash terrace gravels. The terrace gravels are cut by the tributary channel downstream from the base of the Jake Ridge hillslope. The lobe occurs as a fan where the tributary widens (fig. 6). The depositional lobe on the road is poorly sorted and contains a fine-grained matrix. It was deposited as a fan where the hillslope flattens to about 5° (fig. 7a). Debris deposits on the road and along the east-west tributary both contain boulders up to about 1 m in diameter (fig. 7b). At the intersection of the tributary and Fortymile Wash no debris larger than cobble size was observed.

PHOTOGRAMMETRY

Photogrammetry is the science of obtaining reliable measurements from photographic images (Slama, et al., 1980). The most common use of photogrammetric techniques is the production of topographic maps from stereographic aerial photographs. Photogrammetric techniques and multiple sets of stereo photographs taken during successive time increments (multi-temporal) provide an ideal means of recording topographic change caused by active processes. Examples of processes that have been studied using photogrammetry include, mass movements (Chandler and Moore, 1989; Baum and Fleming, 1991), volcanic activity (Jordan and Kieffer, 1981; Thompson et al., 1992), glacier mass balance and dynamics (Lundstrom et al., in press), tectonism (Bucknam, 1987; Fairer et al., 1989), and erosion (Mills and Keating, 1992; Mills, 1992; Coe et al., 1993).

Digital elevation models (DEMs), often derived directly from photogrammetric measurements, provide a three-dimensional representation of the earth's surface. Commonly available DEM data, such as USGS-7.5-minute-quadrangle DEM data with 30 m resolution, are often used as a base on which to overlay and geometrically rectify thematic-image data (eg. Toutin, et. al., 1991). Perspective-view and shaded-relief maps are often created from DEMs for landform analysis (eg. Thelin and Pike, 1991). DEMs have been used for geomorphologic applications but their spatial resolution is typically not adequate for large-scale studies of small individual landforms (eg. Band, 1986, Tribe, 1991).

Volumetric analyses using photogrammetrically-derived, elevation measurements from multi-temporal sets of stereo photographs are common in civil engineering, cut-and-fill problems and stock-pile inventory applications (eg. Massa, 1958, Huberty and Anderson, 1990). Typically, such volumetric analyses involve the calculation of elevation differences between successive sets of cross-section or DEM measurements, and then numerically integrating these differences to calculate volumes of material lost or gained. This approach can also be applied to geomorphology studies that examine recent modifications of the land surface.

Our study uses DEMs with 2.0 m spatial resolution, measured from multi-temporal, aerial photographs, to examine changes in the land-surface at Jake Ridge. Pre-storm photographs were obtained from the extensive photographic inventory that is available for the Yucca Mountain area and post-storm photographs were taken in 1991.

Stereo Pair Orientation and DEM Measurement

DEMs were measured from pre-storm (1982, 1:8000 scale) and post-storm (1991, 1:3000 scale, fig. 8) stereographic pairs. The 1982 photographs contained a previously identified set of easting, northing, and elevation (xyz) ground-control points. The 1982 stereo pair was oriented (see Hunter and Smart, 1988, Ghosh, 1988) to these ground-control points in a Kern DSR15*, analytical-stereo plotter (Chapuis and van den Berg, 1988). After the

1982 stereo pair was oriented in the plotter, the xyz coordinates of points that were photo-identifiable in the 1982 and 1991 photography were recorded and transferred to the 1991 stereo pair. These photo-identified points were then used as ground-control points to orient the 1991 stereo pair in the plotter. Using this orientation procedure, the 1982 and 1991 photographs tied together to within an overall xy-standard deviation of 0.14 m and an overall z-standard deviation of 0.14 m. If the 1982 photographs were of a larger scale (e.g., 1:3000), the orientation error would have been significantly lower.

Each DEM, which consisted of an xyz grid with 2.0-m-xy-spatial resolution, was measured from within a 48,390 m^2-polygonal-study area of each stereo pair (fig. 8). The boundaries of the grid window and the 2.0-m grid spacing were defined digitally. Kern grid measurement software moved the measuring mark of the plotter to each xy grid node along 2.0 m spaced lines trending south to north. After the software locked the xy location of the measuring mark on each grid node, the plotter operator moved the measuring mark to the surface of the ground and recorded the elevation (z value). The same xy-grid-node locations were occupied and measured in each stereo pair. About 12,000 elevation points were measured in each stereo pair. Because the elevation data were measured on the regularly spaced xy grid, no grid interpolation was necessary to create the DEMs. As a final step, these DEM data sets were imported into potential-field-geophysical software (Cordell et al., 1992) to create and plot color-shaded-relief DEM maps (fig. 9a and 9b). These maps have color-contour intervals of 4 m and show changing elevations and slopes within the study area. The maps are shaded from an azimuth of N.90°E. with a sun angle of 80° above horizontal. These shading parameters were selected to highlight the hillslope channels that trend north-south to northwest-southeast.

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* Use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

Comparison of 1982 and 1991 DEM maps

Differences between the 1982 and 1991 DEM maps are visually striking. The 1982 map contains more noise (pock marks) than the 1991 map because of the poorer resolution of the 1:8000-scale, 1982 photography; a condition which adversely affected the operator's ability to see and measure ground-surface elevations in some areas. Channels are well defined and occur on the upper, middle, and lower hillslope in the 1991 DEM map, but are generally limited to upper hillslope areas in the 1982 DEM map. The faint, northeast-southwest trending lines in the southeast corner of the 1991 map are the sides of a dirt road that runs through the study area. The road is visible because it was graded and debris was piled along both sides of the road during cleanup after the 1984 storm. When selecting the limits of the study area, areas of both positive and negative debris volumes caused by road grading were included so that the volumetric results would not be skewed by the artificially added or removed debris. Because the N.90°E.-shading azimuth is also normal to the original north-south-trending-data-collection lines, slight traces of these lines are highlighted in the lower central and eastern parts of the 1982 map. Data-collection lines do not appear in the 1991 map.

VOLUMETRIC ANALYSIS

In order to perform a volumetric analysis, an elevation-difference DEM was created by subtracting the 1982 DEM from the 1991 DEM (i.e., each 1982 grid node elevation was subtracted from the elevation at the identical 1991 grid node). This elevation-difference DEM and potential-fields software (Cordell et al., 1992) were used to plot an elevation-difference map (fig. 10). Debris volumes were calculated by multiplying the elevation difference at each node by the area of the cell (i.e., elevation difference x 4.0 m^2), and summing. Elevation-difference values that fell within the 2σ-photogrammetric-orientation-error value (±0.28m, rounded to ±0.3 m) were not used in the volume calculations. Eleven polygons were chosen within the study area (fig. 10) to itemize volumetric results in terms of depositional and erosional volumes, and to evaluate the error of calculated volumes. Polygon 1 contains the overall hillslope area that was affected by the debris flows, excluding the depositional (polygons 2 and 3) and inter-channel (polygons 4-11) areas. Polygon 2 includes the depositional area on the road and polygon 3 includes the depositional area along the southern channel. Inter-channel polygons occur between channels and were not affected by the debris flows. These inter-channel areas were identified from 1984-ground-based photography, taken about 1 month after the storm, and from comparisons of 1982 and 1991 aerial photography. These areas are characterized by mature, undisturbed vegetation, channel (debris-flow) levees at their outer edges, and lack of erosional scarring and evidence of fresh deposition within their interiors. Selecting these areas was a reasonably objective process, although we could not identify minor stripping of colluvium or deposition of errant boulders (rockfalls) from the cliff that may have occurred within the areas. Because the volume change in these polygons is theoretically zero, they were used as control polygons to evaluate the error of volumes calculated for polygons 1-3.

RESULTS

Elevation-Difference Map

The elevation-difference map (fig. 10) shows areas of deposition (positive elevation-difference DEM values) in red colors and areas of erosion (negative elevation-difference DEM values) in purple colors. The yellow color on the map indicates areas that fall between ±0.3 m. Thus, the map reveals the distribution and relative amounts of erosion and deposition that occurred during the 1984 storm. Note that the main depositional areas are near the road and along the east-west-trending southern channel, whereas the main erosional areas are along channels and on the upper hillslope. Two areas of maximum erosion occur on the upper hillslope (darkest purple) where large pieces of bedrock were removed. The maximum depth of erosion caused by the 1984 flows, excluding the two dark-purple areas, is about 1.2 m. This also constitutes the maximum thickness of deposition at the base of the hillslope and in the tributary. Small areas within the main depositional lobe at the road that show more than 1.2 m of deposition are the result of road grading after the storm. The major patterns of erosion and deposition revealed by the elevation-difference map, were verified by visual inspection in the field.

Volumetric Budget

Volumetric results for each polygon are summarized in table 1. Table 1a lists raw volumes for polygons 1-3. These values show a negative volume change of 4,370 m^3 and a positive volume change of 2,367 m^3 within a total area of 39,752 m^2. Tables 1b and 1c contain the volumetric results of inter-channel polygons 4-11, and corrected volumes for polygons 1-3, respectively. If all of the photogrammetric-elevation measurements were perfectly accurate, the sum of the volumes within each of the polygons in table 1b would be zero. The results in table 1b, however, indicate that our volumetric error for individual polygons ranges from -0.009 m^3/m^2 to +0.039 m^3/m^2 (see volume-change column in table 1b). When all of the volumes from polygons 4-11 are summed, however, the result (+4 m^3) is very close to zero. This indicates that our measurement error is random when all inter-channel polygons are evaluated. The overall volumetric error for all of the inter-channel polygons, which is calculated by dividing +4 m^3 by the total area of the inter-channel polygons (8638 m^2), is less than 0.0005 m^3/m^2. Because the inter-channel polygons are distributed throughout the study area (fig. 10), we conclude that the random-measurement error in the inter-channel polygons is representative of the measurement error in polygons

1-3. Thus, the total volume sum in table 1a (-2003 m^3) is accepted as a valid estimate of the amount of material removed from the study area. However, the total positive (+160 m^3) and negative (-157 m^3) inter-channel-volume sums, given in table 1b are too high and too low, respectively (i.e., they should both be zero). Because measurement error in these inter-channel areas is representative of the areas of real change (polygons 1-3), the total positive (+2367 m^3), and negative (-4370 m^3), raw-volume sums in table 1a must also be too high and too low, respectively. To correct for this error, a volumetric correction factor was calculated by dividing the positive and negative volume sums from the inter-channel polygons by the total area of the inter-channel polygons (i.e., -160 m^3/8638 m^2 and +157 m^3/8638 m^2). The mean-resulting value of ± 0.0183 m^3/m^2 was used as the volumetric-correction factor. Multiplying this correction factor by the total area of polygons 1-3 (39752 m^2) yields a ±727 m^3 volume correction. Applying this correction to the positive and negative raw volumes yields corrected-volume sums of +1639 m^3 and -3642 m^3 (table 1c). Dividing the total-negative-corrected volume (-3642 m^3) by the total area for polygons 1-3 (39752 m^2) gives a gross, mean depth of erosion of -0.092 m for the areas of known elevation change on the hillslope. Of the total volume of sediment eroded, 45 percent (1639 m^3) was deposited within the study area and the remaining 55 percent (2003 m^3) was deposited in the tributary to Fortymile Wash, and within the main wash itself; both of which are located outside the photogrammetric study area. This overall depositional budget, as well as the budget for individual polygons, is summarized in table 2.

Possible Sources of Error

There are several possible sources of error (in addition to the random-photogrammetric-measurement error mentioned in the previous section) that are inherent in our elevation-difference map and volumetric results. The first is caused by the inherent assumption that the pre-storm, and post-storm, sediment densities have not changed. In reality, this is not true. For example, some of the 1984-debris-flow levees consist of boulder-sized clasts and lack the fine-grained matrix present in the original bouldery colluvium. This would therefore tend to skew depositional volumes in a positive direction. Another factor that would similarly skew the results is the fact that some areas on the hillslope were first cut by erosion and then refilled by deposition. Where refilling occurred, the elevation difference used to calculate the volume at these nodes would not account for the actual amount of erosion that had taken place.

A factor related to the method's limit of resolving surface-elevation change would tend to offset the errors stated above. As previously stated, any elevation change between ±0.3 m is shown as no change on the elevation-difference map, and was not included in our volumetric calculations. In general, deposits from the debris flows tend to be flatter and more laterally extensive than the eroded source areas on the upper hillslope. This would tend to skew depositional volumes in a negative direction because more elevation changes in depositional areas would occur between ±0.3 m than in erosional areas.

DISCUSSION

The preceding meteorologic, hydrologic, and volumetric analyses of the July 1984 storm and debris flows provide an opportunity to expand upon what is now known about debris-flow potential and modern hillslope erosion at Yucca Mountain. The following discussion addresses these issues.

Local Hydrogeologic Controls and Debris-Flow Triggering Conditions

The July 1984 occurrence of debris flows at Jake Ridge, but not to the southwest at Yucca Mountain where rain gages YA and YR were located, seems to indicate a variable susceptibility of Yucca Mountain area hillslopes to debris flows. Although slope gradients and colluvial-cover thicknesses at Yucca Mountain and Jake Ridge are similar, Jake Ridge may be more susceptible to the occurrence of debris flows because of differences in underlying bedrock geology. Jake Ridge is underlain by the relatively impermeable volcanic rocks of Calico Hills. Yucca Mountain is mostly underlain by fractured members of the Paintbrush Tuff (Scott and Bonk, 1989). The fractured Paintbrush Tuff may allow more infiltration of rainfall and runoff than the Calico Hills volcanic rocks. Although multiple debris flows have occurred on Yucca Mountain hillslopes underlain by the Paintbrush Tuff (Glancy, in press), the amount and intensity of rainfall that triggered these flows is unknown. During the July 1984 storm, the infiltration capability of the Paintbrush Tuff may have reduced the cumulative colluvial saturation and hillslope runoff to a degree that prevented debris-flows at Yucca Mountain.

The distribution of rainfall in the Yucca Mountain area on July 21 and 22 is uncertain. Rainfall records from gages YR and YA, compared to records from gage 4JA, indicate that rainfall was highly variable over a short distance (about 14 km). Jake Ridge may have received substantially more or less rainfall (total accumulation and intensity) than at gages YA and YR because of this localized rainfall variability. Because the bedrock at Jake Ridge may be less permeable than that at Yucca Mountain (ie, more susceptible to promoting debris flows) Jake Ridge could have received lower rainfall accumulation and intensities than Yucca Mountain and still experienced debris flows.

The precise time of debris-flow occurrence at Jake Ridge is also uncertain. On the basis of total accumulation and intensity records from gages YR and YA (fig. 3), debris flows most likely occurred during the afternoon of July 21. The large runoff recorded on July 21 at stream gage SG near Jake Ridge (fig. 4) supports a hypothesis of general similarity in rainfall characteristics between Yucca Mountain and Jake Ridge, which further supports the occurrence of debris flows on July 21. However, because there was little antecedent moisture in the colluvial mantle prior to the morning of July 21 when rainfall began, rainfall on that day may have done little more than saturate the colluvium so that it was more easily mobilized by less and lower-intensity rainfall on July 22. Thus, the exact time of slope failure remains uncertain. Consequently, more data are needed before any type of rainfall-intensity and duration limiting threshold can be developed for predicting debris flows in the Yucca Mountain area.

Colluvium Removed by the 1984 Debris Flows

Our volumetric results indicate that about 3640 m^3 of sediment was eroded from the south-facing hillslope of Jake Ridge. The entire south-facing hillslope area is about 77,100 m^2 and the area of known elevation change on the hillslope caused by the 1984 debris-flows (polygon 1, fig. 10) is about 39,800 m^2 (about 50 percent). Field observations indicate that non-channelized areas of the south-facing hillslope are generally mantled by 0-2 m of colluvium. If a mean value of 1 m is used for the amount of unconsolidated colluvium cover, then approximately 77,000 m^3 of debris would have existed on the south-facing hillslope prior to the 1984 storm. Therefore, about 5 percent of the available colluvium was eroded during the two-day storm.

Recurrence Interval

The recurrence interval of debris flows at a specific site is largely determined by two factors: the frequency of storms with the potential to initiate debris flows, and the susceptibility of the land's surface to debris mobilization. The determination of storm frequency in the southern Greast Basin poses a formidable challenge because of the lack of meteorological and climatic data for severe storms. Gaging sites where precipitation data have been recorded are widely scattered and generally have not been in operation for long-periods of time. Also, multiple, large-magnitude storms have rarely been recorded at the same locality. This study provides the first known data for the Yucca Mountain area that gives a sense of the amount and intensity of precipitation necessary to trigger debris flows.

Available meteorologic, hydrologic, and historical data indicate that storms similar to that witnessed at Jake Ridge occur almost annually in the region encompassed within about a 400 km radius around Yucca Mountain. However, the short-term recurrence interval and areal distributions of these storms is erratic. Several years may pass, for example, with little or no flooding. During other years, however, the region, and even specific areas (ie., the Yucca Mountain area), can experience multiple severe-storm events. The summer of 1984 is the best known period of intensive, wide-spread, and recurrent storm activity in the region. During July, August, and September, 1984, the region experienced at least a dozen localized severe storms comparable to the July 21 storm at Yucca Mountain.

Thus, recurrence intervals for severe storms within the region are short, on the order of only a few years at the longest. However, storm recurrence intervals for a specific area or drainage within the region are significantly longer; the length of these intervals is disappointingly uncertain. On the basis of current knowledge, we believe that a frequency of 50-100 years is a reasonable-minimum estimate for severe (ie, July 1984 magnitude) storms revisiting a specific area within the region.

Yucca Mountain and surrounding areas exhibit numerous examples of debris-flow scars and deposits of Quaternary age. There are multiple debris-flow deposits, believed to be of late Quaternary age, within a small drainage on the east-facing side of Yucca Mountain (Glancy, in press). In spite of the abundant debris-flow deposits, recurrence intervals of debris flows on individual hillslopes are difficult to determine because of the lack of dateable materials within deposits. Based on a compilation of data from extreme-erosional events in various regions of the world, Wolman and Gerson (1978, fig.7) list regional recurrence intervals in arid climates that range from 50 to over 900 years. About 200 km west of Yucca Mountain, recurrence intervals of 300-350 years have been documented for debris flows on the west and east flanks of the White Mountains (Beaty, 1970, 1990; Hubert and Filipov, 1989). Although the White Mountains have more relief, greater vegetation variability, and receive 2 to 3 times the average-annual precipitation of Yucca Mountain (Hubert and Filpov, 1989), they are affected by many of the same regional flows of atmospheric moisture. The regional influence of atmospheric-moisture circulation prevailed during July 1984. This is evidenced by satellite images and by the Oct. 1985 cover of Geology which pictures deposition from a July 18, 1984, debris-charged flow in Busher Creek on the east flank of the White Mountains (Beaty, 1985).

In terms of debris-flow recurrence interval at Jake Ridge, if storms of similar magnitude and intensity as the July 1984 storm were to revisit Jake Ridge every 100 years, for example, and the hillslope responded to such a storm with similar debris flows, then most of the pre-July 1984 colluvium (about 77,000 m^3) would be stripped in a few thousand years. A 300-year storm interval would strip the available colluvium in about 6,000 years. These scenarios assume that no new hillslope colluvium is weathered from the underlying bedrock during that time. Whitney and Harrington (1988) suggest that most of the coarse hillslope colluvium that mantles hillslopes in the Yucca Mountain area was weathered during cooler, pluvial climates. Additionally, they observe that hillslope processes operating under the present dry, interpluvial climate are not capable of producing coarse hillslope colluvium. Some of the colluvium on Jake Ridge appears to have been stable for at least tens of thousands of years, as evidenced by its very existence and by accumulations of rock varnish on the surface of boulders in the colluvium. We therefore conclude that the recurrence interval of debris-flow erosion at Jake Ridge (on a scale comparable to that of 1984) is probably greater than 100 years, and may be greater than 300 years.

CONCLUSIONS

This study shows that about 3640 m^3 (5 percent) of the available colluvium was eroded from the Jake Ridge hillslope during a two-day period of convective rainstorms. Nearby raingages recorded up to 69 mm of rain at intensities that reached 73 mm/hour. The mean depth of erosion for areas of known-elevation-change on the hillslope was about 0.092 m (0.092 m^3/m^2). The maximum depth of erosion and deposition was about 1.2 m. About 10 percent of the eroded colluvium was deposited on the slope as channel levees and small lobes, 35 percent was deposited near the base of the slope, and the remainder, 55 percent, is presumed to have been deposited in a tributary channel to Fortymile Wash and in the wash itself. Thus, this study demonstrates that hillslope erosion at Yucca Mountain in the present dry, semi-arid climate is characterized by severe, but infrequent storms that cause localized hillslope stripping which results in aggradation on lower hillslopes and adjacent channels. Based on the percentage of available colluvium eroded during the storms, and the stable nature of the remaining colluvium, the recurrence interval for large-scale, debris-flow erosion at Jake Ridge is estimated to be greater than 100 years, and possibly greater than 300 years. Jake Ridge may be more susceptible to the occurrence of debris flows than Yucca Mountain because of differences in the underlying bedrock geology.

The photogrammetric approach used in this study is heavily dependent upon the availability, scale, and resolution quality of pre-event stereographic photographs. The accuracy of the method is principally controlled by the scale of the pre-event photographs because post-event photography can be flown at any desired scale. Elevation changes between ± 0.3 m could not be confidently detected using the pre-storm 1:8000 scale photography. There are many possible geologic/hydrologic applications of the photogrammetric methods presented in this paper. The availability of large-scale stereographic photographs, however, is critical to the success of such studies. This is especially true for areas of known historical changes to the land's surface and in specific study areas such as Yucca Mountain. Possible future studies at Yucca Mountain that might benefit from such photogrammetric applications are: estimating long-term Quaternary erosion rates by measuring the volume of material eroded from preserved hillslope deposits, logging of trench and natural fault exposures, and development of area-wide, debris-flow hazard maps.

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Figures and Tables

Figure 1. Index map showing Yucca Mountain and Jake Ridge. SG is a stream gage in Fortymile Wash, elevation ~ 3675 ft. (1120 m). YR and YA are tipping-bucket rain gages (0.01 in./tip) operated by Sandia National Laboratories in 1984. Gage YR is at the crest of Yucca Mountain, elevation ~ 4818 ft. (1469 m). Gage YA is at the east base of Yucca Mountain, elevation ~ 3751 ft. (1143 m). 4JA is a rain gage operated by the U.S National Weather Service, elevation ~3440 ft. (1049 m).

Figure 2. Jake Ridge viewed from the south. Light-colored scars are the tracks of the 1984 flows. The top of the butte is about 350 m away from the photographer. Topographic

relief from the base of the hillslope to the top of the butte is approximately 130 m. Photograph taken 8/16/84.

Figure 3. Cumulative rainfall records for July 21 and 22, 1984 storm events at gages YA and YR. Total accumulation at gage YR was 69.3 mm on July 21 and 16.5 mm on July 22 (0.8 mm of rain fell between 1504 and 1659 on July 22 that is not shown on the graph). Total accumulation at gage YA was 64.4 mm on July 21 and 20.4 mm on July 22 (0.5 mm fell between 0624 and 0644 hours on July 22 that is not shown on the graph).

Figure 4. Streamflow record from gage SG in Fortymile Wash.

Figure 5. (a) View to north of a single channel at mid-hillslope level. Channel depth (about 1.7 m) is indicated by the tube held at eye-level by the geologist in the middle of the channel. Photograph taken 3/21/92. (b) Lower hillslope channel cut by the 1984 flows. Channel depth is about 1 m. Photograph taken 3/21/92.

Figure 6. Depositional lobe in tributary of Forty-mile wash. Lobe thickness is about 1 m (see geologist with hammer). Coarse debris in foreground is from another tributary of Fortymile Wash and was not from the 1984 Jake Ridge debris flows. Photograph taken 3/21/92.

Figure 7. (a) Deposits at the base of the main and southern channels. View is to south-east from about half-way up the slope. The main lobe on the road is about 30 m wide and 75 m long at the widest and longest points. Fortymile Wash is visible in the distance. A second depositional lobe occurs in the tributary to Fortymile Wash. See pickup truck for scale. Photograph taken 8/16/84. (b) Close-up view of main depositional lobe on the

road prior to regrading. View is to the north. Maximum depth of the lobe is about 1 m. See pickup truck for scale. Photograph taken 8/16/84.

Figure 8. Stereographic pair of aerial photographs (1991) used for DEM measurements. Approximate boundary of the study area is outlined. Original photo scale approximately 1:3000. The road is about 5 m wide. Photograph frame numbers 326 and 327 taken by EG+G on 9/30/91 with Wild aerial camera 7167 (213.78 mm lens).

Figure 9. Color-shaded relief maps. Illumination is from an azimuth of N90E and a sun angle of 80° above the horizontal. Grid and elevation units are meters. Color contour interval is 4 m. (a) Color-shaded relief map of the 1982 DEM. (b) Color-shaded relief map of the 1991 DEM.

Figure 10. Elevation-difference map. Red and purple colors indicate areas of positive and negative elevation change, respectively. Yellow shows areas that fall within the 2 σ ($\pm$0.3m) photogrammetric orientation error. The road is indicated by dashed lines. Numbered polygons are used to itemize volume changes and calculate measurement error (see table 1 and Volumetric Budget text). Grid and elevation difference units are meters. Locations of photographs shown in figures 2, 5a, 5b, 7a and 7b are denoted by dots and labels F2, F5a, F5b, F7a, and F7b, respectively (arrows on dots indicate camera directions).

Table 1. Volumetric results calculated for each polygon in figure 10. A bar is used when the number of significant figures justified is different than the number shown.

(a) Raw volumes for polygons 1-3 (areas of visible elevation change) without any correction applied.

Polygon Number	Area (m^2)	Positive Volume (m^3)	Negative Volume (m^3)	Volume Sum (m^3)	Volume Change (m^3/m^2)
1	333$\bar{2}$3	+984	-4233	-3249	-0.098
2	25$\bar{6}$9	+790	-13	+777	+0.302
3	38$\bar{6}$0	+593	-124	+469	+0.122
	39752	+2367	-4370	-2003	

(b) Raw volumes for polygons 4-11 (areas of no visible elevation change).

4	37$\bar{1}$6	+100	-44	+56	+0.015
5	5$\bar{8}$3	+26	-3	+23	+0.039
6	8$\bar{8}$6	+6	-25	-19	-0.021
7	2$\bar{5}$5	0	-3	-3	-0.012
8	6$\bar{3}$9	+3	-25	-22	-0.034
9	23$\bar{5}$5	+22	-49	-27	-0.011
10	1$\bar{1}$0	+3	-4	-1	-0.009
11	$\bar{9}$4	+1	-4	-3	-0.0$\bar{3}$2
	8638	+161	-157	+4	

(c) Corrected volumes for polygons 1-3. Corrections were made based on data from table 1b (see text for explanation).

1	333$\bar{2}$3	+374	-3623	-3249	-0.098
2	25$\bar{6}$9	+743	+34	+777	+0.302
3	38$\bar{6}$0	+522	-53	+469	+0.122
	397$\bar{5}$2	+1639	-3642	-2003	

Table 2. Depositional budget expressed as percentages of the total amount eroded from the hillslope. Percentages were calculated from data in tables 1a and 1c. The tributary and Fortymile Wash are outside the photogrammetric study area.

Polygon Number	Raw Volumes Percent of 4370 m^3	Corrected Volumes Percent of 3642 m^3
1	23	10
2	18	21
3	14	14
In Tributary and Fortymile Wash	45	55

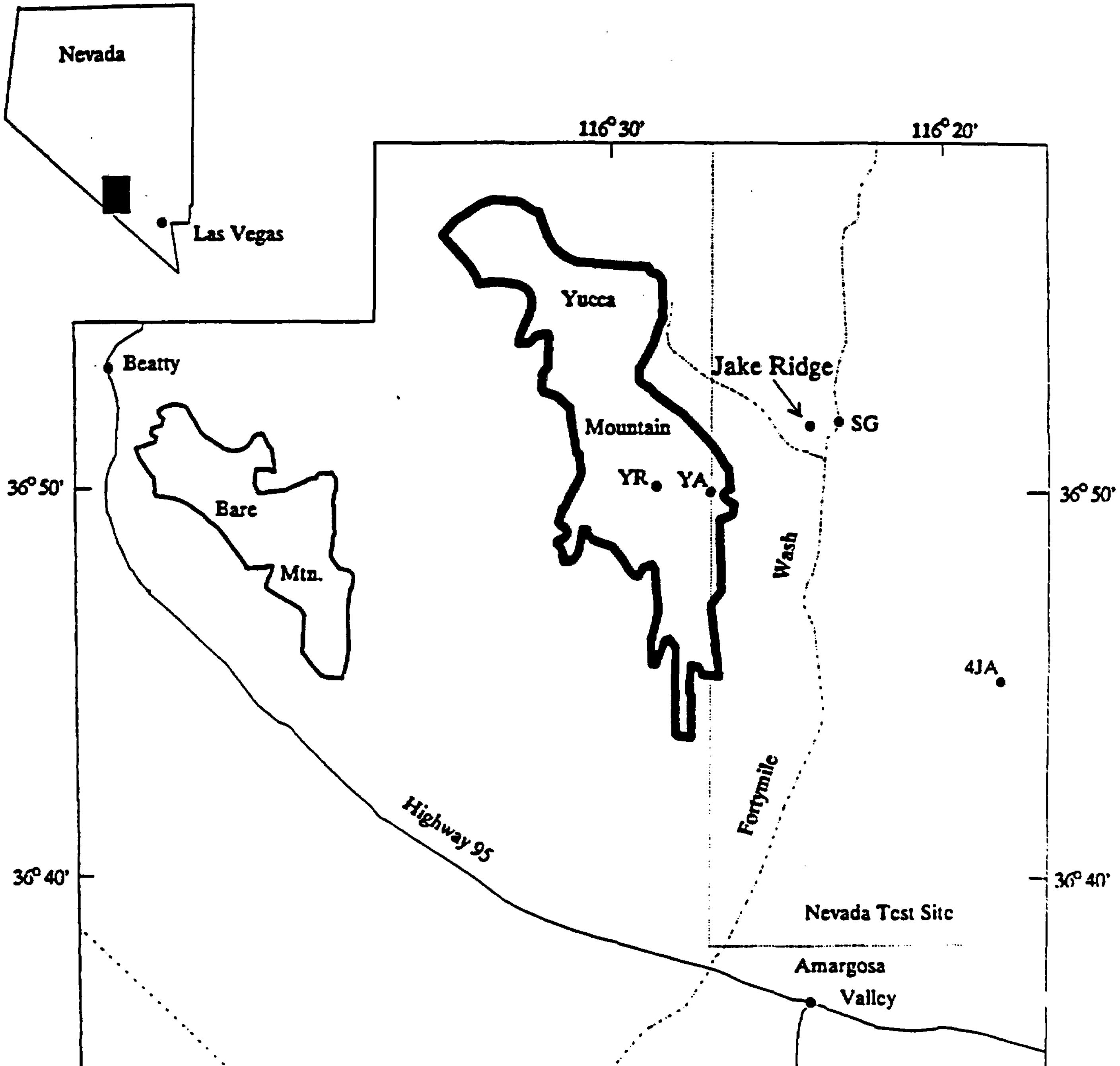

Nevada
Las Vegas
116° 30'
116° 20'
Yucca
Mountain
Jake Ridge
SG
YR
YA
Beatty
Bare
Mtn.
36° 50'
36° 50'
Wash
Fortymile
4JA
Highway 95
36° 40'
36° 40'
Nevada Test Site
Amargosa
Valley

Figure 2

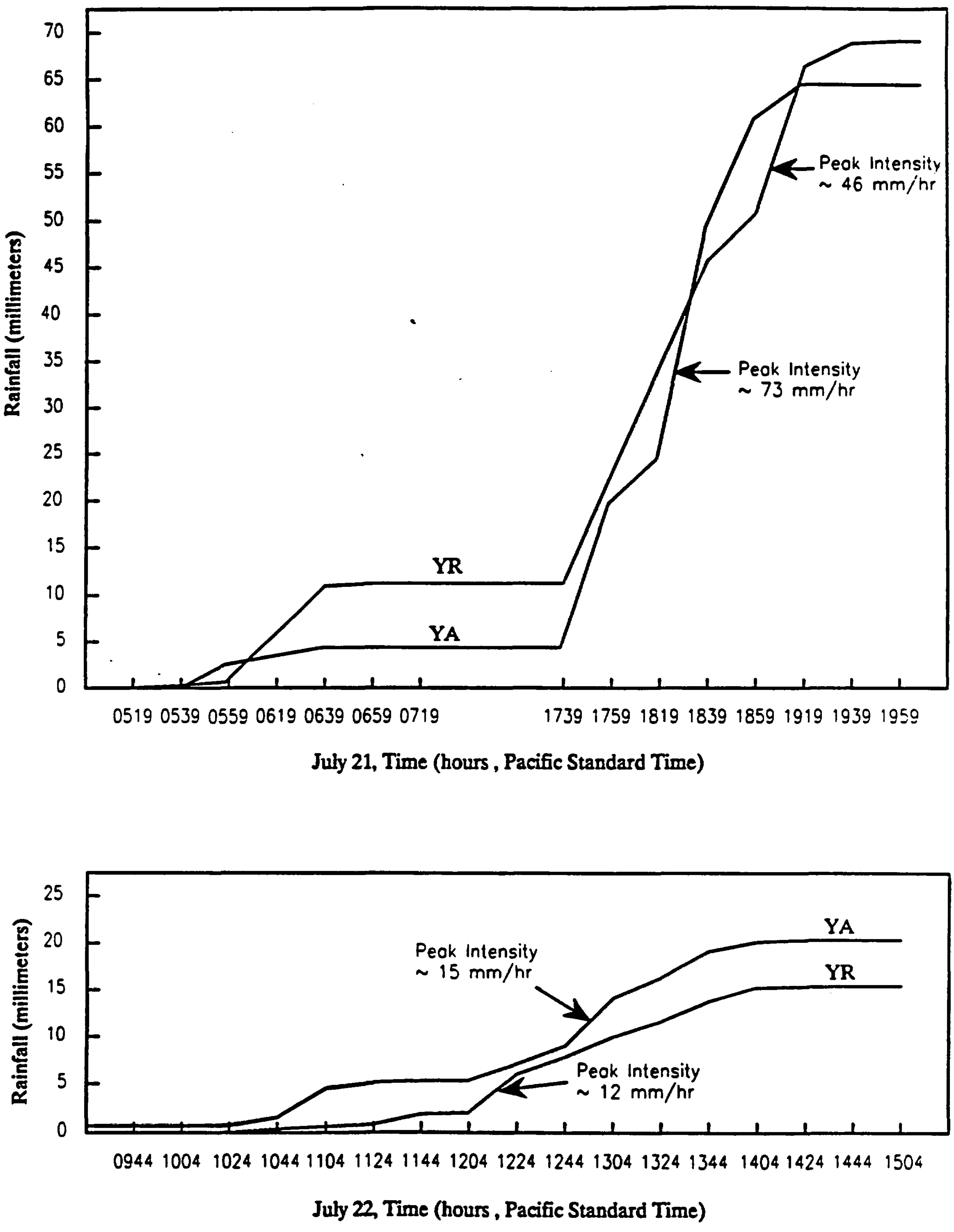

Rainfall (millimeters)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
YR
YA
Peak Intensity
~ 46 mm/hr
Peak Intensity
~ 73 mm/hr
0519 0539 0559 0619 0639 0659 0719
1739 1759 1819 1839 1859 1919 1939 1959
July 21, Time (hours , Pacific Standard Time)
Rainfall (millimeters)
25
20
15
10
5
0
YA
YR
Peak Intensity
~ 15 mm/hr
Peak Intensity
~ 12 mm/hr
0944 1004 1024 1044 1104 1124 1144 1204 1224 1244 1304 1324 1344 1404 1424 1444 1504
July 22, Time (hours , Pacific Standard Time)

Figure 3

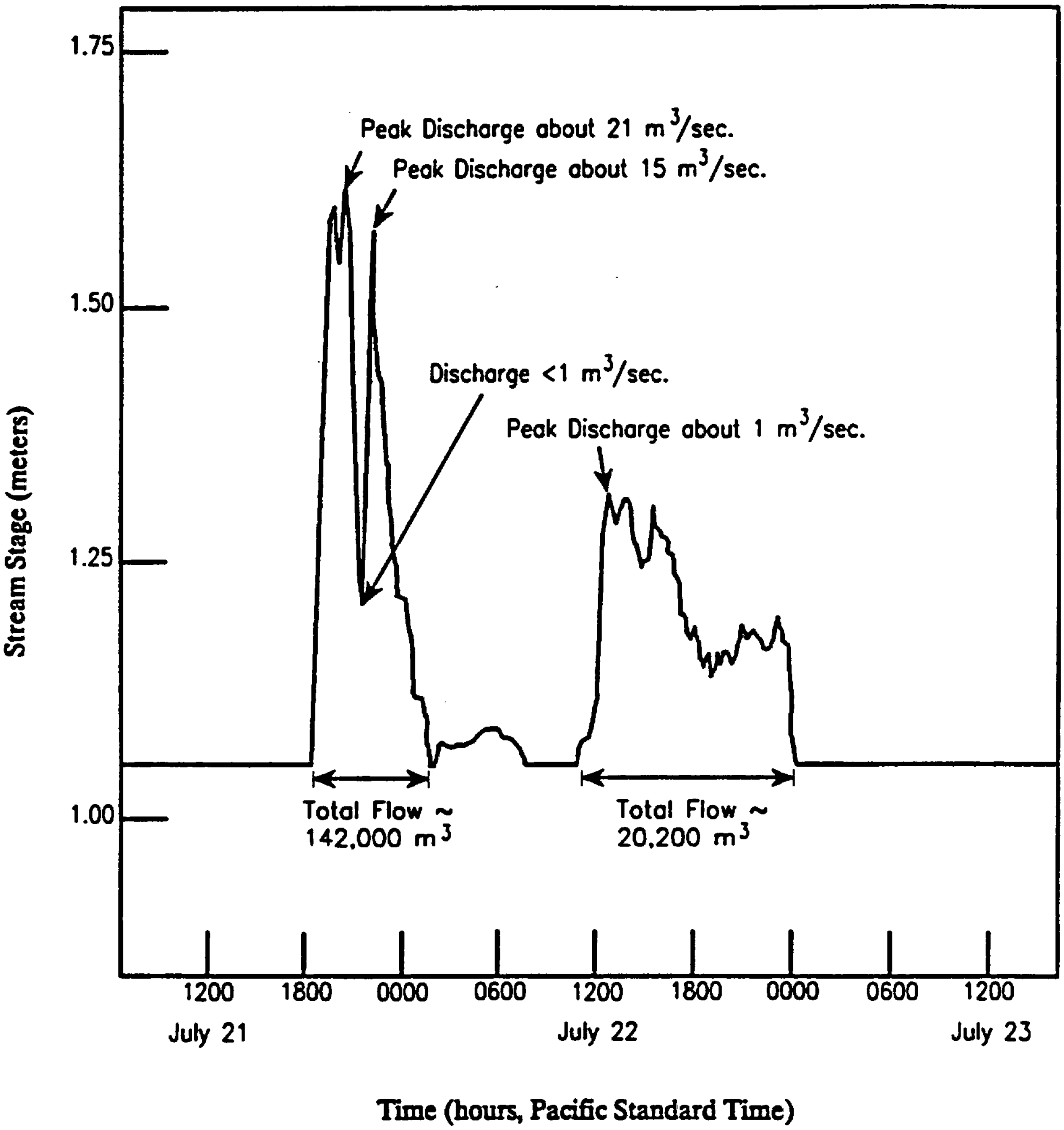

Stream Stage (meters)
1.75
1.50
1.25
1.00
Peak Discharge about 21 m³/sec.
Peak Discharge about 15 m³/sec.
Discharge <1 m³/sec.
Peak Discharge about 1 m³/sec.
Total Flow ~ 142,000 m³
Total Flow ~ 20,200 m³
1200
1800
0000
0600
1200
1800
0000
0600
1200
July 21
July 22
July 23
Time (hours, Pacific Standard Time)

Figure 4

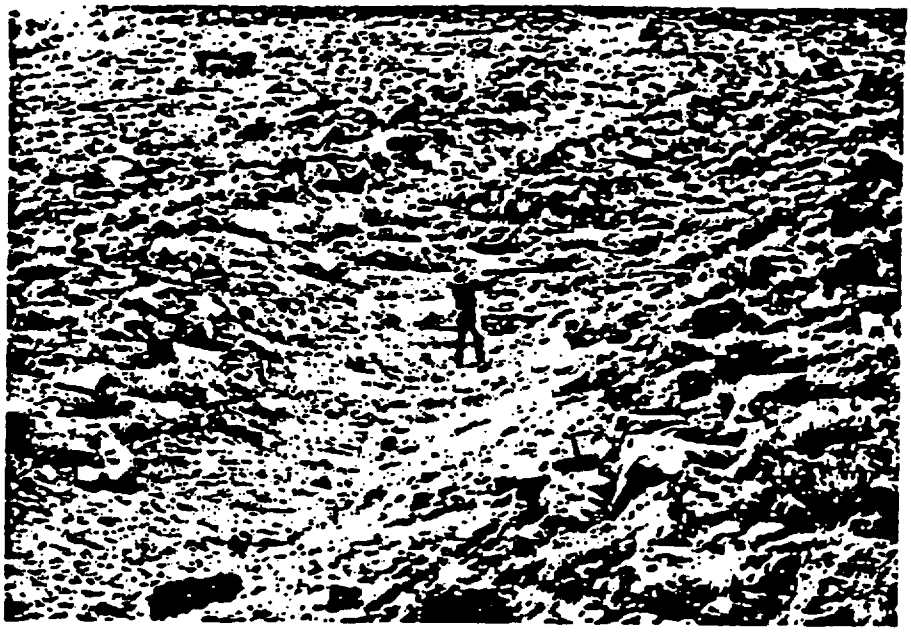


Figure 5a

Figure 5b

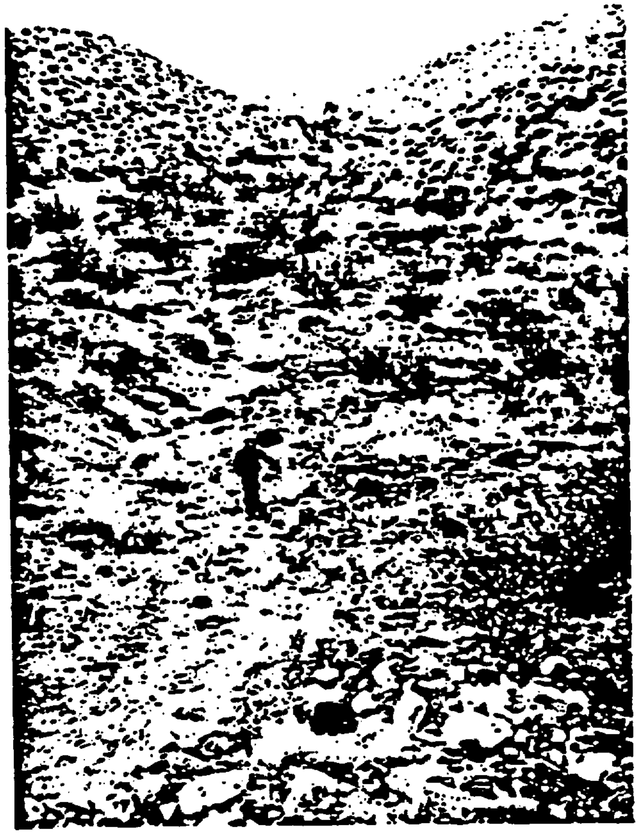


Figure 6

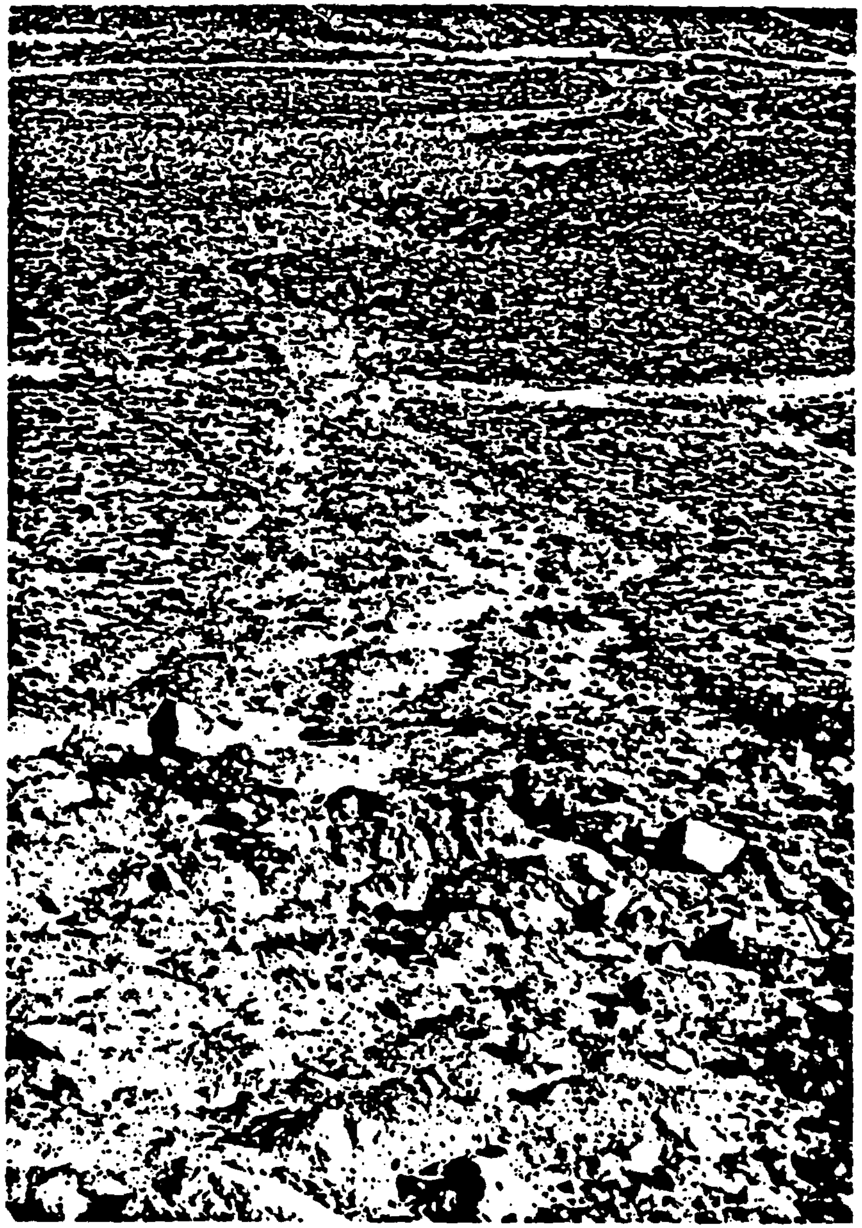
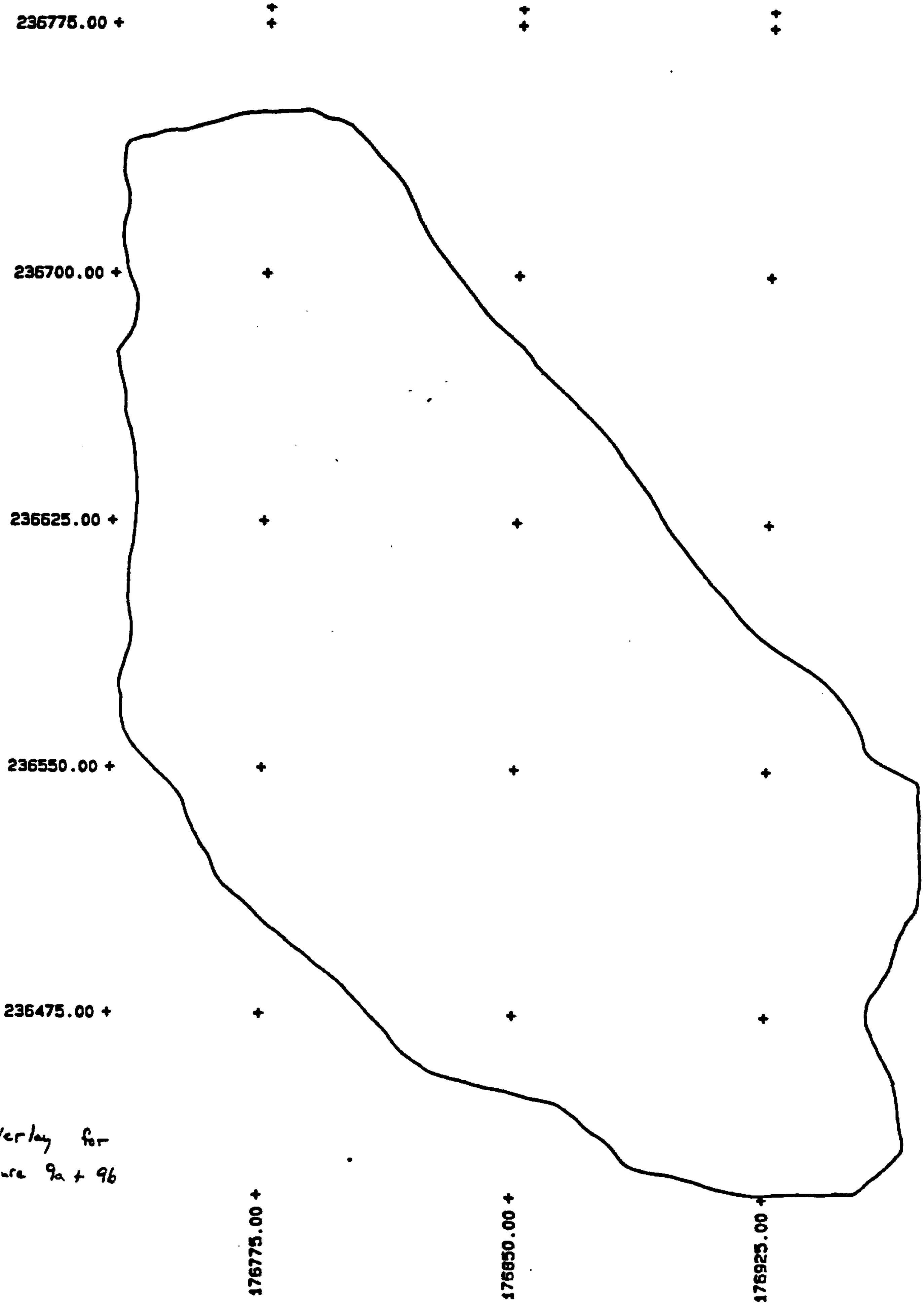


Figura 7b

Figure 8, right



Overlay for figure 9a + 9b


1236.
1232.
1228.
1224.
1220.
1216.
1212.
1208.
1204.
1200.
1196.
1192.
1188.
1184.
1180.
1176.
1172.
1168.
1164.
1160.
1156.
1152.
1148.
1144.
1140.
1136.
1132.
1128.
1124.
1120.
meters

Figure 9a


1236.
1232.
1228.
1224.
1220.
1216.
1212.
1208.
1204.
1200.
1196.
1192.
1188.
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1168.
1164.
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1156.
1152.
1148.
1144.
1140.
1136.
1132.
1128.
1124.
1120.
meters

Figure 9b

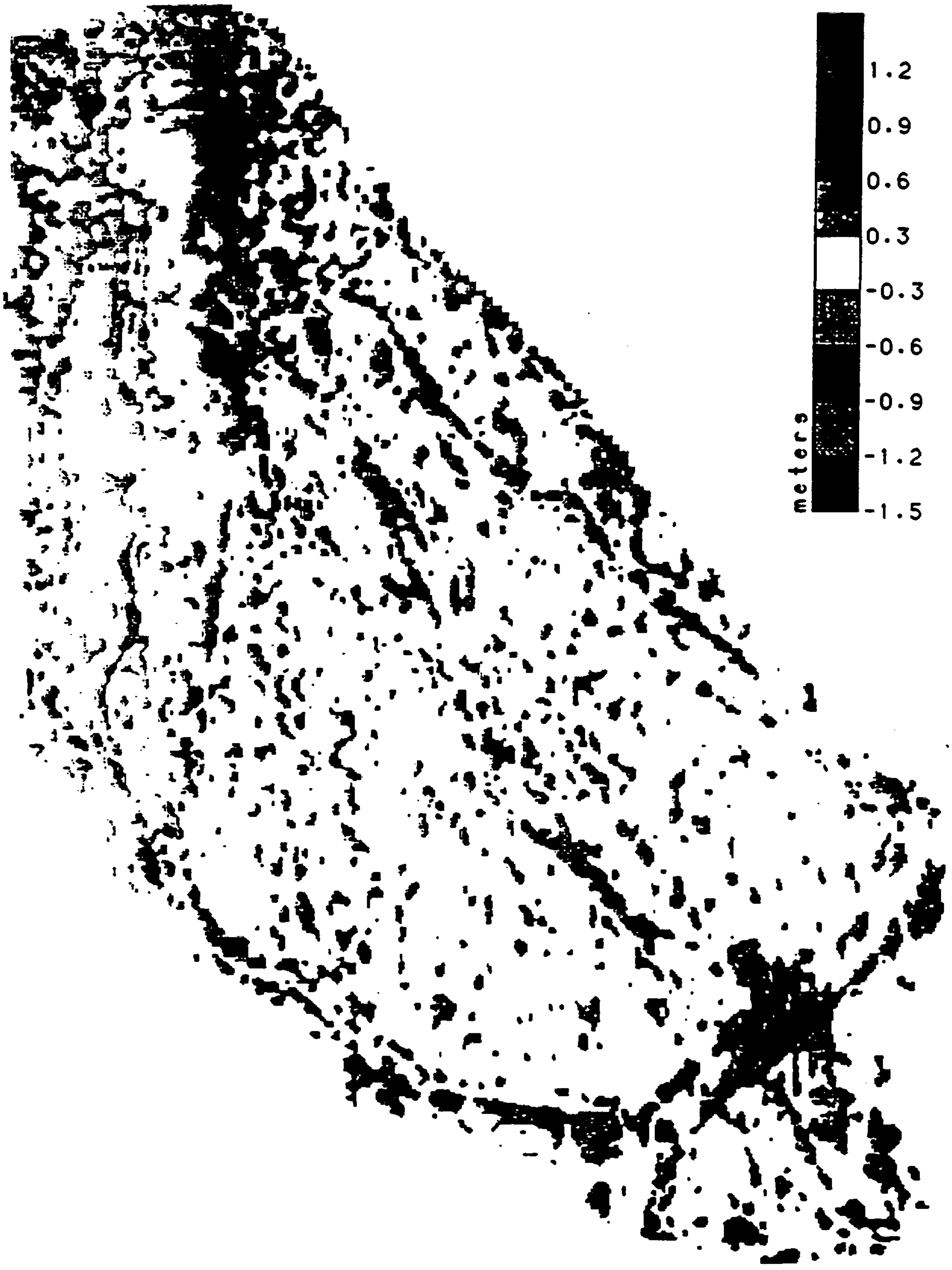
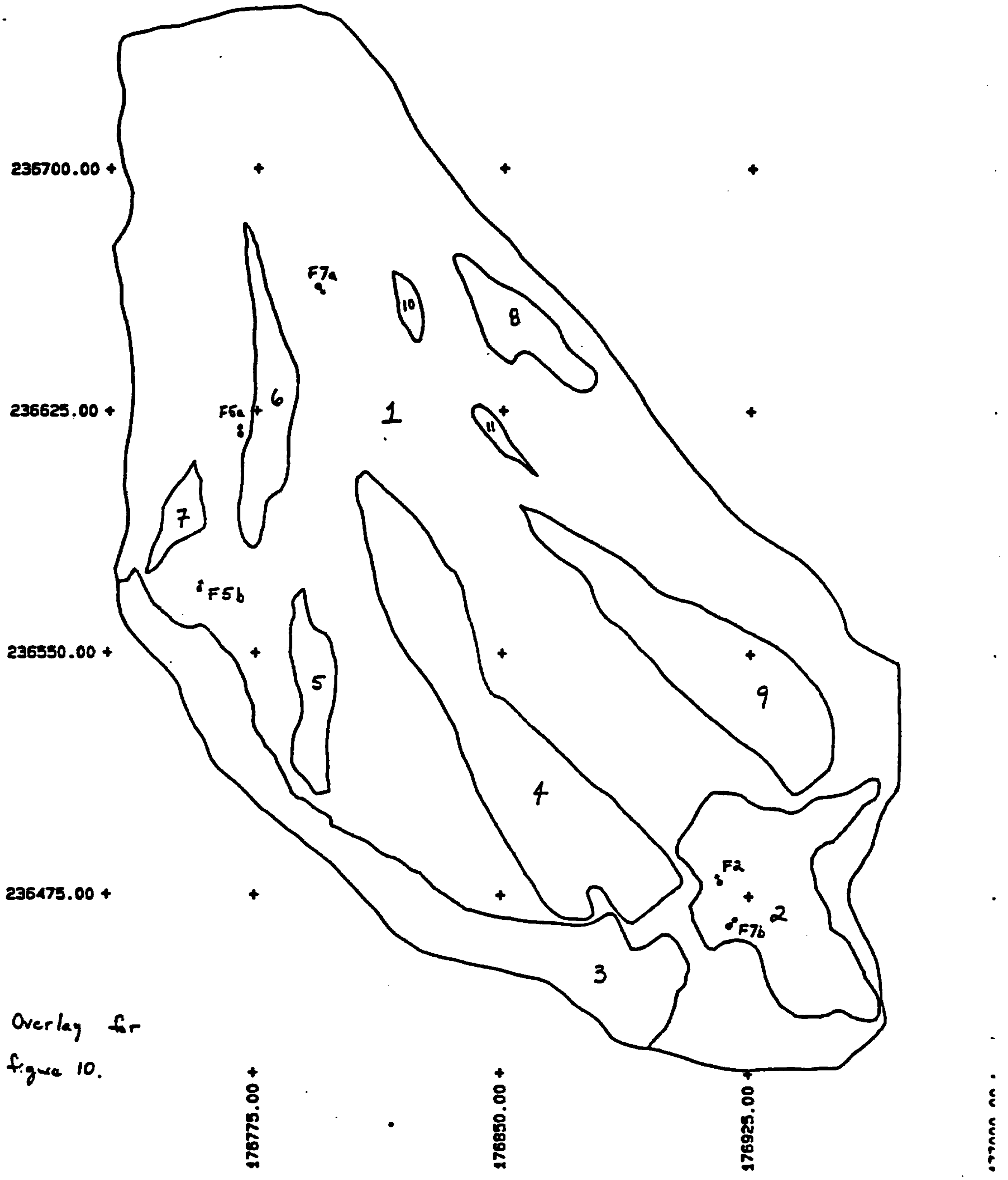


Figure 10



Overlay for figure 10.

Report for DTN: LA000000000011.001

ROCK VARNISH CATION-RATIO DATA

WBS: 1.2.5.3.6
QA: QA
MR93080922

Attachment # 1

KEV	DISK 1 15	(Note)	DISK 1 20	(Note)	DISK 1 25	(Note)	DISK 1 30	(Note)	DISK 2 10	(Note)	DISK 2 15	(Note)	DISK 2 20	(Note)	DISK 2 25	(Note)	DISK 2 30	(Note)	Field Id	Lab Id	Erosion Report Number
VCR SITE																					
1			4.010		3.542	00001									3.561	00001	4.091		CDR092087-101	KYM-A	YMR-1
2					3.505	00001	3.097								3.713		3.619	00002	CDR092087-101	KYM-A	YMR-1
3					3.725		3.514	00001							3.345	00001			CDR092087-101	KYM-A	YMR-1
4					3.350	00001									3.204	00001			CDR092087-101	KYM-A	YMR-1
5			3.930		3.676	00001									3.594	00001	3.990		CDR092087-101	KYM-A	YMR-1
6					3.032	00002									3.362		3.351	00001	CDR092087-101	KYM-A	YMR-1
1			3.056		2.991	00001							3.815		3.532	00002			CDR092087-102	KYM-B	YMR-1
2			3.176	00001	3.239								3.317	00002	3.594				CDR092087-102	KYM-B	YMR-1
3	3.462		3.391	00002	3.404										2.800	00001			CDR092087-102	KYM-B	YMR-1
4			3.104		2.779	00001							3.046	00001	3.156				CDR092087-102	KYM-B	YMR-1
5			2.920	00001	3.357								2.755	00001	3.454				CDR092087-102	KYM-B	YMR-1
6					2.777	00001							3.007		3.017	00001			CDR092087-102	KYM-B	YMR-1
7													2.974	00001	3.204				CDR092087-102	KYM-B	YMR-1
1					3.410	00002									3.264	00001	3.486		CDR092087-104	KYM-D	YMR-1
2					3.165	00001									3.477	00002	3.951		CDR092087-104	KYM-D	YMR-1
3					2.393	00001									2.983	00001			CDR092087-104	KYM-D	YMR-1
4					2.817	00001							3.396		2.964	00001			CDR092087-104	KYM-D	YMR-1
5					3.200	00001									2.848	00001			CDR092087-104	KYM-D	YMR-1
6					2.817	00001									3.393	00002			CDR092087-104	KYM-D	YMR-1
7															3.237	00001			CDR092087-104	KYM-D	YMR-1
1			2.965	00001	3.195		3.593						3.163	00001	3.340				CDR092087-105	KYM-E	YMR-1
2	3.029	00001													3.017	00001			CDR092087-105	KYM-E	YMR-1
3			3.201		3.275	00002							3.298	00001	3.302				CDR092087-105	KYM-E	YMR-1
4					3.105	00001							3.302		3.357	00001			CDR092087-105	KYM-E	YMR-1
5			2.914	00001	3.087								3.551		3.412	00001			CDR092087-105	KYM-E	YMR-1
6			3.505		3.147	00001							3.645		3.402	00001			CDR092087-105	KYM-E	YMR-1
7			3.586		3.327	00002	3.505												CDR092087-105	KYM-E	YMR-1
1			3.269	00001	3.408						3.076	00001	3.094		3.439				CDR092087-106	KYM-F	YMR-1
2			2.769	00001	2.974						3.457		3.067	00001	3.094				CDR092087-106	KYM-F	YMR-1
3			2.752	00001							3.963		2.652	00001	3.194				CDR092087-106	KYM-F	YMR-1
4	4.989		4.792	00002	5.172								4.129		4.083	00002			CDR092087-106	KYM-F	YMR-1
5	3.100	00001	3.853										3.269	00001	3.405				CDR092087-106	KYM-F	YMR-1
6	3.198	00001	3.381								3.133	00001	3.204		3.233				CDR092087-106	KYM-F	YMR-1
1			2.525	00001	2.784								2.540	00001	2.661				CDR092087-107	KYM-G	YMR-1
2			2.604		2.505	00001							2.924		2.731	00001			CDR092087-107	KYM-G	YMR-1
3			2.650		2.611	00001							2.944		2.704	00001			CDR092087-107	KYM-G	YMR-1
4					2.710	00001							2.504	00001	2.645				CDR092087-107	KYM-G	YMR-1
5			3.309		2.703	00002	3.250								3.028	00002			CDR092087-107	KYM-G	YMR-1
6					2.550	00001							2.964		2.737	00001			CDR092087-107	KYM-G	YMR-1
1			4.605		4.347	00001							3.060		3.047	00001			CDR092087-108	KYM-H	YMR-1
2					5.459	00002							3.262	00001	3.264				CDR092087-108	KYM-H	YMR-1
3			4.771		4.126		4.102	00001							3.510	00002	3.776		CDR092087-108	KYM-H	YMR-1
4					4.558		4.409	00001							3.111	00001			CDR092087-108	KYM-H	YMR-1
5			5.175		5.038	00002	5.638								3.118	00001			CDR092087-108	KYM-H	YMR-1
6					4.510	00001									2.727	00001			CDR092087-108	KYM-H	YMR-1
7					4.453	00001													CDR092087-108	KYM-H	YMR-1

Attachment # 2

KEV	DISK 1 15	(Note)	DISK 1 20	(Note)	DISK 1 25	(Note)	DISK 1 30	(Note)	DISK 2 10	(Note)	DISK 2 15	(Note)	DISK 2 20	(Note)	DISK 2 25	(Note)	DISK 2 30	(Note)	Field Id	Lab Id	Erosion Report Number
VCR SITE																					
1							4.735	00001									3.122	00001	6110401	YM-01	YMR-2
2							4.287	00001									3.262	00001	6110401	YM-01	YMR-2
3							4.097	00002									3.000	00001	6110401	YM-01	YMR-2
4							4.361	00001									3.112	00001	6110401	YM-01	YMR-2
5							4.279	00001									3.260	00001	6110401	YM-01	YMR-2
6							4.584	00001									3.360	00001	6110401	YM-01	YMR-2

WBS: 1.2.5.3.6
QA: QA
MR93080922

Attachment # 2

	DISK 1								DISK 2												
KEV	15	(Note)	20	(Note)	25	(Note)	30	(Note)	10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)			
VCR SITE																			Field Id	Lab Id	Erosion Report Number
1							4.159	00001									3.806	00001	6110402	YM-02	YMR-2
2							3.500	00001									3.733	00001	6110402	YM-02	YMR-2
3							4.061	00001									3.189	00001	6110402	YM-02	YMR-2
4							3.702	00001									3.354	00001	6110402	YM-02	YMR-2
5							3.935	00001									3.897	00001	6110402	YM-02	YMR-2
6							4.430	00002									3.903	00002	6110402	YM-02	YMR-2
1							6.704	00002									4.452	00001	6110403	YM-03	YMR-2
2							5.142	00001									4.228	00001	6110403	YM-03	YMR-2
3							4.716	00001									4.049	00001	6110403	YM-03	YMR-2
4							5.479	00001									5.092	00002	6110403	YM-03	YMR-2
5							5.240	00001									5.087	00001	6110403	YM-03	YMR-2
6							6.324	00002									4.570	00001	6110403	YM-03	YMR-2
7							6.029	00002											6110403	YM-03	YMR-2
8							5.355	00001											6110403	YM-03	YMR-2
1							6.418	00002									5.196	00001	6110404	YM-04	YMR-2
2							5.321	00001									5.344		6110404	YM-04	YMR-2
3							5.262	00001									5.588	00002	6110404	YM-04	YMR-2
4							5.945	00002									5.001	00001	6110404	YM-04	YMR-2
5							4.597	00001									5.263	00001	6110404	YM-04	YMR-2
6							5.037	00001									5.439	00001	6110404	YM-04	YMR-2
7							6.838	00002											6110404	YM-04	YMR-2
8							6.046	00002											6110404	YM-04	YMR-2
9							5.000	00001											6110404	YM-04	YMR-2
1							4.755	00001									5.137	00001	6110405	YM-05	YMR-2
2							4.483	00001									5.593	00001	6110405	YM-05	YMR-2
3							5.626	00002									5.224	00001	6110405	YM-05	YMR-2
4							4.667	00001									5.475	00001	6110405	YM-05	YMR-2
5							4.613	00001									5.231	00001	6110405	YM-05	YMR-2
6							4.617	00001									6.117	00002	6110405	YM-05	YMR-2
7																	5.869	00002	6110405	YM-05	YMR-2
1							5.227	00001									6.636	00001	6110407A	YM-07A	YMR-2
2							6.130	00001									7.009	00001	6110407A	YM-07A	YMR-2
3							6.090	00001									10.293	00002	6110407A	YM-07A	YMR-2
4							6.274	00002									16.057	00002	6110407A	YM-07A	YMR-2
5							6.271	00001									6.636		6110407A	YM-07A	YMR-2
6							5.600	00001									4.932	00001	6110407A	YM-07A	YMR-2
7																	4.898		6110407A	YM-07A	YMR-2
1							5.051	00001									4.764	00001	6110407B	YM-07B	YMR-2
2							5.168	00002									4.775	00001	6110407B	YM-07B	YMR-2
3							5.123	00001									5.216	00001	6110407B	YM-07B	YMR-2
4							4.910	00001									5.343	00002	6110407B	YM-07B	YMR-2
5							4.058	00001									4.568	00001	6110407B	YM-07B	YMR-2
6							4.491	00001									4.982	00001	6110407B	YM-07B	YMR-2
1							5.017	00001									5.710	00001	6110408B	YM-08B	YMR-2
2							5.513	00002									5.719	00001	6110408B	YM-08B	YMR-2
3							4.411	00001									4.302	00001	6110408B	YM-08B	YMR-2
4							4.603	00001									4.807	00001	6110408B	YM-08B	YMR-2
5							4.440	00001									6.905	00002	6110408B	YM-08B	YMR-2
6							4.560	00001									5.024	00001	6110408B	YM-08B	YMR-2
1							3.978	00001									10.943	00002	6110409	YM-09	YMR-2
2							3.824	00001									7.055	00001	6110409	YM-09	YMR-2
3							4.981	00001									7.086	00001	6110409	YM-09	YMR-2
4							5.633	00002									6.471	00001	6110409	YM-09	YMR-2
5							4.968	00001									9.519	00002	6110409	YM-09	YMR-2
6							4.805	00001									10.000	00002	6110409	YM-09	YMR-2
7							5.124	00002									7.446	00001	6110409	YM-09	YMR-2
8																	7.407	00001	6110409	YM-09	YMR-2
1							5.708	00001									3.461	00001	6110410	YM-10	YMR-2
2							6.202	00001									4.460	00002	6110410	YM-10	YMR-2
3							6.874	00001									3.649	00001	6110410	YM-10	YMR-2
4							8.515	00002									3.877	00001	6110410	YM-10	YMR-2
5							6.658	00001									4.343	00001	6110410	YM-10	YMR-2
6							7.468	00001									4.306	00001	6110410	YM-10	YMR-2

Attachment # 3

KEV	DISK 1 15	(Note)	20	(Note)	25	(Note)	30	(Note)	DISK 2 10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)			
VCR SITE																			Field Id	Lab Id	Erosion Report Number
1	4.245	00002	4.333		4.503								3.777	00001					6120401	WYM-01	YMN-1
2	3.906	00001	4.160		4.501						4.260	00002	4.851		4.350				6120401	WYM-01	YMN-1
3	4.195	00001	5.929										3.454	00001	4.515				6120401	WYM-01	YMN-1
4	5.667		4.041	00001									4.085	00001	4.153				6120401	WYM-01	YMN-1
5			3.505	00001									4.503		3.727	00001			6120401	WYM-01	YMN-1
6			3.604	00001							3.825	00001	4.330		5.095				6120401	WYM-01	YMN-1
1	3.277	00001	3.321		3.833						3.174	00001							6120402	WYM-02	YMN-1
2			3.314	00001	3.588						2.703	00001							6120402	WYM-02	YMN-1
3	3.390		3.301	00001							3.559		3.408	00001					6120402	WYM-02	YMN-1
4	6.162		3.962		3.920	00002					3.427	00001	3.970						6120402	WYM-02	YMN-1
5			3.673		3.655	00001					3.303		3.280	00001					6120402	WYM-02	YMN-1
6	3.000	00001	4.131								3.667	00002							6120402	WYM-02	YMN-1
1	5.790		5.609		5.557	00001					4.135	00001	5.316		5.057				6120403	WYM-03	YMN-1
2	4.505	00001	6.220		5.719				4.529	00001	4.550		6.083						6120403	WYM-03	YMN-1
3	5.615	00001	6.439						5.593		4.980		5.059		4.865	00002			6120403	WYM-03	YMN-1
4	7.130		5.667	00001							3.946	00001	4.545		4.434				6120403	WYM-03	YMN-1
5			6.109		5.789	00002					4.955		4.105	00001					6120403	WYM-03	YMN-1
6					5.097	00001			4.752		4.901		4.566	00001					6120403	WYM-03	YMN-1
1			3.594	00001	3.743								3.571		3.174	00001			6120404	WYM-04	YMN-1
2			3.200	00001											3.589	00001			6120404	WYM-04	YMN-1
3			3.198	00001									2.759	00001					6120404	WYM-04	YMN-1
4			3.026	00001									3.150	00001					6120404	WYM-04	YMN-1
5			3.137	00001									3.910	00002					6120404	WYM-04	YMN-1
6			3.967	00002							3.210	00001	3.677						6120404	WYM-04	YMN-1
1	4.599		4.564	00001									3.933	00001	4.275				6120405	WYM-05	YMN-1
2	5.292		5.097	00001	5.479								4.817		4.600	00002	5.190		6120405	WYM-05	YMN-1
3			6.173		5.836	00002									4.111	00001	4.255		6120405	WYM-05	YMN-1
4			6.044		6.043	00002							3.861	00001	4.105				6120405	WYM-05	YMN-1
5			5.471		5.456	00001							3.897	00001					6120405	WYM-05	YMN-1
6			5.265		5.107	00001							4.930		4.140	00001			6120405	WYM-05	YMN-1
7			4.717	00001	5.200														6120405	WYM-05	YMN-1
1			3.176	00001	3.105		3.291						2.882	00001	3.034				6120406A	WYM-06A	YMN-1
2			2.073	00001											2.603	00001			6120406A	WYM-06A	YMN-1
3			2.862	00001											2.892	00002			6120406A	WYM-06A	YMN-1
4			2.750	00001											2.581	00001			6120406A	WYM-06A	YMN-1
5			3.095	00001											2.481	00001			6120406A	WYM-06A	YMN-1
6			3.809	00002											2.664	00001			6120406A	WYM-06A	YMN-1
1					3.403	00002							3.320	00002	3.395				6120406B	WYM-06B	YMN-1
2			3.015	00001	3.459										2.805	00001			6120406B	WYM-06B	YMN-1
3			3.017	00001											3.147	00001			6120406B	WYM-06B	YMN-1
4			2.828	00001											2.877	00001			6120406B	WYM-06B	YMN-1
5			3.312	00001											3.065	00001			6120406B	WYM-06B	YMN-1
6			2.590	00001											2.976	00001			6120406B	WYM-06B	YMN-1

Attachment # 4

KEV	DISK 1 15	(Note)	20	(Note)	25	(Note)	30	(Note)	DISK 2 10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)			
VCR SITE																			Field Id	Lab Id	Erosion Report Number
1							2.532	00001									2.885	00001	6120411	LWYM-A	YMN-2
2							2.733	00001									3.074	00001	6120411	LWYM-A	YMN-2
3							3.796	00002									2.940	00001	6120411	LWYM-A	YMN-2
4							3.280	00002									3.009	00001	6120411	LWYM-A	YMN-2
5							3.250	00002									3.320	00002	6120411	LWYM-A	YMN-2
6							3.009	00001									3.088	00002	6120411	LWYM-A	YMN-2
7							2.839	00001									2.736	00001	6120411	LWYM-A	YMN-2
8							3.602	00002									3.286	00002	6120411	LWYM-A	YMN-2
9							2.925	00001											6120411	LWYM-A	YMN-2
1							4.727	00001									4.650	00001	6120412	LWYM-B	YMN-2
2							4.518	00001									4.521	00001	6120412	LWYM-B	YMN-2
3							4.152	00001									5.254	00002	6120412	LWYM-B	YMN-2

WBS: 1.2.5.3.6
QA: QA
MR93080922

Attachment # 4

KEV	DISK 1								DISK 2												
VCR SITE	15	(Note)	20	(Note)	25	(Note)	30	(Note)	10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)	Field Id	Lab Id	Erosion Report Number
4							4.951	00002									4.952	00001	6120412	LWYM-B	YMN-2
5							4.736	00001									4.710	00001	6120412	LWYM-B	YMN-2
6							4.738	00001									4.605	00001	6120412	LWYM-B	YMN-2
7																	5.066	00002	6120412	LWYM-B	YMN-2
1							3.738	00002									3.415	00002	6120413	LWYM-C	YMN-2
2							3.330	00002									3.466	00002	6120413	LWYM-C	YMN-2
3							3.867	00002									3.156	00001	6120413	LWYM-C	YMN-2
4							3.100	00001									3.633	00002	6120413	LWYM-C	YMN-2
5							2.957	00001									3.042	00001	6120413	LWYM-C	YMN-2
6							3.108	00001									2.967	00001	6120413	LWYM-C	YMN-2
7							3.271	00002									3.022	00001	6120413	LWYM-C	YMN-2
8							3.237	00001									3.024	00001	6120413	LWYM-C	YMN-2
9							3.154	00001											6120413	LWYM-C	YMN-2
1							3.388	00001									3.366	00002	6120414	LWYM-D	YMN-2
2							2.631	00001									2.805	00001	6120414	LWYM-D	YMN-2
3							3.313	00001									3.025	00001	6120414	LWYM-D	YMN-2
4							3.060	00001									3.252	00002	6120414	LWYM-D	YMN-2
5							3.203	00001									3.456	00002	6120414	LWYM-D	YMN-2
6							3.504	00002									3.048	00001	6120414	LWYM-D	YMN-2
7							3.514	00002									3.167	00001	6120414	LWYM-D	YMN-2
8							3.464	00002									2.835	00001	6120414	LWYM-D	YMN-2
9							3.413	00002											6120414	LWYM-D	YMN-2
1							4.049	00001									4.060	00001	6120415	LWYM-E	YMN-2
2							4.174	00001									4.791	00001	6120415	LWYM-E	YMN-2
3							4.235	00001									4.321	00001	6120415	LWYM-E	YMN-2
4							3.944	00001									4.849	00002	6120415	LWYM-E	YMN-2
5							4.338	00002									4.306	00001	6120415	LWYM-E	YMN-2
6							4.309	00002									4.452	00001	6120415	LWYM-E	YMN-2
7							4.457	00002											6120415	LWYM-E	YMN-2
8							4.208	00001											6120415	LWYM-E	YMN-2
9							4.398	00002											6120415	LWYM-E	YMN-2
1							4.417	00002									3.863	00001	6120416	LWYM-F	YMN-2
2							3.809	00001									4.250	00001	6120416	LWYM-F	YMN-2
3							3.629	00001									4.318	00001	6120416	LWYM-F	YMN-2
4							4.018	00002									5.173	00002	6120416	LWYM-F	YMN-2
5							3.720	00001									4.740	00002	6120416	LWYM-F	YMN-2
6							3.308	00001									5.578	00002	6120416	LWYM-F	YMN-2
7							4.875	00002									5.058	00002	6120416	LWYM-F	YMN-2
8							3.692	00001									4.110	00001	6120416	LWYM-F	YMN-2
9																	3.923	00001	6120416	LWYM-F	YMN-2
1							3.524	00001									2.809	00001	6120417	LWYM-H	YMN-2
2							3.414	00001									3.077	00001	6120417	LWYM-H	YMN-2
3							3.642	00001									2.903	00001	6120417	LWYM-H	YMN-2
4							3.912	00001									2.966	00001	6120417	LWYM-H	YMN-2
5							3.951	00002									3.189	00002	6120417	LWYM-H	YMN-2
6							4.062	00002									2.971	00001	6120417	LWYM-H	YMN-2
7							3.667	00001											6120417	LWYM-H	YMN-2
1							3.088	00001									4.012	00001	6120418	LWYM-I	YMN-2
2							3.277	00001									3.622	00001	6120418	LWYM-I	YMN-2
3							2.790	00001									4.232	00002	6120418	LWYM-I	YMN-2
4							2.625	00001									3.958	00001	6120418	LWYM-I	YMN-2
5							2.914	00001									4.011	00001	6120418	LWYM-I	YMN-2
6							3.467	00002									3.786	00001	6120418	LWYM-I	YMN-2

WBS: 1.2.5.3.6
QA: QA
NN93080922

Attachment # 5

	DISK 1								DISK 2												
KEV	15	(Note)	20	(Note)	25	(Note)	30	(Note)	10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)			
VCR SITE																			Field Id	Lab Id	Erosion Report Number
1			3.990		3.510		3.321	00001							3.802		3.340	00002	CDM092887-101	YMN-1	YMN-3
2							2.741	00001					3.776		3.762	00002	3.796		CDM092887-101	YMN-1	YMN-3
3							3.175	00001					2.973	00001	3.398				CDM092887-101	YMN-1	YMN-3
4					3.293		3.142	00001					3.302		2.803	00001	3.495		CDM092887-101	YMN-1	YMN-3
5					4.110		3.762	00002					2.328	00001	2.948				CDM092887-101	YMN-1	YMN-3
6							3.037	00001					2.912	00001	3.221				CDM092887-101	YMN-1	YMN-3
7													3.074		3.146	00001	3.586		CDM092887-101	YMN-1	YMN-3
1			2.601		2.492	00001	2.847						3.650		3.347		3.174	00001	CDM092887-102	YMN-2	YMN-3
2			2.550	00001	2.588		2.570								3.936		3.028	00002	CDM092887-102	YMN-2	YMN-3
3							2.305	00001							3.889		2.811	00001	CDM092887-102	YMN-2	YMN-3
4					3.126		2.953	00002							2.809	00001	3.069		CDM092887-102	YMN-2	YMN-3
5					2.664		2.452	00001							3.635		3.473	00001	CDM092887-102	YMN-2	YMN-3
6					2.830	00001	2.959								3.163	00001	3.663		CDM092887-102	YMN-2	YMN-3
1					2.982		2.917	00001							3.108	00002	3.315		CDM092887-103	YMN-3	YMN-3
2					3.765	00001	4.000								2.636	00001			CDM092887-103	YMN-3	YMN-3
3							4.085	00002							3.141	00001			CDM092887-103	YMN-3	YMN-3
4					4.060		4.056	00002							2.856	00001			CDM092887-103	YMN-3	YMN-3
5			3.500		3.219	00001	3.043								2.991	00001			CDM092887-103	YMN-3	YMN-3
6					4.780		3.912	00001							3.037	00001			CDM092887-103	YMN-3	YMN-3
7					3.569	00001	3.595												CDM092887-103	YMN-3	YMN-3
1			5.325		3.211	00001	3.707								3.052	00001	3.261		CDM092887-104	YMN-4	YMN-3
2					3.410		3.042	00001							3.533		3.513	00002	CDM092887-104	YMN-4	YMN-3
3					3.684		3.602	00002					3.885		3.728	00002	4.306		CDM092887-104	YMN-4	YMN-3
4					3.375		3.064						3.230		3.113	00001	4.006		CDM092887-104	YMN-4	YMN-3
5					3.287	00001	3.349								2.949	00001			CDM092887-104	YMN-4	YMN-3
6							3.008	00001							3.472	00001			CDM092887-104	YMN-4	YMN-3
7					3.293	00002	3.510						3.423		3.734		3.333	00001	CDM092887-104	YMN-4	YMN-3
1					2.830	00001	2.866								4.075		3.167	00001	CDM092887-105	YMN-5	YMN-3
2					3.404	00002	3.490								3.049	00001	3.539		CDM092887-105	YMN-5	YMN-3
3			3.455		3.191	00001	3.907								4.337		3.688	00002	CDM092887-105	YMN-5	YMN-3
4					4.422		3.900	00002							3.229	00001	3.505		CDM092887-105	YMN-5	YMN-3
5							2.701	00001							3.775	00002	3.076		CDM092887-105	YMN-5	YMN-3
6							2.606	00001							3.103	00001	3.527		CDM092887-105	YMN-5	YMN-3
7							3.010	00001							3.760		3.170	00001	CDM092887-105	YMN-5	YMN-3
1															2.738	00001	3.130		CDM092887-106	YMN-6	YMN-3
2															2.802	00001	3.102		CDM092887-106	YMN-6	YMN-3
3															3.009	00001	3.735		CDM092887-106	YMN-6	YMN-3
4															3.036	00001	3.198		CDM092887-106	YMN-6	YMN-3
5															2.769	00001	3.594		CDM092887-106	YMN-6	YMN-3
6															3.230		3.103	00001	CDM092887-106	YMN-6	YMN-3
1					3.060	00001	3.153				3.191		2.882	00001	3.037				CDM092887-107	YMN-7	YMN-3
2					3.452		3.193	00002			3.008		2.965		2.826	00001			CDM092887-107	YMN-7	YMN-3
3					2.680	00001							3.140		2.909	00001			CDM092887-107	YMN-7	YMN-3
4					3.125	00001							3.196		3.040	00002			CDM092887-107	YMN-7	YMN-3
5					3.026	00001							3.000	00001	3.308				CDM092887-107	YMN-7	YMN-3
6					2.447	00001							2.854	00001	3.157				CDM092887-107	YMN-7	YMN-3
1			3.152		3.059	00001									2.655	00001	2.793		CDM092887-108	YMN-8	YMN-3
2					2.673	00001									2.755	00002			CDM092887-108	YMN-8	YMN-3
3					3.247		2.920	00001							2.682	00001	2.685		CDM092887-108	YMN-8	YMN-3
4							2.609	00001									2.569	00001	CDM092887-108	YMN-8	YMN-3
5							3.019	00001									2.467	00001	CDM092887-108	YMN-8	YMN-3
6							2.836	00001									2.630	00001	CDM092887-108	YMN-8	YMN-3
1			3.864	00001	4.269								3.220	00001	3.560				CDM092887-109	YMN-9	YMN-3
2			4.019	00001	4.359								3.701		3.409		3.396	00001	CDM092887-109	YMN-9	YMN-3
3			4.220	00002	4.245		4.471								3.707		3.433	00002	CDM092887-109	YMN-9	YMN-3
4			3.550	00001	3.833								3.910		3.144	00001			CDM092887-109	YMN-9	YMN-3
5			3.649	00001	3.621										3.126	00001			CDM092887-109	YMN-9	YMN-3
6			3.988	00001	4.000										3.608		3.408	00001	CDM092887-109	YMN-9	YMN-3

WBS: 1.2.5.3.6
QA: QA
MR93080922

Attachment # 6

	DISK 1								DISK 2												
KEV	15	(Note)	20	(Note)	25	(Note)	30	(Note)	10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)			Erosion Report
VCR SITE																			Field Id	Lab Id	Number
1			4.044		4.043		3.006	00001											041005	NYM-A	YMN-1
2					3.000	00001	3.097												041005	NYM-A	YMN-1
3					5.003	00001													041005	NYM-A	YMN-1
4					3.533	00001	4.020												041005	NYM-A	YMN-1
5					3.373	00001													041005	NYM-A	YMN-1
6			3.794		3.700	00001													041005	NYM-A	YMN-1
1			3.070	00001	4.009								4.596		4.130	00001			041005-C	NYM-C	YMN-1
2			3.901	00001	4.725								4.230	00001	4.747				041005-C	NYM-C	YMN-1
3			4.277		3.052	00001							4.030		4.259	00002			041005-C	NYM-C	YMN-1
4			4.695		4.320	00003							3.937	00001					041005-C	NYM-C	YMN-1
5					3.633	00001							4.243	00001					041005-C	NYM-C	YMN-1
6					3.790	00001							4.192	00001					041005-C	NYM-C	YMN-1
1	4.010		3.503	00001	3.654								4.417	00001	4.410				613041	NYM-01	YMN-1
2	4.270		4.000	00001	4.195								4.430		4.295	00001			613041	NYM-01	YMN-1
3	5.440	00002	6.393										3.932	00001					613041	NYM-01	YMN-1
4			4.162		3.934	00001					5.009		4.070	00002	5.462				613041	NYM-01	YMN-1
5			3.260	00001	3.699						4.545	00001	4.691						613041	NYM-01	YMN-1
6			3.664	00001							4.495	00001	4.606						613041	NYM-01	YMN-1
1	2.057	00001	2.069		3.160								2.922	00001	3.463				613042	NYM-02	YMN-1
2	3.473		3.140	00001							3.210	00001	3.544		3.701				613042	NYM-02	YMN-1
3			3.017	00001							2.576	00001							613042	NYM-02	YMN-1
4	2.507	00001	3.127								2.347	00001							613042	NYM-02	YMN-1
5	2.604	00001									2.537	00001							613042	NYM-02	YMN-1
6	4.404		3.715	00002							3.350	00002	3.035						613042	NYM-02	YMN-1
1	2.975		2.640	00001									3.153	00001	3.156				613043	NYM-03	YMN-1
2			2.603	00001									3.490		3.100	00001			613043	NYM-03	YMN-1
3			2.900	00002	3.130						4.704		4.471		4.343	00002			613043	NYM-03	YMN-1
4					2.764	00001							3.139	00001					613043	NYM-03	YMN-1
5					2.669	00001							3.133	00001					613043	NYM-03	YMN-1
6			3.110		2.000	00001							3.000	00001					613043	NYM-03	YMN-1
1			2.515	00001	2.040								3.073		2.027	00001			613044	NYM-04	YMN-1
2			2.774	00002	2.700										3.245	00001			613044	NYM-04	YMN-1
3			2.540	00001									3.752		3.651	00002			613044	NYM-04	YMN-1
4			2.731	00001									3.200		3.075	00001			613044	NYM-04	YMN-1
5			2.357	00001									3.031	00001	3.050				613044	NYM-04	YMN-1
6			2.400	00001									3.495		2.991	00001			613044	NYM-04	YMN-1
1	3.650	00002	3.932		4.009								3.529		3.057	00001			613046	NYM-06	YMN-1
2	3.655		3.310	00001									3.202	00001	3.355				613046	NYM-06	YMN-1
3			3.170	00001											3.150	00001			613046	NYM-06	YMN-1
4			3.171	00001	3.095										3.203	00001			613046	NYM-06	YMN-1
5	3.426		3.570		3.419	00001							3.509		3.305		3.007	00002	613046	NYM-06	YMN-1
6					3.049	00001											2.976	00001	613046	NYM-06	YMN-1

Attachment # 7

	DISK 1								DISK 2												
KEV	15	(Note)	20	(Note)	25	(Note)	30	(Note)	10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)			Erosion Report
VCR SITE																			Field Id	Lab Id	Number
1							2.570	00001									2.504	00001	690410	LSN-010	LSN-1
2							2.521	00001									2.231	00001	690410	LSN-010	LSN-1
3							2.674	00002									2.079	00001	690410	LSN-010	LSN-1
4							2.590	00001									3.134	00002	690410	LSN-010	LSN-1
5							2.572	00001									2.190	00001	690410	LSN-010	LSN-1
6							2.659	00001									2.549	00001	690410	LSN-010	LSN-1
1							2.126	00001									2.649	00001	690411	LSN-011	LSN-1
2							2.409	00001									2.609	00002	690411	LSN-011	LSN-1
3							2.309	00001									2.496	00001	690411	LSN-011	LSN-1
4							2.596	00001									2.453	00001	690411	LSN-011	LSN-1
5							2.540	00001									2.563	00001	690411	LSN-011	LSN-1
6							2.760	00002									2.400	00001	690411	LSN-011	LSN-1
1							1.067	00001									2.104	00001	6904111	LSN-111	LSN-1

WBS: 1.2.5.3.6
QA: QA
NR93080922

Attachment # 7

		DISK 1								DISK 2												
REV	VCR SITE	15	(Note)	20	(Note)	25	(Note)	30	(Note)	10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)	Field Id	Lab Id	Erosion Report Number
	2							2.226	00001									2.246	00001	6984111	LSM-111	LSM-1
	3							2.067	00001									2.064	00001	6984111	LSM-111	LSM-1
	4							2.043	00001									2.265	00002	6984111	LSM-111	LSM-1
	5							2.231	00001									2.245	00001	6984111	LSM-111	LSM-1
	6							2.359	00002									1.845		6984111	LSM-111	LSM-1
	1							2.357	00001									2.288	00001	698412	LSM-012	LSM-1
	2							2.597	00001									2.497	00001	698412	LSM-012	LSM-1
	3							2.716	00001									2.260	00001	698412	LSM-012	LSM-1
	4							2.348	00001									2.500	00002	698412	LSM-012	LSM-1
	5							2.588	00001									2.229	00001	698412	LSM-012	LSM-1
	6							2.853	00002									2.302	00001	698412	LSM-012	LSM-1
	1							2.890	00001									2.567	00001	698413	LSM-013	LSM-1
	2							2.917	00001									2.019	00001	698413	LSM-013	LSM-1
	3							2.920	00001									3.195	00002	698413	LSM-013	LSM-1
	4							2.808	00001									2.408	00001	698413	LSM-013	LSM-1
	5							3.007	00002									2.837	00002	698413	LSM-013	LSM-1
	6							2.795	00001									2.431	00001	698413	LSM-013	LSM-1
	7																	2.629	00001	698413	LSM-013	LSM-1
	1							2.479	00001									2.992	00002	698416	LSM-016	LSM-1
	2							2.509	00001									2.541	00001	698416	LSM-016	LSM-1
	3							2.322	00001									2.549	00001	698416	LSM-016	LSM-1
	4							2.269	00001									2.520	00001	698416	LSM-016	LSM-1
	5							2.845	00001									2.693	00001	698416	LSM-016	LSM-1
	6							3.165	00002									3.043	00002	698416	LSM-016	LSM-1
	7																	3.448	00002	698416	LSM-016	LSM-1
	8																	2.612	00001	698416	LSM-016	LSM-1
	1							2.601	00001									2.611	00001	698417	LSM-017	LSM-1
	2							2.409	00001									2.199	00001	698417	LSM-017	LSM-1
	3							2.436	00001									2.182	00001	698417	LSM-017	LSM-1
	4							2.437	00001									2.752	00002	698417	LSM-017	LSM-1
	5							2.315	00001									2.679	00001	698417	LSM-017	LSM-1
	6							2.620	00002									2.555	00001	698417	LSM-017	LSM-1
	1							2.804	00001									1.903	00001	698418	LSM-018	LSM-1
	2							2.363	00002									2.558	00002	698418	LSM-018	LSM-1
	3							2.807	00001									2.504	00001	698418	LSM-018	LSM-1
	4							1.943	00001									2.406	00001	698418	LSM-018	LSM-1
	5							2.074	00001									2.331	00001	698418	LSM-018	LSM-1
	6							1.986	00001									2.357	00001	698418	LSM-018	LSM-1
	1							3.556	00002									3.163	00002	698419	LSM-019	LSM-1
	2							2.879	00001									3.099	00001	698419	LSM-019	LSM-1
	3							2.755	00001									2.840	00001	698419	LSM-019	LSM-1
	4							3.163	00001									2.901	00001	698419	LSM-019	LSM-1
	5							3.229	00001									2.937	00001	698419	LSM-019	LSM-1
	6							3.361	00001									2.992	00001	698419	LSM-019	LSM-1
	1							2.722	00001									2.590	00001	M100285-1	LSM-01	LSM-1
	2							2.376	00001									2.435	00001	M100285-1	LSM-01	LSM-1
	3							2.388	00001									2.385	00001	M100285-1	LSM-01	LSM-1
	4							3.235	00002									2.478	00001	M100285-1	LSM-01	LSM-1
	5							2.582	00001									2.506	00001	M100285-1	LSM-01	LSM-1
	6							2.313	00001									3.141	00002	M100285-1	LSM-01	LSM-1
	1							2.244	00001									2.231	00001	M100285-2	LSM-02	LSM-1
	2							2.547	00002									2.463	00002	M100285-2	LSM-02	LSM-1
	3							2.376	00001									2.256	00001	M100285-2	LSM-02	LSM-1
	4							2.015	00001									2.279	00001	M100285-2	LSM-02	LSM-1
	5							1.837	00001									2.233	00001	M100285-2	LSM-02	LSM-1
	6							2.356	00002									2.125	00001	M100285-2	LSM-02	LSM-1
	1							2.719	00001									2.886	00001	M100285-3	LSM-03	LSM-1
	2							2.909	00001									3.103	00001	M100285-3	LSM-03	LSM-1
	3							2.733	00001									2.652	00001	M100285-3	LSM-03	LSM-1
	4							3.014	00001									2.718	00001	M100285-3	LSM-03	LSM-1
	5							3.132	00002									2.781	00001	M100285-3	LSM-03	LSM-1
	6							2.541	00001									3.029	00001	M100285-3	LSM-03	LSM-1
	1							3.045	00001									2.715	00001	M100285-4	LSM-04	LSM-1
	2							3.425	00001									2.951	00002	M100285-4	LSM-04	LSM-1
	3							3.321	00001									2.582	00001	M100285-4	LSM-04	LSM-1
	4							2.970	00001									2.855	00001	M100285-4	LSM-04	LSM-1

Attachment # 7

	DISK 1								DISK 2												
KEV	15	(Note)	20	(Note)	25	(Note)	30	(Note)	10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)			
VCR SITE																			Field Id	Lab Id	Erosion Report Number
5							2.836	00001									2.667	00001	N100205-4	LFM-04	LFM-1
6							3.431	00002									2.359	00001	N100205-4	LFM-04	LFM-1
1							2.721	00001									3.481	00002	N100205-5	LFM-05	LFM-1
2							2.713	00001									2.864	00001	N100205-5	LFM-05	LFM-1
3							2.503	00001									2.690	00001	N100205-5	LFM-05	LFM-1
4							2.652	00001									2.958	00001	N100205-5	LFM-05	LFM-1
5							2.431	00001									2.910	00001	N100205-5	LFM-05	LFM-1
6							3.114	00002									2.392	00001	N100205-5	LFM-05	LFM-1
7							3.160	00002											N100205-5	LFM-05	LFM-1
1							2.959	00001									2.335	00001	N100205-6	LFM-06	LFM-1
2							2.812	00001									2.457	00001	N100205-6	LFM-06	LFM-1
3							3.216										2.710	00001	N100205-6	LFM-06	LFM-1
4							2.938	00001									2.848	00002	N100205-6	LFM-06	LFM-1
5							3.414	00002									2.403	00001	N100205-6	LFM-06	LFM-1
6							3.121	00001									2.296	00001	N100205-6	LFM-06	LFM-1
1							2.223	00001									3.050	00001	N100205-7	LFM-07	LFM-1
2							2.861	00002									3.163	00002	N100205-7	LFM-07	LFM-1
3							2.788	00001									2.693	00001	N100205-7	LFM-07	LFM-1
4							2.559	00001									2.757	00001	N100205-7	LFM-07	LFM-1
5							2.667	00001									2.669	00001	N100205-7	LFM-07	LFM-1
6							2.512	00001									3.128	00001	N100205-7	LFM-07	LFM-1

Attachment # 8

	DISK 1								DISK 2												
KEV	15	(Note)	20	(Note)	25	(Note)	30	(Note)	10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)			
VCR SITE																			Field Id	Lab Id	Erosion Report Number
1							2.567	00001									2.682	00001	6100431	LOSM-01	SKM-2
2							3.080	00001									2.523	00001	6100431	LOSM-01	SKM-2
3							3.189	00002									2.595	00001	6100431	LOSM-01	SKM-2
4							2.786	00001									2.553	00001	6100431	LOSM-01	SKM-2
5							2.897	00001									2.474	00001	6100431	LOSM-01	SKM-2
6							2.530	00001									2.800	00002	6100431	LOSM-01	SKM-2
1							2.786	00001									2.844	00001	6100432	LOSM-02	SKM-2
2							3.779	00002									2.822	00001	6100432	LOSM-02	SKM-2
3							4.517	00002									3.158	00002	6100432	LOSM-02	SKM-2
4							2.811	00001									2.747	00001	6100432	LOSM-02	SKM-2
5							2.888	00001									2.941	00001	6100432	LOSM-02	SKM-2
6							2.910	00001									2.808	00001	6100432	LOSM-02	SKM-2
7							3.043	00002											6100432	LOSM-02	SKM-2
8							2.845	00001											6100432	LOSM-02	SKM-2
1							2.521	00001									2.294	00001	6100433	LOSM-03	SKM-2
2							2.593	00001									2.575	00001	6100433	LOSM-03	SKM-2
3							2.511	00001									2.352	00001	6100433	LOSM-03	SKM-2
4							2.613	00001									2.701	00002	6100433	LOSM-03	SKM-2
5							2.793	00001									2.683	00002	6100433	LOSM-03	SKM-2
6							2.849	00002									2.420	00001	6100433	LOSM-03	SKM-2
7																	2.559	00001	6100433	LOSM-03	SKM-2

Attachment # 9

	DISK 1								DISK 2												
KEV	15	(Note)	20	(Note)	25	(Note)	30	(Note)	10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)			
VCR SITE																			Field Id	Lab Id	Erosion Report Number
1							3.033	00001									2.683	00001	610841-02	TOSM-02	SKM-1
2							3.471	00002									2.631	00001	610841-02	TOSM-02	SKM-1
3							2.888	00001									2.862	00001	610841-02	TOSM-02	SKM-1
4							2.787	00001									2.971	00002	610841-02	TOSM-02	SKM-1
5							3.187	00001									2.595	00001	610841-02	TOSM-02	SKM-1

Attachment # 9

	DISK 1								DISK 2										
KEV	15	(Note)	20	(Note)	25	(Note)	30	(Note)	10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)	
VCR SITE																			Field Id
6							2.800	00001									2.888	00001	610841-0
1							3.932	00001									2.872	00001	610841-0
2							3.332	00001									2.951	00001	610841-0
3							3.766	00001									3.049	00001	610841-0
4							3.068	00001									2.983	00001	610841-0
5							3.684	00001									3.130	00001	610841-0
6							4.040	00002									3.489	00002	610841-0
1							2.131	00001									2.669	00001	610841-0
2							2.318	00001									2.626	00001	610841-0
3							2.814	00001									2.706	00001	610841-0
4							2.207	00001									2.485	00001	610841-0
5							2.371	00002									2.748	00001	610841-0
6							2.340	00001									2.841	00002	610841-0
1							2.875	00001									3.192	00002	610841-0
2							3.084	00001									2.817	00001	610841-0
3							2.694	00001									3.090	00001	610841-0
4							2.962	00001									2.527	00001	610841-0
5							2.782	00001									2.593	00001	610841-0
6							3.707	00002									2.789	00001	610841-0
1							4.724	00001									5.840	00001	610841-0
2							4.661	00001									5.673	00002	610841-0
3							4.613	00001									5.083	00001	610841-0
4							4.392	00001									4.570	00001	610841-0
5							5.214	00002									4.919	00001	610841-0
6							4.758	00001									4.888	00001	610841-0
1							2.954	00001									2.200	00001	610841-0
2							2.920	00001									2.455	00001	610841-0
3							2.672	00001									2.516	00001	610841-0
4							2.857	00001									2.466		610841-0
5							2.722	00001									2.756	00002	610841-0
6							2.971	00002									2.557	00001	610841-0

Attachment #10

	DISK 1								DISK 2										
KEV	15	(Note)	20	(Note)	25	(Note)	30	(Note)	10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)	
VCR SITE																			Field Id
1							2.178	00001									2.062	00001	2111051A
2							1.960	00001									2.057	00001	2111051A
3							2.175	00001									2.232	00001	2111051A
4							1.905	00001									2.172	00001	2111051A
5							1.916	00001									2.329	00002	2111051A
6							2.360	00002									2.113	00001	2111051A
1							2.652	00001									2.492	00001	2111051A
2							2.958	00001									2.462	00001	2111051A
3							2.735	00001									2.496	00001	2111051A
4							2.074	00001									2.476	00001	2111051A
5							3.405	00002									2.664	00002	2111051A
6							2.673	00001									2.662	00001	2111051A
7							3.132	00002											2111051A
1							2.205	00001											2111051A
2							2.167	00001											2111051A
3							2.239	00001											2111051A
4							2.410	00001											2111051A
5							2.272	00001											2111051A
6							2.533	00002											2111051A
1							2.707	00002									2.090	00001	2111051A
2							1.959	00001									2.432	00001	2111051A
3							2.346	00001									2.279	00001	2111051A
4							2.058	00001									2.501	00002	2111051A
5							2.307	00001									1.837	00001	2111051A
6							2.254	00001									1.802	00001	2111051A

Attachment #11

KEV / VCR SITE	DISK 1 15	(Note)	20	(Note)	25	(Note)	30	(Note)	DISK 2 10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)	Field Id	Lab Id	Erosion Report Number
1							2.339	00001									2.453	00001	2111051-01	MRM-01	STM-3A
2							2.658	00001									3.021	00002	2111051-01	MRM-01	STM-3A
3							2.700	00002									2.516	00001	2111051-01	MRM-01	STM-3A
4							2.475	00001									2.532	00001	2111051-01	MRM-01	STM-3A
5							2.547	00001									2.727	00001	2111051-01	MRM-01	STM-3A
6							2.244	00001									2.311	00001	2111051-01	MRM-01	STM-3A
1							4.305	00001									4.630	00002	2111051-02	MRM-02	STM-3A
2							3.908	00001									3.921	00001	2111051-02	MRM-02	STM-3A
3							4.397	00001									4.573	00001	2111051-02	MRM-02	STM-3A
4							4.520	00001									4.031	00001	2111051-02	MRM-02	STM-3A
5							4.770	00001									4.015	00001	2111051-02	MRM-02	STM-3A
6							5.066	00002									4.613	00001	2111051-02	MRM-02	STM-3A
1							2.031	00001									2.420	00001	2111051-03	MRM-03	STM-3A
2							2.200	00001									2.603	00002	2111051-03	MRM-03	STM-3A
3							2.809	00002									2.144	00001	2111051-03	MRM-03	STM-3A
4							1.885	00001									2.333	00001	2111051-03	MRM-03	STM-3A
5							2.404	00001									2.500	00001	2111051-03	MRM-03	STM-3A
6							2.794	00001									2.244	00001	2111051-03	MRM-03	STM-3A
1							2.634	00001									2.521	00001	2111051-04	MRM-04	STM-3
2							2.813	00002									3.323	00002	2111051-04	MRM-04	STM-3
3							2.512	00001									2.420	00001	2111051-04	MRM-04	STM-3
4							2.586	00001									2.511	00001	2111051-04	MRM-04	STM-3
5							2.642	00001									2.567	00001	2111051-04	MRM-04	STM-3
6							2.812	00001									2.501	00001	2111051-04	MRM-04	STM-3
1							2.621	00002									2.720	00001	2111051-05	MRM-05	STM-3A
2							2.278	00001									2.796	00001	2111051-05	MRM-05	STM-3A
3							2.523	00001									2.669	00001	2111051-05	MRM-05	STM-3A
4							2.563	00001									2.842	00001	2111051-05	MRM-05	STM-3A
5							2.409	00001									3.353	00002	2111051-05	MRM-05	STM-3A
6							2.239	00001									2.908	00001	2111051-05	MRM-05	STM-3A
1							2.752	00001									2.846	00001	2111051-06	MRM-06	STM-3A
2							2.221	00001									3.037	00002	2111051-06	MRM-06	STM-3A
3							2.321	00001									2.300	00001	2111051-06	MRM-06	STM-3A
4							2.415	00001									2.540	00001	2111051-06	MRM-06	STM-3A
5							2.811	00002									2.357	00001	2111051-06	MRM-06	STM-3A
6							2.695	00001									2.356	00001	2111051-06	MRM-06	STM-3A

Attachment #12

KEV / VCR SITE	DISK 1 15	(Note)	20	(Note)	25	(Note)	30	(Note)	DISK 2 10	(Note)	15	(Note)	20	(Note)	25	(Note)	30	(Note)	Field Id	Lab Id	Erosion Report Number
1	2.045		2.016		1.905	00001	2.076								1.740	00001	1.755		CDM072700-11	BM-01	BM-1
2					2.051		1.913	00001							1.772	00001	1.839		CDM072700-11	BM-01	BM-1
3					1.752	00001	2.022								1.865	00001			CDM072700-11	BM-01	BM-1
4					2.070		1.897	00001							1.791	00001			CDM072700-11	BM-01	BM-1
1					1.851		1.817	00001							1.863	00001	2.041		CDM072700-12	BM-02	BM-1
2					2.008		1.927	00001							1.799	00001			CDM072700-12	BM-02	BM-1
3					2.023		1.914	00001							1.746	00001			CDM072700-12	BM-02	BM-1
1					2.170	00001	2.252						1.897	00001	2.177				CDM072700-13	BM-03	BM-1
2					2.261	00001	2.274						2.228		2.192	00001			CDM072700-13	BM-03	BM-1
3					2.123	00001	2.299						1.963	00001	2.142				CDM072700-13	BM-03	BM-1
1					2.000		1.864	00001							2.024		1.976	00001	CDM072700-14	BM-04	BM-1
2							1.860	00001							2.505		2.259	00001	CDM072700-14	BM-04	BM-1
3					1.915	00001	1.976								2.000	00001			CDM072700-14	BM-04	BM-1
4															2.052	00001			CDM072700-14	BM-04	BM-1
1			3.124		2.955	00001	3.014								3.065	00002			CDM072700-15	BM-05	BM-1
2					3.042	00001									2.503	00001			CDM072700-15	BM-05	BM-1
3					2.700										2.106	00001			CDM072700-15	BM-05	BM-1
4															2.525	00001			CDM072700-15	BM-05	BM-1
1					1.909		1.800	00001									1.910	00001	CDM072700-16	BM-06	BM-1
2							1.992	00001							1.962	00001	1.969		CDM072700-16	BM-06	BM-1
3							2.090	00001									2.430	00002	CDM072700-16	BM-06	BM-1
4															2.060	00001	2.146		CDM072700-16	BM-06	BM-1

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SESSION 142, 1:00 p.m.
THURSDAY, NOVEMBER 9, 1989
QUATERNARY II
CCC: 267

INFORMATION ONLY

Nº 13410

HOLOCENE PALEOWINDS IN THE MOJAVE DESERT RECORDED BY ROCK VARNISH DATING OF VENTIFACTS: GREENHOUSE ANALOGY

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The mapping of ventifact groove trends on large boulders and bedrock outcrops in the Mojave Desert provides a record of near surface strong wind circulation. Accelerator-radiocarbon and cation-ratio dating of rock varnishes formed on these grooves provides close minimum ages for the cessation of aeolian abrasion, from the mid-Holocene to the present.

Three radiocarbon (R) and 9 cation-ratio (CR) dates are available at this time. All are minimum limiting estimates for the end of aeolian abrasion. WNW facing ventifacts at Tortoise Hill, SE of Ludlow, yield varnish ages of 5.5 ± 0.6 ka (CR), 5.6 ± 0.5 ka (CR), and 6.0 ± 0.1 ka (R). A SE facing ventifact at the same site is 3.6 ± 0.3 ka (CR). Similar ventifacts in the Cronese Basin yield ages of 5.4 ± 0.3 ka (CR), 4.5 ± 0.1 ka (R), 5.1 ± 0.3 ka (CR), 5.4 ± 0.4 ka (CR), and 5.3 ± 0.6 ka (CR). Ventifacts on the Amboy Lava Flow yielded ages 2.7 ± 0.3 ka (CR) and 2.5 ± 0.1 ka (R), whereas those on the Pisgah Lava Flow are < 0.3 ka (CR).

Based on this preliminary ventifact data set, and on the evidence of dune building episodes in the Cronese basin and vicinity, it appears that aeolian activity was more active in the Mojave Desert in the mid-Holocene. The nature of aeolian abrasion contains time- and space-transgressive elements, with some areas experiencing a cessation of abrasion while others continue to remain active.

These results demonstrate that a thorough mapping and dating of mid Holocene ventifacts would provide a unique regional record of near surface strong wind paleocirculation. If the period before about 5000 years ago was a time of greater global warmth, this regional paleocirculation record could prove to be a valuable analog to a greenhouse earth.

Nº 20471

BARIUM CONCENTRATION IN ROCK VARNISH: IMPLICATIONS FOR CALIBRATED ROCK VARNISH DATING CURVES

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Cation-ratio dating is an effective means of dating a variety of geomorphic surfaces, utilizing a ratio of minor cations [(K+Ca)/Ti] in rock varnish. Although this ratio is directly related to the Ti concentration, it can also be affected by the presence of Ba that may be analytically included in the recorded concentration of Ti.

Ba is a minor constituent found in virtually all rock varnishes sampled from southern Nevada including the Lake Mead area, Las Vegas Valley, and the Yucca Mountain region. Ba is heterogeneously distributed in rock varnish, both with depth in the varnish and laterally across the varnish surface. Ba concentrations appear greater in younger varnishes (<100 ka) than in older varnishes (>500 ka), and they are greater in varnishes on topographically low surfaces than in varnishes on hillslope or ridge deposits.

The presence of Ba in rock varnish is problematic when the analyses are by energy dispersive spectroscopy (EDS), where the Ti K-alpha and K-beta peaks overlap the Ba L-alpha and L-beta peaks, respectively. Unless the overlapping lines are deconvolved, a part of the Ba L-alpha peak is recorded as a component of the Ti K-alpha peak, yielding an erroneously large value for Ti. In order to evaluate the effect of Ba concentration on our Yucca Mountain rock-varnish dating curve we have utilized both a quantitative EDS program (MICROQ) with the scanning electron microscope and a wavelength-dispersive analyzer with the electron microprobe to derive Ti values that are unaffected by Ba. Small amounts of Ba do not yield a Ba L-alpha peak large enough to change significantly the value of the calculated varnish cation ratio (VCR). The effect of Ba on calculated VCRs is most pronounced for younger varnish samples, where Ba concentrations are high, resulting in calibrated rock varnish dating curves with too low a slope for the young part of the curve.

Nº 1787

ROCK VARNISH, ALLUVIAL FANS, AND TECTONISM IN THE SOUTHERN OWENS VALLEY, CALIFORNIA

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We are using geologic mapping, remote sensing, relative dating techniques, and rock varnish analyses to constrain the history of fan aggradation and tectonism in the southern Owens Valley.

Bouldery deposits adjacent to Lone Pine Creek, a perennial stream draining a formerly glaciated basin in the Sierra Nevada, extend eastward up to 10km from the range front. An unusual sequence of stream capture events has isolated and preserved alluvial fan surfaces of four distinct ages. Comparison with chronosequences studied on other Sierran fans suggests that the surfaces at Lone Pine range in age from Holocene to perhaps Tahoe.

The younger fans are composed predominately of poorly stratified, poorly sorted, matrix-supported diamictons probably deposited by debris flows. Limited exposures in older fans suggest that a greater percentage of these deposits are clast-supported and are likely of fluvial origin. All deposits contain a predominance of granodiorite and aplitic clasts derived from the Mount Whitney pluton.

A scarp of the Lone Pine Fault of the Owens Valley Fault Zone offsets at least two of the fan surfaces (Lubetkin and Clark, 1988). In addition to using our age estimates for offset fan units, we are using thermoluminescence, varnish radiocarbon, and varnish cation-ratios to constrain the timing of movement on this fault scarp.

Nº 24416

PALEOCLIMATIC IMPLICATIONS OF CHLORIDE PROFILES: APPLICATIONS FOR TOXIC WASTE DISPOSAL AND LONG TERM GROUND WATER PROTECTION, WHISKY FLAT AND BEATTY, NEVADA

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Chloride mass balance (CMB) was used at Whisky Flat and Beatty, Nevada to determine the impact of long-term climatic change on ground water recharge rates and percolation depths. Availability of paleoclimatic information permitted reconstruction of qualitative changes in effective precipitation which could be compared with rates and depths determined from the CMB method. CMB results support earlier interpretations of increased effective precipitation in the Pleistocene. In addition, two subsurface moisture studies at Beatty drew similar conclusions regarding percolation depths.

Six sites at Whisky Flat and one at Beatty were cored and analyzed for distribution of chloride with depth. High, intermediate, and low chloride concentration zones appeared in each chloride profile. Recharge rates for Whisky Flat, based on the low concentration zone, are 0.04-0.8 mm/yr. 0.8 mm/yr is interpreted as representing the maximum recharge rate possible through the alluvial sediments under conditions of increased effective precipitation. Recharge is limited to the upper 8 m at Beatty.

High chloride concentrations occur at the Beatty site at 1.75-4.5 m and at Whisky Flat in the upper 7.7 m. This zone probably records the maximum depth of root influence during the Pleistocene. Intermediate chloride concentrations occur from 4.5-7.7 m at Beatty and from 7.7-8.6 m at Whisky Flat. This is interpreted as recording the most frequent depth of deep percolation prior to the change in vegetation which proceeded to concentrate chloride higher in the profile. The two zones indicate a lag time between the changes. Thus, sediments above 8.6 m at Whisky Flat and 7.7 m at Beatty occur within the long-term, hydrologically active zone. Sediments below are within a hydrologically semi-stable zone. In both areas, recharge appears to have been minimal to nonexistent, even under the wetter Pleistocene climate.

Nº 24497

LATE QUATERNARY AEOLIAN GEOMORPHOLOGY OF THE DALE LAKE SAND SHEET, MOJAVE DESERT, CALIFORNIA

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The Dale Lake Sand Sheet consists of a series of climbing dunes deposited against the southwest flank of the Sheephole Mountains in the southern Mojave Desert. Several ephemeral streams have dissected the sand sheet exposing the underlying sediments. The latter exhibit significant paleosols and other weathering horizons. The largest of the "dune wadis" is about 2 km long, 90 to 100 m wide at its contact with the bedrock, and up to 40 m deep. The surface of the sand sheet is mostly stabilized by vegetation and veneered with rock talus from the adjoining mountains.

Geomorphic and sedimentological analysis of aeolian sediments, combined with scanning electron microscopy (SEM) of quartz-grain characteristics, suggest 6 to 8 dune-building episodes during late Quaternary time. It is likely that at least 4 aeolian episodes have occurred since the last Wisconsinan glacial maximum around 18 ka, with peak deposition during earlier Holocene time, followed by reduction of aeolian activity and the formation of rock varnish around 5 ka. One major episode, with several depositional pulses, probably occurred between 8 and 5 ka.

The dune-building episodes most probably follow significant climatic transitions, such as the Pleistocene-Holocene transition during which atmospheric conditions changed from cool and wet to hot and arid. The various aeolian sediments accumulated largely in response to the lowering of water levels in lake basins and a consequent increase in fine sediment availability, and to stronger and more persistent winds.

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BARIUM CONCENTRATION IN ROCK VARNISH: IMPLICATIONS FOR CALIBRATED ROCK VARNISH DATING CURVES

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Abstract

Cation-ratio dating of rock varnish is a recently developed technique for obtaining surface exposure ages of a wide variety of geomorphic surfaces. As originally proposed, the technique utilizes a ratio among minor cations [(K+Ca)/Ti] in rock varnish. Although this varnish cation ratio is related to the Ti concentration, it can also be affected by the presence of Ba that may be partially included in the analyzed concentration of Ti. Barium is a minor constituent found in virtually all rock varnishes sampled from the Lake Mead area, Las Vegas Valley, and the Crater Flat region of southern Nevada. Barium is heterogeneously distributed in rock varnish, associated predominantly with Mn and secondarily with sulfur (detrital barite). Barium concentrations are apparently greater in varnishes found on young surfaces (< 100 ka) than in varnishes found on older surfaces (> 500 ka), and they are apparently greater in varnishes on low elevation surfaces than in varnishes on hill-slope or ridge deposits.

In energy dispersive spectroscopy (EDS), Ba L_α and L_β peaks overlap with Ti K_α and K_β peaks. Unless decomposed, the overlapping peaks may yield erroneously large values for Ti. We have compared the effect of Ba concentration on calculated varnish cation ratios using: (1) quantitative EDS with the scanning electron microscope (SEM) that decomposes Ti and Ba peaks; (2) quantitative wavelength-dispersive spectroscopy (WDS) with an electron probe microanalyzer (EPM); (3) semi-quantitative EDS with the SEM that decomposes Ti and Ba peaks; and (4) semi-quantitative EDS with the SEM that does not decompose Ti and Ba lines. Results suggest small amounts of Ba relative to Ti will not significantly change the value of the calculated varnish cation ratio with or without decomposition. However, if Ba concentrations are high relative to Ti, the effect on cation ratios is pronounced, resulting in anomalously low cation ratios. As younger varnishes and varnishes on topographically lower surfaces apparently have higher Ba concentrations, the effect of Ba on cation ratios calculated for younger rock varnishes and lower surfaces will be greater.

KEY WORDS: Rock varnish, cation-ratio dating, barium, barium-titanium decomposition, Southern Nevada, scanning electron microscopy.

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Introduction

Rock varnish is a Mn- and/or Fe-rich coating commonly found on rock exposures in arid and semiarid regions. Dorn (1983) proposed a technique for using rock varnish to estimate the age of geomorphic surfaces utilizing a ratio of minor elements in the varnish [(Ca+K)/Ti] calculated for specific geographic areas. This ratio is thought to decrease with varnish age and has been calibrated using isotopically dated surfaces to construct rock varnish dating curves (plots of cation ratio versus log time). The importance of the rock varnish dating technique lies in the wide variety of young (< 1 Ma) geomorphic surfaces that possess rock varnish on surface clasts and thus could potentially yield surface exposure ages derived from rock varnish analysis.

It is now commonly accepted that rock varnish components are of detrital origin, with 30% to 70% of the varnish composed of eolian transported clay minerals (e.g., Potter and Rossman, 1979). Manganese and Fe are markedly enhanced in the varnish over levels within eolian detritus. Barium has been reported to be a minor constituent of rock varnishes (Engle and Sharp, 1958, Potter and Rossman, 1979), but the prevalence and distribution of Ba in rock varnish, either geographically or within a single sample, has not been previously described. Furthermore, the relationship of Ba incorporated in rock varnish to the regional dust composition and proximity to Ba sources has not been addressed. In this paper we discuss two aspects of Ba as a constituent of rock varnishes: (1) the distribution of Ba in rock varnishes from southern Nevada; and (2) the effect that this occurrence of Ba has on measuring Ti concentrations and therefore on calculated cation ratios used in rock varnish dating curves.

Low concentrations (< 2 wt%) of Ba in the presence of Ti are difficult to detect when the analysis is by energy-dispersive spectroscopy (EDS). The K_α and K_β lines for Ti occur at nearly the same energies (within ~50 eV) as the L_α and L_β lines for Ba, resulting in the overlap of these peaks in an EDS analysis (Fig. 1). The problem of peak overlap of Ba and Ti occurs in any analysis that uses EDS, whether in conjunction with a scanning electron microscope (SEM), an electron probe

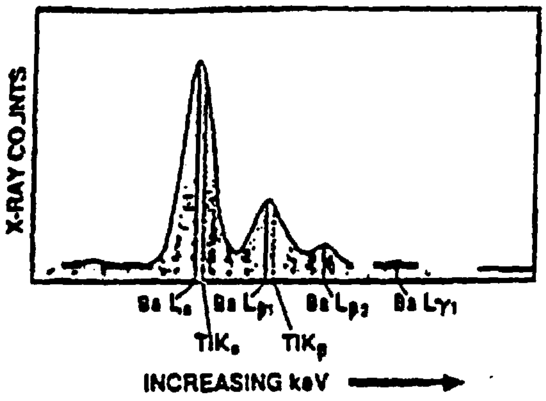

Figure 1. SEM EDS spectra of material containing both Ti and Ba illustrating the overlap of Ti K_α and K_β and Ba L_α and L_β peaks.

microanalyzer (EPM), or a proton probe utilizing proton induced x-ray emission (PIXE). If the peak overlaps are not decomposed following analysis, then a portion of the Ba concentration will be misidentified as Ti. This will result in an erroneously high Ti concentration, and consequently, a cation ratio that is erroneously low.

In earlier analyses of rock varnishes from southern Nevada, Harrington and Whitney (1987) used a Tracor Northern standardless semi-quantitative EDS program (SSQ) that performed no decomposition of peak overlaps during SEM analysis. Based on our present understanding of Ba occurrence in rock varnishes in this region, we believe the Ti concentrations that were calculated during these earlier analyses erred towards overestimation, yielding cation ratios that were lower than would be calculated using Ti concentrations unaffected by Ba occurrence.

Dorn (1989b, p. 575) has stated that "Energy-dispersive X-rays analyzed with a SEM cannot separate barium from titanium when they are in similar concentrations at levels around 1%". In this paper we document that, in fact, such separation of Ba from Ti is possible using both quantitative (MICRO Q) and semi-quantitative (SQ) Tracor Northern EDS analytical programs, each of which decompose overlapping Ti and Ba peaks. We also document that SEM EDS analyses yield similar results to wavelength dispersive spectrometer (WDS) analyses of the same varnish using an EPM. Comparison of our SEM and EPM results with reported proton probe PIXE analyses of rock varnish on the same geomorphic features (Dorn, 1989a), indicates a systematic difference in Ba values for similar aged rock varnish and suggests the lack of adequate separation of Ba from Ti during the reported PIXE analyses.

Materials and Methods

The data discussed in this paper were acquired on an ISI-DS 130 SEM and a Cameca MBX EPM. Both were equipped with Tracor Northern 5500 EDS systems. EDS analyses utilized three programs of which one was quantitative (MICRO Q), and two were semi-quantitative (SQ and SSQ). WDS analyses on the EPM provides quantitative data. SEM and EPM analyses were made both on rock varnish surfaces and cross-sections of rock varnish. SEM cation ratio analyses of varnish surfaces follow the procedure described in Harrington and Whitney (1987) and Harrington and Raymond (1989). We analyze the varnish on 2 cm diameter, 0.5 cm thick disks made from cores drilled through the varnish and rock substrate on each varnished clast. A low magnification (~ 30x) is used to obtain a relatively large surface area (~ 12 mm^2) in each analysis. The SEM analysis is performed using a working distance of 30 mm, a takeoff angle of 40 degrees, and a counting time of 100 to 130 s with 20% to 30% dead time. We use progressively increasing accelerating voltages to obtain deeper penetration into the varnish. SEM analyses of cross-section transects utilized the same working distance and take off angle, but maintained a spot size acquisition mode, and accelerating voltage of 15 kV, and an acquisition time of 100 s.

EPM analyses of varnish surfaces and cross-sections utilizing Bence Albee corrections are based on standards and use a preset counting precision of 1% with a default maximum time of 40 seconds for each element analyzed. Analyses of Ti and Ba in rock varnish seldom achieve the 1% counting precision and, instead, are terminated at the 40 second default time. Counting precision for these elements is generally < 7%. Analyses are also frequently defaulted at 40 seconds in the analysis of Ca and K with a counting precision generally < 3%. Each EPM analysis of Ba for surface samples represents the average concentration for three 400 μm^2 rastered area analyses on a varnished disk. Cross-section analyses were acquired in a spot mode.

Using the EDS program MICRO Q, all x-ray peak intensities are $\phi(\rho Z)$ (PRZ) corrected before elemental weight percents are calculated for varnish constituents. MICRO Q utilizes sets of elemental reference standards to perform quantitative analyses. This program allows these reference standards to be input at each of the accelerating voltages at which analyses will be run. Additionally, MICRO Q performs a decomposition of peak overlaps resulting in Ti values unaffected by the presence of Ba within the varnish (Table 1). In standards that contain either Ba or Ti, but not both, generally only the element present was recorded in the analyses at concentrations above detection limits.

In addition to MICRO Q, a second SEM program, SQ, has been used to decompose overlapping Ba-Ti peaks. SQ analyzes x-ray spectra using a library of references stored on disk. Since standard data are retrieved from storage rather than acquired prior to analysis, the SQ program is considered semi-quantitative. The program uses multiple least squares analysis and a PRZ matrix correction procedure to calculate elemental concentrations.

Table 1. MICRO Q and SQ analyses of standards

Standard	Concentration in Standard (wt%)	Concentration (wt%) WDS-Microprobe	MICRO Q Analyses (wt%)	SQ Analyses (wt%)
Barite			N=5	N=5
BaO	65.43		65.17±0.03	55.34±0.63
TiO_2	≤0.00		0.60±0.38	BDL
Augite			N=10	N=10
BaO	≤0.00		BDL**	0.02±0.06
TiO_2	0.74		0.88±0.06	0.83±0.05
Benitoite			N=12	N=12
BaO	37.05		37.38±1.60	37.31±1.14
TiO_2	19.35		19.29±3.16	18.51±2.59
Synthetic Varnish*		N=5	N=5	N=15
BaO	0.62	0.60±0.13	0.80±0.05	0.62±0.12
TiO_2	1.84	1.73±0.08	1.77±0.03	1.73±0.06

* Synthetic varnish is sample FV-1 from Bierman and Kuehner (to be published).

** BDL below detection limit (detection limit for Ba and Ti is 0.1 wt%).

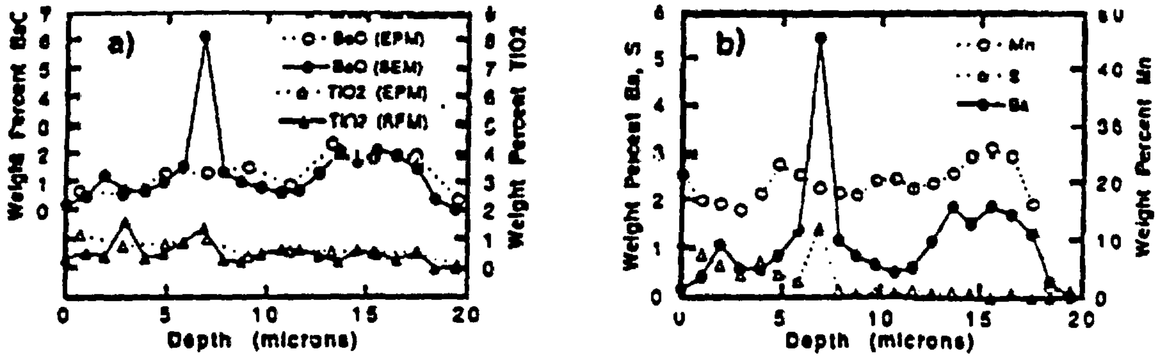

Figure 2a (at left). Replicate line transects of BaO and TiO_2 obtained by SEM EDS analysis using the program SQ and by EPM WDS analysis. Transect 3 on rock varnish sample PW3-25, from Petroglyph Wash, AZ, near Lake Mead, NV. Analytical uncertainty for each EPM analysis is generally about 9-18% for Ba and 10-20% for Ti. Analytical uncertainty for each SEM analysis is generally about 6-20% for Ba and 7-28% for Ti.

Figure 2b (at right). SEM EDS line transects of Ba, S, and Mn in rock varnish cross-sections. Transect 3 on sample PW3-25, from Petroglyph Wash, AZ, near Lake Mead, NV. Transect acquired at 15 kV with 100 second count times, and reduced using SQ program. Analytical uncertainty for each analysis is generally about 1% for Mn, 6-20% for Ba, and 13-37% for S.

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A third SEM program, SSQ, uses a standardless technique that applies peak integration with Krome's Law background modelling to calculate elemental concentrations. SSQ does not decompose Ti and Ba peaks. The SEM is configured in the same manner for MICRO Q, SQ, and SSQ.

Results

One method of checking the ability of SQ to successfully decompose overlapping Ba-Ti peaks is by comparing SEM SQ line transects through varnish cross-sections with EPM WDS analysis transects at approximately the same locations. Although comparisons are limited by the absolute siting of analytical points in the EPM due to poorer image resolution and larger electron beam diameter, general trends in Ba and Ti along transects may be compared. In Figure 2a, TiO_2 values obtained on the SEM using SQ and on the EPM using WDS analysis are similar, and both show decrease in TiO_2 concentration with depth. In addition, BaO values from the two instruments are generally similar, including a broad peak in BaO at a depth of about 13 to 18 µm. A major BaO peak recorded on the SEM at 7 µm, but not measured on the EPM apparently represents a micron-sized detrital barite grain, evidenced by a peak in sulphur at the same spot in the SEM transect (Fig. 2b), that did not fall within the volume of x-ray excitation of the EPM transect. Other than the correlation of Ba with S due to occasional barite grains, the primary correlation of Ba in analyzed rock varnish cross-sections is with Mn (Fig 2b, Fig. 3).

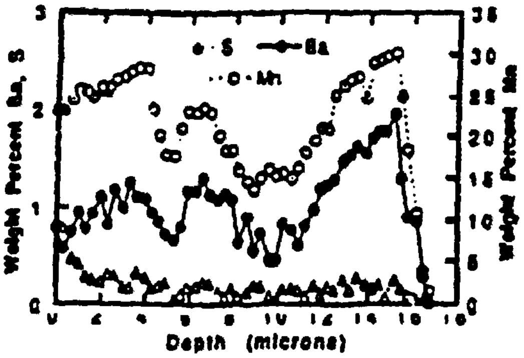

Figure 3. SEM EDS line transects of Ba, S, and Mn in rock varnish cross-sections. Transect 4 on sample LB10-3, from Lava Butte near Las Vegas, NV. Transect acquired at 15 kV with 100 seconds count times, and reduced using SQ program. Analytical uncertainty for each analysis is typically about 1% for Mn, 6-20% for Ba, and 40-60% for S.

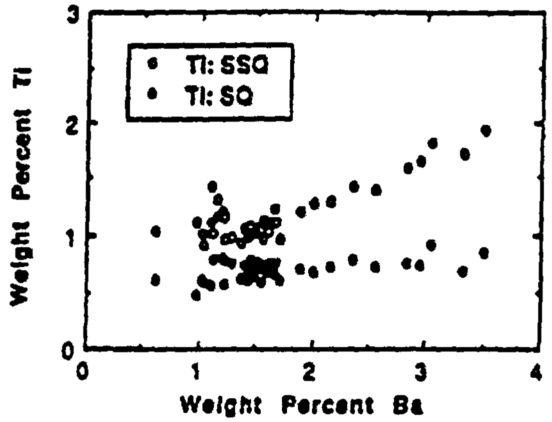

Figure 4. Comparison of SSQ derived Ti concentrations with SQ derived Ti concentrations. Rock varnish samples LB10-3 and LB11-2, from Lava Butte near Las Vegas, NV. Replicate SSQ and SQ analyses acquired at 10, 15, 20, 25, and 30 kV for nine 0.2-12 mm^2 spots, with 200 seconds counting times. Analytical uncertainty for each analysis is 1-3% for the reported SSQ Ti values, 5-15% for the SQ Ti values, and 4-24% for the SQ Ba values.

The inadequacy of SSQ, the EDS program without Ti and Ba decomposition, to provide reliable Ti concentrations in the presence of Ba can be illustrated by comparing spot analyses replicated with SQ and SSQ. Titanium concentrations obtained with SSQ are consistently greater than Ti values from SQ (Fig. 4) due to overlap of the Ba L_α peak with the Ti K_α peak. The Ti values using SSQ are highest where Ba concentrations are highest.

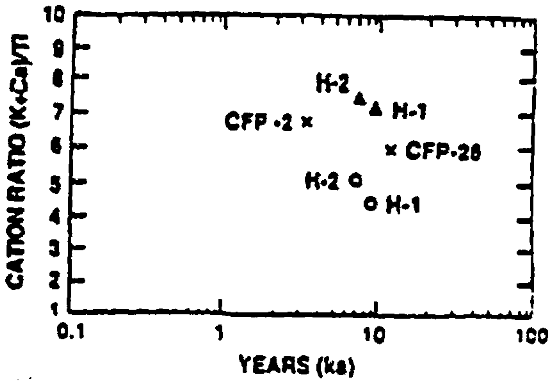

Figure 5. Cation ratios from Holocene surfaces in southern Nevada. Points H-1 and H-2 are from Las Vegas Valley, NV. (Δ) are mean cation ratios calculated with Ba-Ti decomposition performed using SEM EDS MICRO Q analyses. (O) are mean cation ratios calculated using SEM EDS SSQ analyses with no Ba-Ti decomposition. (X) are mean cation ratios of Dorn (1989a) by PIXE analysis.

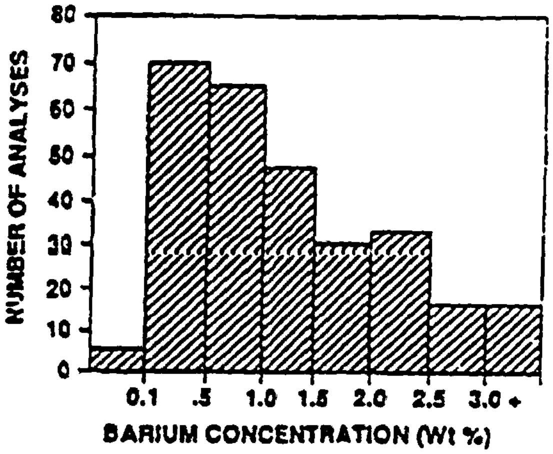

Figure 6. Ba concentrations in rock varnish samples from southern Nevada. Data obtained by EPM analyses using 400 μm^2 spot sizes and SEM analyses of 12 mm^2 areas. Minimum detection limits for Ba are 0.1 wt%.

The effect of Ba on calculation of rock varnish cation ratios if Ba and Ti peaks are not decomposed can be illustrated by comparing cation ratios calculated from SEM analyses of varnish disks using SSQ (non-decomposed) with cation ratios calculated from SEM analyses of the same disks using MICRO Q (decomposed). For rock varnish collected from two Holocene surfaces in Las Vegas Valley, cation ratios using SSQ are more than 30 % lower than cation ratios calculated using MICRO Q (Fig. 5).

Table 2. Barium concentrations in rock varnish for selected deposits from the Crater Flat area, Nevada

Site	Estimated Age(ka)**	Average Ba Concentration (wt%)	Number and Type* of Analyses
Black Cone (lava flow)	1100±200	0.55±0.09	9(P)
		0.34±0.26	5(MQ)
		0.00	5(PI)
Red Cone (lava flow)	1100±135	0.58±0.17	10(P)
		0.00	5(PI)
Lathrop Wells Cone (lava flows)	uncertain	0.48±0.20	5(MQ)
		0.00	15(PI)
Alluvial Surfaces (Crater Flat and Forty mile Wash)			
Q2C	255±15	0.97±0.24	13(P)
JWB-20	190±45	0.00	5(PI)
Q2B	160±70	1.02±0.53	11(P)
CFP-29	137±25	0.00	10(PI)
CF-3	40±10	1.74±0.67	11(P)
		1.75±0.52	15(MQ)
CFP-32	30±0.5	0.00	5(PI)

* (P) = Microprobe (This Paper); (MQ) = SEM using MICRO Q (This Paper); (PI) = PIXE (Dorn, 1989a).
** Age estimates are detailed in Harrington and Whitney (1987) and Dorn (1989a).

Based on over 250 SEM and EPM spot analyses and numerous elemental line scans on varnish cross-sections, the following observations can be made concerning Ba occurrence in rock varnish samples from southern Nevada and adjacent areas:

(1) Barium was detected in 98% of rock varnishes analyzed from the Lake Mead area, from Las Vegas Valley, NV, and from the Crater Flat area in Nye County, NV (Fig. 6). Sampled varnished surfaces range in age from < 10 ka to over 1 Ma; topographic positions of varnish collection sites range from the lowest parts of intermontane basins, at or just above local base levels, to > 300 meters above the basin floors. Rock varnishes from the Cima volcanic field, California (Raymond et al., 1991, this issue) and from New Mexico yielded similar percentages of Ba.

(2) Barium concentrations recorded for southern Nevada varnishes were as high as 3.8 wt% for a varnish surface spot analysis and average > 1.5 wt% for all varnish surface analyses. Concentrations are commonly 1-2 times that of Ti.

(3) Barium concentrations can vary by more than a factor of two both laterally and vertically within rock varnish on a single clast. Average Ba concentrations among a suite of clasts taken from a single geomorphic surface also commonly vary by more than a factor of two.

(4) Barium apparently occurs in higher concentrations in younger varnishes than in significantly older varnishes in the Crater Flat area of southern Nevada. Average Ba concentrations of 0.55 and 0.58 wt% were measured in varnishes on 1.1 Ma lava flow surfaces at Black and Red Cones, whereas average Ba concentrations of 0.97 to 1.75 wt% were measured on nearby alluvial surfaces with estimated ages of 255-40 ka (Table 2).

(5) Barium occurs in higher concentrations in varnishes formed on surfaces at lower elevations in basins than in varnishes on surfaces high on hillslopes or ridges. For example, rock varnish on a hillslope boulder deposit on Little Skull Mountain, NV, has lower Ba values (average concentration 0.23 wt%) than rock varnish occurring 170 meters lower in the basin at Black Cone (0.55 wt%, Table 2). Both varnishes have similar estimated ages, about 1 Ma. Similarly, rock varnish on a boulder deposit on the crest of Yucca Mountain yields lower Ba concentrations (0.47 wt%) than rock varnish with a similar estimated age 400 m lower on an alluvial surface in Crater Flat (1.26 wt%).

Discussion

The ubiquity of Ba within investigated rock varnishes from Nevada and adjacent regions suggests the possibility that Ba may be universally present in rock varnishes of the southwestern U.S. Thus, most Ti values measured using EDS, if uncorrected for the presence of Ba, will be erroneously high and calculated cation ratios will be too low. Since Ba concentrations are heterogeneous at all scales, cation ratios from an area, previously obtained with programs performing no Ba-Ti decomposition, can not be satisfactorily adjusted for Ba occurrence by applying a single correction factor. Instead, in constructing rock varnish dating curves, cation ratios should be used for which individual analyses incorporate a Ba-Ti decomposition. The apparent relationship of Ba concentration to varnish age may partially reflect apparent topographic relationships in that younger surfaces generally lie closer to the local base level and therefore lower in the basin than do older, generally higher surfaces. Therefore, Ba concentrations in rock varnish may most influence cation ratios calculated for younger varnishes forming in low-lying basin environments in close proximity to sources of Ba.

Rock varnish dating curves have been constructed for the Crater Flat area by Harrington and Whitney (1987), and by Dorn (1989a). Barium concentrations reported from PIXE analyses of rock varnish by Dorn (1989a, Table 6) differ markedly from our analyses (Fig. 6). Of 117 PIXE analyses of varnish reported by Dorn (1989a) only six include the presence of any detectable Ba. For the other 111 samples, representing 95% of the total analyses, no Ba greater than .01 percent is reported. In addition, we have found Ba in rock varnish on all geomorphic surfaces examined in the Crater Flat area. These sites include several lava flows and colluvial boulder deposits in addition to sites on more than a dozen alluvial surfaces. Dorn (1989a), in contrast, reported Ba in samples from only two of 17 geomorphic surfaces in Crater Flat, and for these two surfaces only half of the total samples were reported to contain any Ba. Sites reported by Dorn (1989a) to contain no Ba include three lava flows where we found average Ba concentrations of approximately 0.5 wt% and three alluvial surfaces of similar estimated age to surfaces where we found pervasive Ba (Table 2).

The lack of reported Ba in the varnish analyses of Dorn (1989a) from the same region where we show an almost universal presence of Ba strongly suggests that Ba was not quantified and that decomposition of Ba-Ti peak overlaps was not adequately performed for his PIXE analyses. Therefore, we believe that the Dorn (1989a) data are biased by erroneously high Ti values in much the same manner as were our earlier SSQ analyses.

Barium in rock varnish seems to be generally associated with Mn, shown by strong positive correlations of Ba and Mn in line transects through varnish cross-sections (Figs. 2b and 3; see also Raymond et al., 1991, this issue). Although in some analyses barite ($BaSO_4$) grains are evidenced by a coincidence of distinct Ba and S peaks (Fig. 2b), Ba and S concentrations commonly have no distinct correlation in line transects (Fig. 3). Thus, Ba concentrations can not be correlated directly with barite occurrence. Rather, Ba content is typically correlative with Mn concentration.

Conclusions

In environments such as southern Nevada, Ba occurrence in rock varnish is apparently ubiquitous. If Ba and Ti peak overlaps are not adequately decomposed during chemical analyses of rock varnish, any rock varnish dating curve calibrated using such erroneously high Ti values will be lower than curves developed using Ti values decomposed from Ba. Therefore, we emphasize the need to re-evaluate all rock varnish dating curves and to refine them as appropriate.

The inadequacy of SSQ to provide reliable Ti concentrations in the presence of Ba suggests the need for re-analysis, using either MICRO Q or SQ, of the rock varnish samples used in the calibration of the rock varnish dating curve of Harrington and Whitney (1987). Similarly, the absence of Ba in PIXE analyses reported by Dorn (1989a), despite the widespread occurrence of Ba in rock varnishes of this region and in other parts of the Southwest, suggests the need for a re-evaluation of his rock varnish chemical data. In particular, we suggest that the rock varnish dating curves generated from these reported PIXE data are suspect, as are any rock varnish dating curves derived from chemical data obtained in a similar fashion.

Finally, available data suggest a correlation of Ba concentration with varnish age. This in turn suggests the possibility that Ba might be useful as a standard elemental component in cation ratio calculations for rock varnish dating.

Acknowledgments

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Discussion with Reviewers

J.A. Minkin: In PIXE analysis the penetration of the beam into the target is much greater than for SEM or EPM (probably up to 20 times as great), and thus the volume sampled in each analysis is much greater in PIXE. Do you think this can account for the discrepancies in the amount of Ba detected by the different methods?

Authors: It should be noted that the PIXE analyses of Dorn (1989a) are made of powdered rock varnish that has been scraped off the substrate on which it was accreted, whereas our varnish analyses are made of *in situ* rock varnish obtained by coring through the varnish into the substrate (see Materials and Method section). Although we find the concentration of Ba to be variable in analyses of both varnish surfaces and cross sections, it is consistently present at higher concentrations than reported in Dorn (1989a). Therefore, we believe that the lower Ba concentrations reported by Dorn are not due to analyzing a larger volume of rock varnish.

J. A. Minkin: Are the cation ratios for Dorn's PIXE analyses in Fig. 5 determined for the same samples as those represented by your SEM analyses? If so, can you suggest what significance there may be to the fact that the two PIXE analyses lie between your SEM data corrected and uncorrected for Ba?

Authors: The samples used for Dorn's PIXE analyses are not the same as those used for our SEM analyses. However, the samples used for the PIXE analyses were obtained from similar types and ages of surfaces within the same geographic area (Crater Flat) of southern Nevada as were the bulk of the samples we analyzed by SEM. We suggest that the discrepancies between our cation ratios, calculated using Ti and Ba values where decomposition has been performed, and the PIXE analyses, may indicate that even if Ba-Ti decomposition is being performed with the reported PIXE analyses, this decomposition is not adequate and the reported Ti concentrations are still erroneously high.

R.I. Dorn: There is a misunderstanding of how to read Table 6 in Dorn (1989a). Table 6 is a direct output of my computer data file. 0.00 was entered if the element is below the limit of detection or if elements were not specifically requested by the user. I forgot to specifically request Ba and many other elements in the output reported in Table 6. Even though Ba was not specifically requested, the laboratory analyzing the samples reported anomalously high levels of Ba in six samples; only anomalously high results were reported in the hard copy output sent to me and these were included in Dorn, 1989a. More typical values were not sent and therefore were not included. I apologize for a confusion that is my fault.

Authors: Indeed it is difficult to compare data when values reported as 0.00 in fact represent values that are anything less than "anomalously high" (< 0.51 wt%, minimum concentration of Ba reported in Table 6, Dorn, 1989a). We note that the average Ba concentration for our 250 analyses was > 1.5 wt% (see text, Fig. 6), higher by a factor of three than the values reported as "anomalously high" by Dorn. In addition, the average Ti concentration within our samples is 0.38 wt% compared to an average value of 1.66 wt% for the samples of Dorn (1989a). Thus, our Ti concentrations are lower by a factor of > 4. We feel, therefore, that until it has been demonstrated that the PIXE analyses incorporate a reliable Ba-Ti decomposition that any curves derived from such data should still be considered suspect.

R.I. Dorn: The authors stress a significant difference between the amount of Ba found by Dorn (1989a) and their results. Because I agree this is an issue that needs to be resolved, it is imperative that the authors clearly present their criteria for (a) how they select varnish to be sampled in the field and (b) whether they analyze every sample collected in the field; if not, how they select the field samples to analyze. Selection criteria that I use are detailed in Dorn (1989a), Krinsley et al. (1990), and Dorn et al. (1990). The authors do not specify in this paper how the 10 to 12 clasts measured from each site are selected. I suspect that different types of samples are being compared, because I get anomalously high barium results if samples are collected differently (Dorn et al., 1990) and because comparisons of PIXE with ICP-AES and wavelength dispersive microprobe on the same samples yield similar (K+Ca)/Ti ratios (Dorn, 1989b; Dorn et al., 1990). Their claims can not be assessed properly unless the authors are as explicit as possible on how they decide which varnishes to analyze.

Authors: We note that the implied high accuracy of Ba measurements by PIXE analyses has never been demonstrated. Before the role of sampling protocol can be considered as a factor in producing variations in the chemical constituents of rock varnish, the accuracy of measurements by analytical systems and procedures need to be established.

The ubiquitous presence of Ba in our rock varnish samples that were collected over a period of three years argues strongly that our chemical data are not simply an artifact of a sampling bias. Analyzed samples were collected from alluvial surfaces, lava flows, hillside boulder deposits, and debris flow lobes from southern Nevada, southern California, northern Arizona, and New Mexico, and from a variety of orientations and topographic positions on sampled surfaces. In addition to criteria outlined in Harrington and Whitney (1987), the samples were collected consistent with most of the criteria discussed by Dorn (1983). Thus, we suggest that the near universal presence of Ba within our samples implies a widespread and common occurrence of Ba in rock varnishes of the southwestern U.S.

J.A. Minkin: I think deconvolution is a more suitable word than decomposition, as used numerous times in this paper. Decomposition has a strong chemical connotation, whereas deconvolution is, I believe, more generally used with reference to curve stripping (which is indeed what you are doing)

Authors: In previous versions of this paper we used "deconvolution" instead of "decomposition" until a colleague pointed out to us that, by a strict mathematical definition, elemental peak stripping routines used in energy dispersive analyses are not deconvolutions. Standard peak stripping routines use a multiple least-squares curve fitting procedure. In contrast, a convolution is the product of Fourier transforms of two functions and true deconvolutions consist of a more involved mathematical procedure. We have chosen to use decomposition as a more generic term for any peak stripping routine. We see no problem with the chemical implication associated with the term decomposition, for indeed we are determining the chemistry of the analytical point.

J.A. Minkin: What are the minimum detection limits (MDL's) for your SEM analyses? Are the weight percents of TiO_2 (Fig. 2a) and S (Fig. 2b) really above the MDL's?

Authors: MDL's for our SEM analyses were calculated as three standard deviations above the intensity (measured as count rate) of the background. MDL's for elements in our rock varnish analyses vary between 0.13 wt% and 0.08 wt% as counting dead time varies between 15% and 40%. Thus, the trends defined by TiO_2 and S in Figs. 2a and 2b reflect analyses above MDL's.

P.R. Bierman: Are there peak overlaps other than Ti-Ba which could result in poor accuracy when using an EDS to gather x-ray spectra?

Authors: In an EDS analysis of rock varnish there is also an overlap of the K K_β peak with the Ca K_α peak. The effect of this overlap, if not decomposed during analysis, would be to increase the concentration of Ca relative to its true value and thus result in cation ratios that were erroneously high. The Tracor Northern programs MICRO Q and SQ perform a decomposition of the Ca-K overlap during analyses in the same manner as the Ba-Ti peak overlap and yield slightly different values for K and Ca than are obtained using the Tracor SSQ program in which no decomposition is performed

P.R. Bierman: What physical or chemical factors could change the concentration of Ba in varnish with age and with topographic position?

Authors: Although little is yet known regarding the factors that control Ba concentrations in rock varnish, it is logical to assume that Ba is brought to the rock varnish as part of the eolian detrital contribution. As such, factors that control or affect the nature and supply of eolian detritus (e.g., climatic changes within the source region for the eolian detritus) likely play an important role in controlling Ba supply to varnish surfaces through time. In addition, as Ba is apparently associated with the Mn component of varnish, as yet undetermined factors that affect Mn concentration may also affect Ba concentration.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PRELIMINARY DESCRIPTION OF QUATERNARY AND LATE PLIOCENE SURFICIAL DEPOSITS AT YUCCA MOUNTAIN AND VICINITY, NYE COUNTY, NEVADA

By

D.L. Hoover

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1989

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PRELIMINARY DESCRIPTION OF QUATERNARY AND LATE PLIOCENE SURFICIAL DEPOSITS AT YUCCA MOUNTAIN AND VICINITY, NYE COUNTY, NEVADA

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D.L. Hoover

ABSTRACT

The Yucca Mountain area, in the south-central part of the Great Basin, is in the drainage basin of the Amargosa River. The mountain consists of several fault blocks of volcanic rocks that are typical of the Basin and Range province. Yucca Mountain is dissected by steep-sided valleys of consequent drainage systems that are tributary on the east side to Fortymile Wash and on the west side to an unnamed wash that drains Crater Flat. Most of the major washes near Yucca Mountain are not integrated with the Amargosa River, but have distributary channels on the piedmont above the river.

Landforms in the Yucca Mountain area include rock pediments, ballenas, alluvial pediments, alluvial fans, stream terraces, and playas. Early Holocene and older alluvial fan deposits have been smoothed by pedimentation. The semiconical shape of alluvial fans is apparent at the junction of tributaries with major washes and where washes cross fault and terrace scarps. Playas are present in the eastern and southern ends of the Amargosa Desert.

The stratigraphic units described in this report range from Pliocene marsh sediments to modern alluvium. The oldest unit, the waterlaid sediments of Amargosa marsh, were deposited mostly in shallow water in an area that covers approximately 1,250 km^2 of the Amargosa Desert. The lower unit of the waterlaid sediments consists of clay, limestone, and minor amounts of sandstone, which were deposited in lacustrine, playa, and paludal environments, and sheet limestones. Two ash beds in the lower unit have radiometric ages of approximately 3.1 and 2.1 Ma. The upper unit of the waterlaid sediments was deposited in channels eroded in the lower unit. The upper unit consists of, in ascending order, sandstones and gravels, chemical and clastic deposits of clay interbedded with limestone, and a tufa caprock. Vertebrate and invertebrate fossils indicate that the upper unit may be as young as early Pleistocene. River gravels of ancestral Rock Valley Wash were deposited in a channel that parallels modern Rock Valley Wash for at least 10 km. These gravels may be equivalent to the upper unit of the waterlaid sediments.

Unit QTa was deposited throughout the Yucca Mountain area, probably soon after deposition of the upper unit of the waterlaid sediments of Amargosa marsh. Unit QTa consists mostly of debris flow deposits and small amounts of alluvial gravel. After deposition, pedimentation removed as much as 50 m of the unit. A soil on the pediment contains a thick calcic horizon. Residual boulders as much as 10 m in diameter protrude above the pediment. After soil development, the unit was dissected by subparallel drainage systems. Ridges between drainages form ballenas that are typical of unit QTa. A regional

unconformity between units QTa and Q2 is defined by the dissected surface of unit QTa, pediment remnants, and the soil on the pediment remnants.

Fossils in a sag pond deposit within unit QTa in Yucca Flat suggest that much of the unit is Quaternary. Terrace deposits, intermediate in age between units QTa and Q2, in the Kyle Canyon area of the Spring Mountains have not been found in the Yucca Mountain area. The sequence of events following deposition of unit QTa and prior to deposition of unit Q2 suggest that unit QTa was deposited significantly before the Bishop ash, 738 ka, was deposited near the base of unit Q2.

Unit Q2 is present throughout the Yucca Mountain area and consists of five subunits: subunit Q2c, alluvial sand and gravel and lesser amounts of debris flow deposits; subunit Q2e, eolian sand; subunit Q2s, alluvial sand; subunit Q2b, alluvial gravel and debris flow deposits; and subunit Q2a, debris flow deposits. Subunits Q2e and Q2s are lithofacies of subunit Q2c. Slopewash deposits in the Yucca Mountain area have a stratigraphic position like that of subunit Q2a, but differ from Q2a in several characteristics and are designated subunit Q2a(?) in this report.

The presence of the Bishop ash at or near the base of subunits Q2e and Q2c at several locations in the Yucca Mountain area indicates that deposition of unit Q2 began before 738 ka. Radiometric ages indicate that a soil within subunit Q2c began development about 425 ka. Surface soils began development on subunit Q2c about 270 ka; on subunit Q2b, about 175 ka; and on subunit Q2a(?), about 40 ka.

Unit Q1 was deposited mostly in washes throughout the Yucca Mountain area. The unit consists of subunit Q1c, alluvial gravel; subunit Q1s, alluvial sand that is a lithofacies of subunit Q1c; subunit Q1e, eolian sands; subunit Q1b, debris flow deposits and minor amounts of alluvial gravels; and subunit Q1a, alluvial sand and gravel. Charcoal within subunit Q1c has been dated at 8.3 ka. Charcoal, fossil seeds, and archaeological material have established three periods of deposition for subunit Q1e: 5,300 to 3,000; 2,000 to 1,000 or less; and 200 yr B.P. to the present. Deposition of subunit Q1a probably began about 1840.

Basalts in Crater Flat have ages of 3.75 Ma, 1.1 Ma, and less than 345 ka. Most of the spring deposits in the Amargosa Desert range in age from pre-QTa to pre-Q2 in age. Spring deposits that are Q2 and Q1 in age are probably restricted to the vicinity of modern springs.

INTRODUCTION

The U.S. Geological Survey began geological, geophysical, and hydrological investigations of Yucca Mountain, Nevada, in 1978. The purpose of these investigations is to provide data for the evaluation of Yucca Mountain as a potential nuclear-waste repository site. This report describes Late Pliocene and Quaternary deposits in the vicinity of Yucca Mountain. Age determinations for these deposits are summarized. The report provides a basis from which the approximate age of faults that displace surficial deposits in the Yucca Mountain area can be determined.

Physiography

Yucca Mountain (fig. 1) is in the south-central part of the Great Basin subprovince of the Basin and Range physiographic province. In the Yucca Mountain area, elevations range from approximately 610 m on the Amargosa River at the southern end of the Amargosa Desert to approximately 2,345 m on Pahute Mesa. Within 100 km of Yucca Mountain (fig. 2), elevations range from -80 m in Death Valley to 3,368 m on Telescope Peak in the Panamint Range on the west (just southwest of fig. 2) and 3,633 m on Charleston Peak in the Spring Mountains (just southeast of fig. 2). The elevation of the piedmont angle (at the junction of the piedmont slope with the bedrock hills) at Yucca Mountain ranges from 865 m at the southernmost ridge to approximately 1,550 m at the head of Yucca Wash. Maximum elevation of Yucca Mountain is 1,783 m at the northern end.

A geologic map of the potential repository site at Yucca Mountain (Scott and Bonk, 1984), a report on the Quaternary faults at and near Yucca Mountain (Swadley and others, 1984), and a report on the structural features and tectonic history of part of the southern Great Basin (Carr, 1984) describe the structural features of Yucca Mountain and the surrounding area. The reader is referred to these reports for descriptions of the structural features mentioned in this report. Landform terminology in this report is in accordance with Peterson's (1981) classification for the Basin and Range province.

The Yucca Mountain area is in the drainage basin of the Amargosa River, which has its headwaters in the western part of Pahute Mesa and drains through the Amargosa Desert and Tecopa Basin into Death Valley (fig. 1). Yucca Mountain consists of one main and several subsidiary, tilted fault blocks of Tertiary volcanic rocks that are typical of the Basin and Range province. West-facing fault scarps on the main fault block have maximum slopes of 60 percent in Solitario Canyon (Scott and Bonk, 1984). A dendritic drainage system was deeply eroded before Quaternary time into the east-facing dip slopes and along faults in the main fault block. Slopes on the main fault block are 10-15 percent near the crests and 20-50 percent on the sides. Small valleys vary from V-shaped with remnants of surficial deposits along the lower valley sides and as thin, narrow deposits in the valley bottoms to flat-bottomed valleys underlain by surficial deposits. The largest valleys, Dune, Drill Hole, and Sever Washes (fig. 3), have sand ramps and alluvial deposits on the valley sides that have slopes of 10 percent and are bordered by terraces underlain by surficial deposits. These terraces are 50 to 300 m wide and have downstream slopes of 3-8 percent.

The sides of ridges that are formed by subsidiary fault blocks have lower slope angles than the sides of ridges formed by the main fault block on both fault scarps and dip slopes. The drainage systems of the subsidiary fault blocks are short, first- and second-order washes that are V-shaped and shallower than washes on the main fault block. The lower slope angles and the lesser development of tributaries in these drainage systems, when compared to those of the main fault block, are the result of lower relief and shorter dip slopes on the subsidiary fault blocks. South of the Dune Wash drainage basin, a few deep V-shaped drainages are present along north-south trending faults, and do not have tributaries.

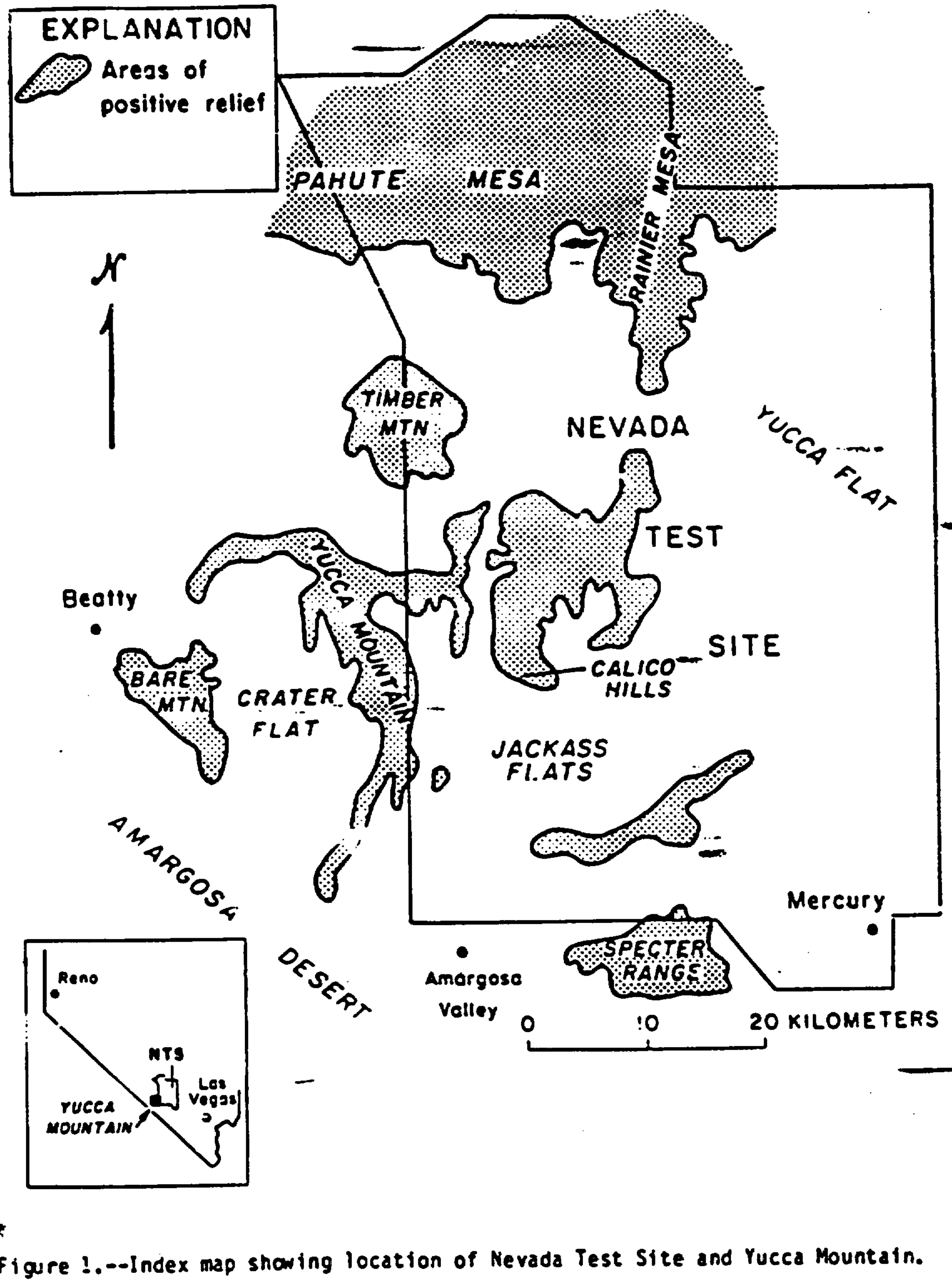

Figure 1.--Index map showing location of Nevada Test Site and Yucca Mountain.

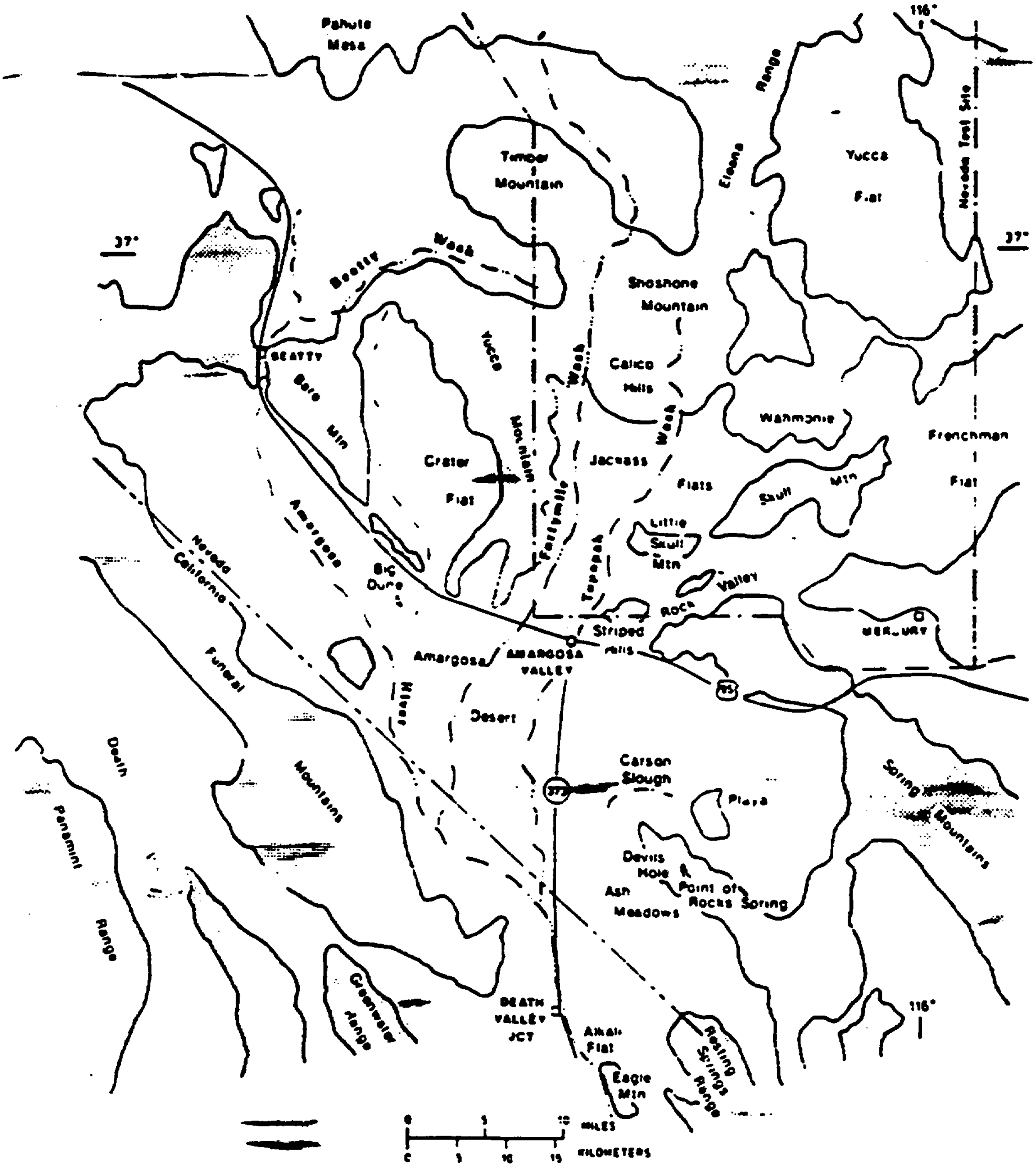

Figure 2.--Bedrock geologic map of Yucca Mountain region.

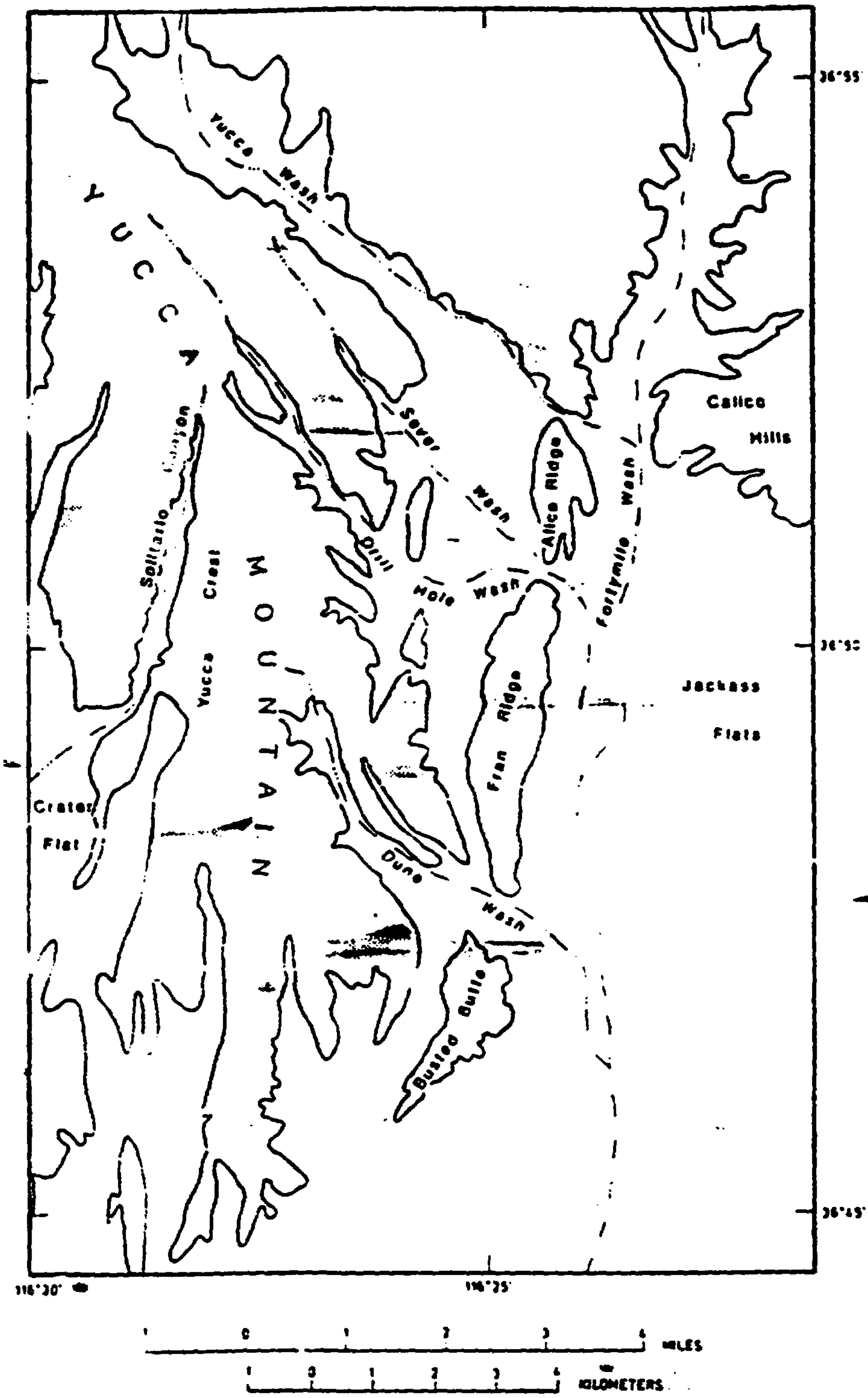

Figure 3.--Physiographic features of Yucca Mountain and vicinity.

Most of the washes that drain east-southeast to east on Yucca Mountain and adjacent fault blocks are consequent washes developed on dip slopes. Valleys that drain to the north or south and valleys at the north end of Yucca Mountain that drain southeast were developed along faults (Scott and Bonk, 1984; Carr, 1984). Although faults are not exposed in Yucca Wash, a geomagnetic anomaly suggests that a probable Miocene structural boundary may have influenced the distribution of older rocks, and thus the location of Yucca Wash (Carr, 1984).

The drainage basin of the Amargosa River above Beatty (fig. 2) is deeply incised in volcanic rocks. Fortymile Wash, Topopah Wash, Rock Valley Wash, Carson Slough, and the unnamed wash that drains Crater Flat are the major tributaries of the Amargosa River between Beatty and the southern end of the Amargosa Desert. East of Rock Valley Wash and Carson Slough, drainage is into the playa at the eastern end of the Amargosa Desert. South and west of the Amargosa River and north of Eagle Mountain, tributaries originating in the Funeral Mountains are much smaller than tributaries north of the river. Although Crater Flat, Fortymile Wash, Topopah Wash, and the unnamed wash that drains Crater Flat are deeply incised on middle to upper piedmont slopes, these washes are not integrated with the Amargosa River. On the lower piedmont slopes south of U.S. Highway 95, these washes are distributary and their runoff reaches the Amargosa River only during times of flooding. Rock Valley Wash and the drainage basin of Carson Slough are integrated with the Amargosa River.

Major landforms in the Yucca Mountain area include rock pediments, ballenas, fan and alluvial pediment remnants,[1] alluvial fans, stream terraces, and playas. The only rock pediment near Yucca Mountain is on argillite of the Eleana Formation in the center of the Calico Hills. Rounded, subparallel ridges, called ballenas, are common on the oldest surficial deposits near bedrock hills. On piedmont slopes between bedrock hills and on the basin floor of the Amargosa Desert, deposits of coalescing alluvial fans of different ages form nearly flat remnants between washes. Most of these fan deposits have been modified by creep and slopewash into smooth alluvial pediments. Because of fan coalescence and alluvial pedimentation, the semiconical topographic expression of alluvial fan cones is absent on most piedmont slopes. Small, semiconical fans are present at the junction of tributaries and larger washes in valleys in the Yucca Mountain area. Just west of Fran Ridge, Drill Hole Wash has a large, low semiconical fan just above the junction with Sever Wash. Steep semiconical fans are present below fault scarps along the east front of Bare Mountain and along terrace scarps east of Beatty. Major washes have stream terraces that extend from near the head of the wash down to where the washes become distributary on the lower part of the piedmont slope. A playa defines the end of a closed drainage system at the eastern end of the Amargosa Desert. Alkali Flat, at the south

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[1] Peterson (1981) uses the term pediment for a surface eroded on unconsolidated material on the piedmont slope. In this report, the adjective, alluvial, is added to avoid confusion with rock pediments by readers unfamiliar with Peterson's terminology.

end of the Amargosa Desert, is a late Pleistocene playa that has been breached by the Amargosa River (fig. 2).

Although calderas north of Yucca Mountain and northwest-trending faults alter the north-south pattern of ranges and valleys that are typical of the Great Basin, the general physiography and types of landforms in the Yucca Mountain area are similar to other areas of the Great Basin. The dimensions and topographic relationships of the landforms in Quaternary deposits in the Yucca Mountain area and in the Amargosa Desert do not differ greatly from those of similar landforms in the closed basins of Frenchman and Yucca Flats and appear to be relatively unaffected by the presence of the Amargosa River.

Previous Work

The bedrock geology of the NTS area has been published in a series of geologic maps at a scale of 1:24,000 (fig. 4). In the Yucca Mountain area, these maps include Topopah Spring NW (Christiansen and Lipman, 1965), Topopah Spring SW (Lipman and McKay, 1965), Topopah Spring (Orkild and O'Connor, 1970), Jackass Flats (McKay and Williams, 1964) and Lathrop Wells (McKay and Sargent, 1970). The geology of the Bare Mountain 15-minute quadrangle was mapped by Cornwall and Kleinhampl (1961). The Quaternary deposits as shown on these quadrangles were simplified and based mostly on clast size and geomorphic position.

Fernald and others (1968) mapped the surficial deposits of Yucca Flat for engineering purposes on the basis of depositional processes and fragment size. Units QTa, Q2, and Q1 were first described in the Syncline Ridge area of western Yucca Flat (Hoover and Morrison, 1980), which has Quaternary deposits similar to those in the Yucca Mountain area. Correlation characteristics and the stratigraphy of Quaternary surficial deposits in the NTS area were described by Hoover and others (1981). Swadley (1983) mapped the Quaternary deposits in the Lathrop Wells quadrangle and Swadley and Carr (1987) mapped Quaternary deposits in the Big Dune quadrangle. Field mapping of the Quaternary deposits in most of the Topopah Spring 15-minute quadrangle by the author was included in a map of the Quaternary geology of the Yucca Mountain area compiled by Swadley and others (1984).

Waterlaid sediments in the Amargosa Desert were first mapped in a reconnaissance investigation of the hydrology of the Amargosa Desert (Walker and Eakin, 1963). Denny and Drewes (1965) mapped these sediments as playa and spring deposits in the Ash Meadows quadrangle. Swadley (1983) mapped the recrystallized chalk caprocks and claybeds separately in the Lathrop Wells quadrangle. The waterlaid sediments have also been mapped in the Big Dune quadrangle (Swadley and Carr, 1987). Mapping of the NE1/4 of the Ash Meadows 15-minute quadrangle by Pexton (1985) established the stratigraphy of the waterlaid sediments and the relationship of these deposits to younger surficial deposits. Studies of the basalts in Crater Flat (Crowe and Carr, 1980) provided the stratigraphic relationships of these basalts to Quaternary and older surficial deposits.

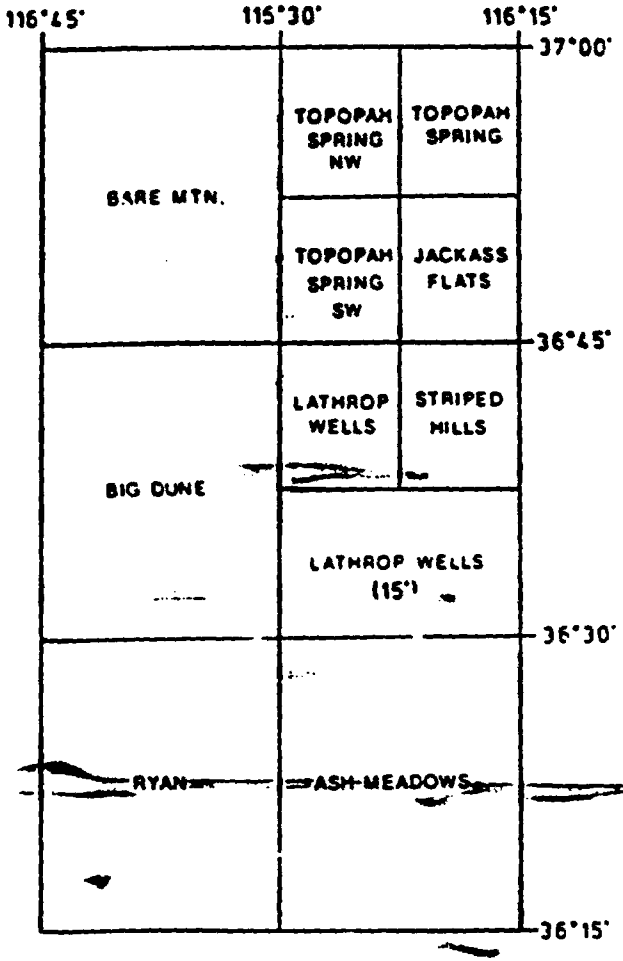

Figure 4.--Index map of the Yucca Mountain area showing outlines of quadrangle maps.

IDENTIFICATION OF QUATERNARY SURFICIAL DEPOSITS

Multiple criteria, called correlation characteristics (Hoover and others, 1981) are used for identification and correlation of surficial deposits in the NTS area. Correlation characteristics are used because Pliocene and Quaternary sediments in nearby areas could not be identified in the NTS area. The detailed Pliocene and Quaternary section of the Searles Lake area in California (Smith, 1979; Smith and others, 1983) was not comparable, because it was deposited in a different environment than the NTS deposits. The Quaternary deposits of the Tule Springs area near Las Vegas (Haynes, 1967) were deposited in a different environment, and over a much shorter time span. The correlation characteristics (see Hoover and others, 1981 for definitions) are:

I. Topography
    A. Macrotopography
    B. Microrelief

II. Drainage
    A. Pattern and development direction
    B. Cross-sectional shape
    C. Depth

III. Soils
    A. A and B-horizons
        1. Color
        2. Secondary clay, carbonate, and silica content
        3. Thickness
    B. Calcic horizon
        1. Stage (Gile and others, 1966)
        2. Thickness

IV. Topographic relationships to other depositional units

V. Desert pavement
    A. Packing and sorting
    B. Maximum fragment size
    C. Rock varnish color and luster

VI. Lithology
    A. Sand and clay content
    B. Color
    C. Maximum fragment size and frequency
    D. Ratio of clast lithologies

The order of these characteristics reflects their decreasing importance in the identification of a stratigraphic unit. Except for the order of listing, these characteristics are the same as described by Hoover and others (1981).

The use of soil properties to identify stratigraphic units was limited to macroscopic differences in the A, B, and calcic horizons that are easily identifiable by geologists unfamiliar with the descriptions and techniques of soil science. These differences include the presence of vesicular A and cambic B horizons, and the presence and the degree of development of argillic

B and calcic horizons. The soil-horizon designations used in this report differ somewhat from those defined by the Soil Conservation Service (Soil Survey Staff, 1975), and are defined in the following paragraphs.

Vesicular A (Av) horizons are surface horizons that contain numerous vesicles that are 1-10 mm in diameter. Av horizons are formed in a layer of silty sand that underlies a desert pavement. Most Av horizons overlie an unconformity at the top of the underlying B or calcic horizon. This unconformity is indicated by: (1) the presence of similar Av horizons on either B or calcic horizons of a single stratigraphic unit, and (2) an abrupt decrease in secondary carbonate in some soils between the Av and the underlying B horizon.

Cambic and argillic B horizons are present on most Pleistocene and older surficial deposits. Cambic B horizons are distinguished on the basis of better developed structure and (or) stronger colors than the underlying horizon. Cambic B horizons lack significant clay accumulation, but a few, thin clay coatings on sand grains and larger fragments are present in some cambic B horizons. Most cambic B horizons are yellowish brown. Argillic B horizons have significant clay accumulations as indicated by abundant clay films. Most argillic B horizons are reddish brown, and contain more clay than the underlying horizon. Some argillic B horizons are indurated by abundant secondary calcium carbonate and locally by secondary silica. Most cambic and argillic B horizons are less than 50 cm thick.

Calcic horizons are characterized by the deposition of abundant calcium carbonate and locally by some secondary silica. The calcic horizons referred to in this report include the Cca, calcic, and petrocalcic horizons of the Soil Survey Staff (1975) and the K horizon of Gile and others (1966). Thicknesses of calcic horizons in this report include the entire thickness of visible secondary carbonate which ranges from less than 0.1 to greater than 1.5 m. The morphological characteristics of secondary carbonate in calcic horizons were used to assign stages as defined by Gile and others (1966). Calcic horizons range from stage I films and coatings on the bottoms of clasts in early Holocene and late Pleistocene deposits to thick, plugged, stage IV horizons in early Pleistocene deposits. The carbonate stages that are reported are the maximum stage developed in the entire calcic horizon (Gile and others, 1966). Carbonate-rich laminae, characteristic of strongly developed stage IV horizons, are common in early Pleistocene and older deposits, but they occur only locally in some middle Pleistocene deposits. Pisolites and brecciated and recemented laminae occur in a few locations in early Pleistocene and older deposits.

STRATIGRAPHY

Stratigraphic units in the Yucca Mountain area range from Precambrian to Holocene. Metamorphic and sedimentary rocks from Precambrian to Mississippian in age and volcanic rocks of Miocene and Pliocene age form the hills and ranges of the Yucca Mountain area. Sedimentary rocks of Miocene and early Pliocene age are present in the Funeral Mountains, at the southern and eastern ends of the Amargosa Desert, and in Crater Flat. All of these rocks are highly deformed and densely faulted. In contrast, the waterlaid sediments in the Amargosa Desert and younger surficial deposits are relatively undeformed and are faulted in only a few places. Late Pliocene and Quaternary deposits in the Yucca Mountain area include the waterlaid sediments of Amargosa marsh, unit QTa, unit Q2, which has five subunits, and unit Q1, which also has five subunits (fig. 5).

Pliocene and Quaternary(?) Deposits

Waterlaid Sediments of Amargosa Marsh

That waterlaid sediments of Amargosa marsh consist of clays, limestones, and tufas that crop out in much of the Amargosa Desert south of lat 36°30' and west of long 116°10'. Scattered outcrops are present along the Amargosa River northwest to lat 36°40', between U.S. Highway 95 and the hills that form the southern edge of Crater Flat, and at the southern end of Crater Flat along the unnamed wash that drains Crater Flat. Driller's logs (Walker and Eakin, 1963) indicate that the waterlaid sediments underlie most of the Quaternary surficial deposits between the Skeleton Hills and the Amargosa River south of U.S. Highway 95. The sediments were deposited in an area called Amargosa marsh in this report (fig. 6). These sediments are referred to as the waterlaid sediments of Amargosa marsh. Amargosa marsh had an area of approximately 1,250 km^2.

Pexton (1985) divided the waterlaid sediments of Amargosa marsh into a lower and an upper unit separated by a disconformity. The lower unit was further divided and mapped as four lithofacies: three units that are mostly argillaceous and a fourth unit of sheet limestones that overlies and interfingers with two of the argillaceous lithofacies; the "lake" deposits and the paludal deposits. The lower unit, as described by Pexton (1985), consists of:

Undifferentiated Pliocene "lake" deposits (unit Tld):

> Mostly brown to green, illitic and montmorillonitic claystones with soft to hard limestone beds, pods, and nodules that contain minor dolomite. Thin sandstone beds are sparse. Clay beds pinch and swell noticeably over short distances and grade into limestone with inclusions of irregular clay masses. Claystones contain only small amounts of magnesium silicate clays. Evaporites were not observed, but masses of selenite and thenardite blooms are found at the surface. Abundant rootmarkings. Contains two ash-fall tuffs. Deposited in floodplains, swamps, ponds, and playas.

Pliocene playa deposits (unit Tpl):

> Mostly buff to brown, hard, blocky claystones that are predominantly magnesium silicate clays with some authigenic potassium feldspar. Some claystones have pelletal textures. Minor, hard, white dolomite sheets grade into soft, white limestone. Calcium carbonate breccia masses (caliche-breccia) found near Carson Slough contain interstitial magnesium silicate clays. Contains one ash-fall tuff. Probably deposited in a seasonally flooded playa.

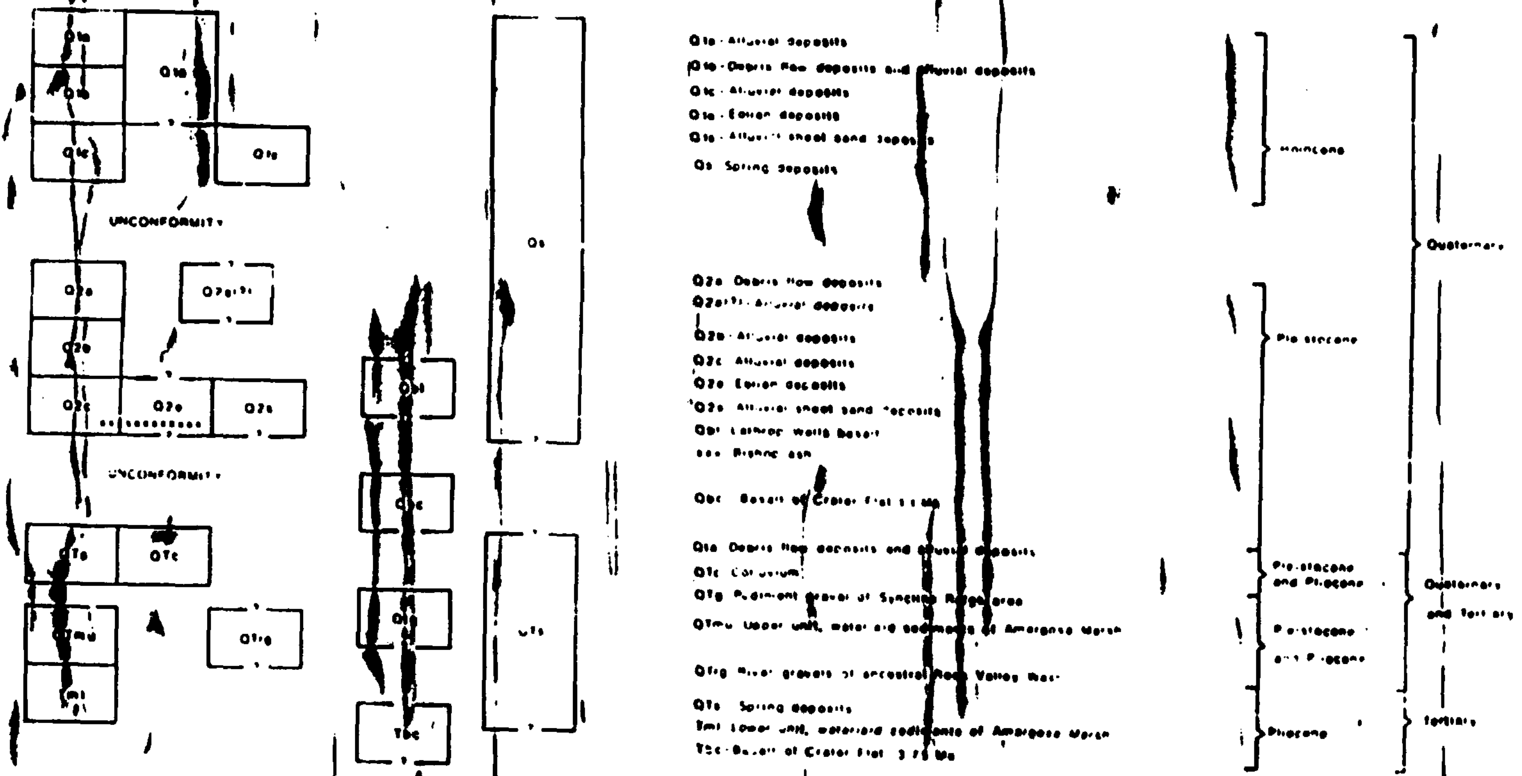

Figure 5.--Correlation chart of late Pliocene and Quaternary stratigraphic units in the Yucca Mountain area. Query indicates that stratigraphic position of base and (or) top is

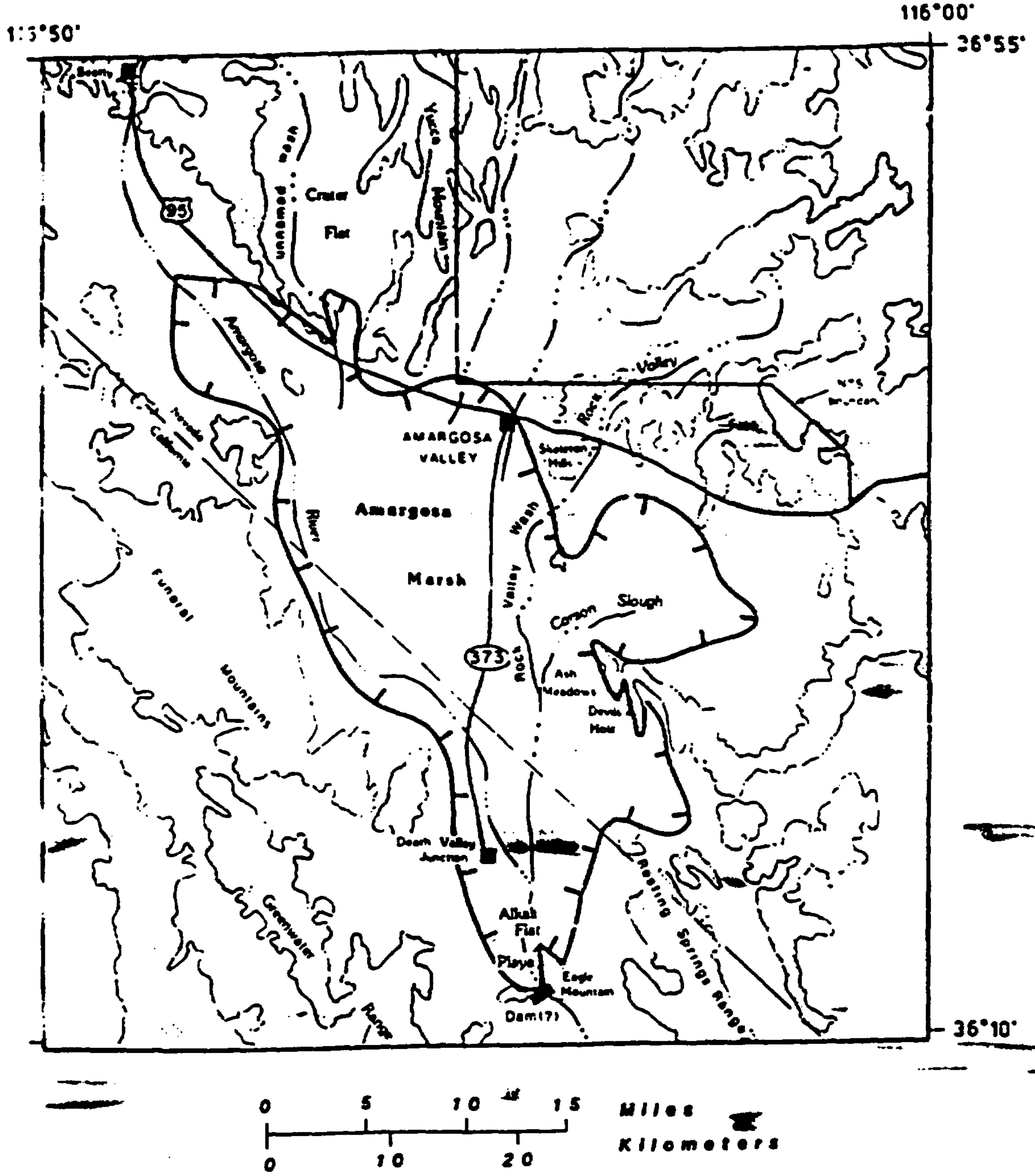

Figure 6.--Approximate area of Amargosa marsh. Boundary based on data from the Lathrop Wells quadrangle (Swadley, 1983), the Big Dune quadrangle (Swadley and Carr, 1987), drill-hole data (Walker and Eakin, 1963), and reconnaissance mapping by the author.

Pliocene paludal deposits (unit Tpa):

> Mostly white, chalky limestones with minor amounts of sandstone and claystones. Claystone occurs as irregular masses of illitic to montmorillonitic clay within chalky limestones. Limestone contains gastropods, bivalves, and ostracodes. Probably deposited in spring-fed marshes and ponds.

Pliocene sheet limestones (unit Tll):

> White to light gray, dense, recrystallized, fenestral limestone sheets. Contains rootmarks and occasional plant casts that resemble plants growing in runoff from springs. Probably deposited in isolated ponds.

The disconformity that separates the lower and upper units has been recognized in the Carson Slough and Rock Valley Wash drainage basins and in the area southwest of Devils Hole. The disconformity is marked by channels that are 3 to 10 m deep and a few meters to a few tens of meters wide. Between Carson Slough and Rock Valley Wash, the channels have a low gradient to the south. South of Carson Slough along the west side of the ridge of Paleozoic rocks that contains Devils Hole, the channels have a slightly steeper gradient to the west. At the south end of this ridge, the channels have a gentle gradient to the southwest.

The upper unit fills the channels cut into the lower unit. The base of the upper unit is marked by coarse sands or gravels. In the Carson Slough and Rock Valley Wash drainage basins, basal sands contain sparse pebbles as much as 2 cm in diameter. Along the west side of the ridge south of Carson Slough, similar sands and local gravels are present in lenses at the base of the upper unit. West of Devils Hole and south of the Paleozoic ridge, the base of the upper unit contains beds of limestone gravel as much as a meter thick. Clasts of the gravels are mostly less than 20 cm in diameter.

Above the basal clastic deposits, the upper unit is mostly white, soft limestone that contains minor amounts of siltstone and claystone. Clay minerals are mostly illite and montmorillonite, but magnesium silicate minerals are also present (Pexton, 1985). Beds are mostly less than 1 m thick.

The deposits of the upper unit are capped by tufa. The tufa is brown to orangish brown in outcrop and medium gray to pale yellowish gray on a fresh surface. The tufa consists of limestone and sandy limestone that preserves casts and moulds of plants and algal structures. Where the plant casts and moulds are well preserved, they contain a triangular reed and two broad-leafed plants that closely resemble plants that grow in the runoff from modern springs. The tufa is usually 1-2 m thick near the head of the channels and thins downslope. In sec. 26, T. 17 S., R. 50 E., the tufa covers an area about 1 km^2 and is 2-4 m thick. Although Pexton (1985) mapped the tufas separately from the underlying sediments of the upper unit, the association of the tufas with the sediments and the channels of the disconformity indicate that the tufas are a lithofacies of the upper unit.

The upper unit is not continuous. The association of the channels of the disconformity and the upper unit, similar lithologies throughout the upper unit, and a similar elevation of the disconformity noted by Pexton (1985) from Carson Slough and Rock Valley Wash to the area southwest of Devils Hole indicates that these deposits were probably deposited at the same time by the same processes.

West of the area mapped by Pexton (1985), a large outcrop of sediments similar to the upper unit may also be the upper unit. The outcrop covers an area about 6 by 3.5 km in the Ash Meadows quadrangle in T. 17 and 18 S., R. 49 E. in Nevada and T. 26 and 27 N., R. 5 E. in California between Nevada State Highway 373 and the Amargosa River. Diatomite and white, soft limestone and claystone are capped by tufa. Sand less than 20 cm thick occurs at the base of the deposit. The sand contains very sparse pebbles that are less than 10 mm in diameter. At the southern end, a lobate shape of the deposit suggests filled channels like the channels filled by the upper unit about 10 km to the east.

Outcrops in the Big Dune quadrangle resemble both the lower and upper units. Along the Amargosa River, claystones and limestones resemble sediments of the lower unit. In the Big Dune quadrangle in secs. 22 and 23 (estimated), T. 14 S., R. 48 E., pebbly tuffaceous sands underlie claystone and diatomite that resemble similar sediments in the upper unit. These sediments are capped by tufa in which mammalian fossils occur. Tufas on the south and west sides of this outcrop appear to occur in channels that slope to the south. In sec. 19, T. 14 S., R. 49 E., claystone and remnants of tufa are exposed south of the hills that bound Crater Flat on a terrace or pediment along the unnamed wash that drains Crater Flat.

In southern Crater Flat in the Big Dune quadrangle in secs. 12 and 13, T. 14 S., R. 48 E. and secs. 7 and 18, T. 14 S., R. 49 E., tufas are interbedded with sand and gravel. Tufas and limestone also form erosional mounds. Along the unnamed wash, where it drains east-southeast, gravel beds dip 5°-15° south to southeast, and are interbedded with tufas. In a trench exposure, the gravel on the north edge of the wash grade vertically from poorly sorted at the base of a bed to well-sorted at the top and laterally from poorly sorted on the north to well sorted to the south. The gravels in the trench are interbedded with pebbly sands. A yellowish to orangish, iron-oxide stained band from 5 to 15 cm thick, which slopes slightly to the south, cuts across bedding of the sands and gravels that have a slightly greater dip to the south. South of the wash, tufa and white, soft limestone form eroded mounds that appear to have been deposited along a north-south line of springs.

In the southern part of the Lathrop Wells quadrangle, Swadley (1983) mapped calcareous clays and silts and dense limestones that are continuous with outcrops mapped by Pexton (1985) as the lower unit of the sediments of Amargosa marsh. Swadley's (1983) unit QTld is equivalent to Pexton's (1985) units Tld, Tpl, and Tpa; Swadley's unit QTll is equivalent to Pexton's sheet limestones, unit Tll. The upper unit was not recognized by Swadley (1983), but areas of calcified vegetal mats in sec. 19 and 30, T. 16 S., R. 50 E. may be the upper unit.

The deposits needed to interpret the early history of Amargosa marsh are concealed by the waterlaid sediments and by younger deposits, but some evidence suggests that at least part of Amargosa marsh may have been occupied by a lake early in its history. The evidence consists of a possible dam at Eagle Mountain and possible beach terraces near the dam, near Devils Hole, and at the north end of the limestone ridge that contains Devils Hole.

The possible dam at Eagle Mountain was formed by older, deformed gravels, alluvial fans, and basalt that may have provided barriers on either side of Eagle Mountain to runoff from Amargosa marsh. Between Eagle Mountain and the Resting Springs Range to the east, older, deformed gravels and alluvial fans provided a barrier that still exists. West of Eagle Mountain, alluvial fans and faulted younger basalts formed a similar barrier. The basalts are probably the same basalts as in the Greenwater Range, less than 5 km from these basalts. The barrier west of Eagle Mountain has been breached by the Amargosa River. When this breaching occurred is uncertain, but the breaching was probably early in the history of Amargosa marsh.

Faint traces of possible beach terraces are present on the basalt at the possible dam, on Paleozoic carbonate rocks near Devils Hole, and at the north end of the limestone ridge that contains Devils Hole. In the Ryan quadrangle, in sec. 30, T. 24 N., R. 6 E., a bench that is 3-5 m wide is cut in basalt almost completely around a knob that is about 5 m higher than the bench. The bench does not coincide with any apparent lithologic changes and is overlain by 0.3-0.6 m of fine-grained material. The fine-grained material could be eolian in origin, but it is not present on other nearby outcrops of basalt. The bench is about 45 m above the waterlaid sediments at an altitude of approximately 652 m.

In the Ash Meadows quadrangle, in sec. 36, T. 17 S., R. 50 E., about 1/2 km west of Devils Hole, a bench is cut across the bedding of Cambrian limestone at an altitude of approximately 737 m. This bench may be an old terrace at the junction of washes in adjacent drainage basins, but similar benches are not present adjacent to other nearby, similar junctions of washes in the limestone. In sec. 23, T. 17 S., R. 50 E. and sec. 19, T. 17 S., R. 51 E., benches about 15 m wide are cut in the limestone at elevations of 725-745 m, and are partly covered by waterlaid sediments of Amargosa marsh. The benches cut across bedding and appear to be unrelated to lithologic differences or faults. The topographic setting and location of the benches make differential weathering or stream erosion unlikely. A few limestone clasts on these benches are highly rounded, but are too deeply pitted by weathering to determine their origin.

River Gravels of Ancestral Rock Valley Wash

The river gravels of ancestral Rocky Valley Wash consist of coarsely crossbedded pebbly sands and sandy gravels that underlie a north-south ridge just west of Rock Valley Wash in the Ash Meadows and Lathrop Wells quadrangles. The outcrops can be traced from sec. 30, T. 17 S., R. 50 E. north for approximately 10 km to the SE 1/4 sec. 19, T. 16 S., R. 50 E. The best exposures are in the SW 1/4 NE 1/4 sec. 19, T. 17 S., R. 50 E., where crossbedding and the relationship to the lower unit of the sediments of Amargosa marsh are well exposed.

Crossbeds are 5-20 cm thick in beds that are 0.3-0.6 m thick. Clasts of volcanic rock as large as 10 cm are scattered in a sandy matrix that is cemented by calcite. A few beds are sandy gravel. Clasts are mostly silicic volcanic rocks, but minor amounts of basalt are present.

The crossbedded sand and gravel fill a channel 1.5 km wide and as much as 5 m deep. Remnants of sheet limestones of the lower unit of the sediments of Amargosa marsh form part of the east bank of the channel. The parallelism of the channel with Rock Valley Wash for at least 10 km indicates that the channel is probably an ancestral Rock Valley Wash.

Slopes and ridgetops above the crossbedded sands are covered by deposits that contain boulders of basalt and other volcanic rocks as much as 0.5 m in diameter. These boulders are probably from the next younger unit, unit QTa.

Pliocene(?) and Quaternary Deposits

Unit QTg

Unit QTg consists of thin-bedded gravels that fill shallow valleys of a dissected pediment between the Eleana Range and Syncline Ridge in western Yucca Flat (fig. 2). The gravels are composed of quartzite, conglomerite, and siliceous argillite derived from the Eleana Range. Clasts are angular, platy, and prismatic, have a maximum dimension 0.7 m, and have thicknesses that are 20 to 50 percent of the maximum dimension. In contrast, the overlying unit QTa contains numerous boulders of Tertiary welded tuff that have diameters of 1 to 10 m, are subangular to subrounded, and are roughly equidimensional. The gravels of unit QTg are as much as 5 m thick near the Eleana Range and 22 m thick near Syncline Ridge beneath units QTa and Q2 (Hoover and Morrison, 1980).

The pediment beneath the gravels is defined by a nearly planar surface that covers approximately 17 km^2 between the Eleana Range and Syncline Ridge. The pediment is cut on gently to steeply dipping quartzite and clayey argillite of the Eleana Formation (Mississippian and Devonian) and on Tippipah Limestone (Permian(?) and Pennsylvanian). Where unit QTg is present on ridges near the Eleana Range, it is overlain in most places by unit QTa. These ridges are 10 to 20 m wide and have rounded to flat tops. The contact between the Eleana Formation and the gravels dips into the ridges. The upper part of the gravels is thoroughly cemented by dense calcium carbonate. At the base of the gravels on one ridge, a trench exposes soft, pulverent to nodular calcium carbonate. The soft carbonate forms 50 percent or more of the matrix in both the gravels and the weathered rock of the underlying Eleana Formation in a zone approximately 0.7 m thick.

Plates of calcium carbonate occur as residual deposits at the edge of the gravel and on the Eleana Formation along the ridges upslope from the edge of the gravel. The carbonate plates can be traced to a thrust fault in the Eleana at the east foot of the Eleana Range. The plates are siliceous near the thrust fault. The carbonate and silica plates and the carbonate in the gravel appear to have been deposited by ground water seeping out of the thrust fault and into the gravel.

Unit QTa

Unit QTa consists of predominantly debris flow deposits and small amounts of alluvium. Unit QTa is present at the periphery of all basins in the NTS area, around isolated bedrock hills in the Amargosa Desert, and as erosional remnants in valleys in the hills and ranges. Unit QTa lies unconformably on Precambrian to Paleozoic sedimentary rocks, on Tertiary volcanic and sedimentary rocks, and on the waterlaid sediments of Amargosa marsh. In the Calico Hills and between Syncline Ridge and the Eleana Range in Yucca Flat, unit QTa was deposited on unit QTg and pediments that were cut on argillite of unit J of the Eleana Formation. In most areas, exposures of unit QTa are less than 2 km from the hills and ranges. In a few places, such as Rock Valley Wash near the Skeleton Hills and in Crater Flat, exposures are 10 km or more from the ranges. The maximum observed thickness of unit QTa is approximately 55 m.

Natural exposures of unit QTa are sparse. The best developed soils and landforms that are typical of unit QTa occur between Yucca Mountain and Alice Ridge, just south of Yucca Wash (fig. 3). Debris flow deposits and poorly sorted alluvial gravel that may have been reworked from debris flows are exposed in Crater Flat trenches 1 (lat 36°48'14", long 116°29'50") and 2 (lat 36°46'59", long 116°30'38") and in some of the deeper washes near these trenches.

Unit QTa crops out as elongate, well-rounded ridges called ballenas. The ballenas are separated by washes that form parallel to subparallel drainage systems. The washes, where not filled by unit Q2 or dissected by Holocene erosion, have rounded cross sections. Relief on the ridges ranges from 1 to 25 m; the macrotopography is rounded. Microrelief is flat except where erosion during the pedimentation of unit QTa has left residual cobbles and boulders protruding above the desert pavement. Within 1-2 km of bedrock hills, residual boulders are as much as 10 m in diameter. At distances of 5 km, residual boulders are less than 1 m in diameter. Along Rock Valley Wash south of U.S. Highway 95, basalt boulders from Skull Mountain, more than 30 km away, are commonly 0.5 to 1 m in diameter. Residual boulders are rarely present on deposits younger than unit QTa.

Soils on unit QTa typically consist of an Av horizon and a calcic horizon. The Av horizon on unit QTa overlies the calcic horizon or, where present, an argillic B horizon. The Av horizon is formed in material that is probably much younger than the underlying deposits. Thickness of the Av horizon ranges from 10 to 40 cm. The B horizon has been eroded from most QTa soils. Only one area, just south of Yucca Wash and west of Alice Ridge, has been found with an argillic B horizon intact in a QTa soil. At this location, the argillic B horizon is dark reddish brown, contains abundant clay, and is approximately 50 cm thick. Secondary silica increases downward in the B horizon. Where the argillic B horizon is preserved, the calcic horizon has engulfed the lower part of the B horizon and consists of laminar layers that enclose lenses of pale-brown opaline silica that are as much as 5 cm thick. The laminar layers that enclose these silica lenses are dense, hard, and probably contain secondary silica. Calcic horizons of unit QTa are stage II to III at elevations of about 700 m in the Ash Meadows area and stage IV above 900 m in the Yucca Mountain area. Stage IV calcic horizons are 2 to 3 m thick. Laminar layers are present in most stage IV calcic horizons.

Pisolites and brecciated and recemented laminar layers occur in a few locations.

On the uppermost part of piedmont slopes, interfluves of unit QTa between washes that head in the bedrock hills, are topographically above units Q2 and Q1. Deposits of QTa are also present at drainage junctions within bedrock hills, as erosional remnants on pediments, and as the highest erosional terrace along major washes within bedrock hills. On Yucca Mountain, remnants of unit QTa are present on steep slopes 20-50 m above the bottoms of some washes. Terraces and dissected hills of unit QTa are present on lower piedmont slopes along Rock Valley Wash from U.S. Highway 95 south to about lat 36°30'. At distances of 5 km or more from bedrock hills, unit QTa is buried by younger surficial deposits on most piedmont slopes.

Desert pavement on unit QTa is very densely packed and poorly to moderately sorted. Maximum fragment size in the pavement is about 20 cm, but residual boulders, which range from 0.5 to as much as 10 m in diameter, commonly protrude above the pavement. Varnish on pavements and residual boulders is shiny brownish black to black, 0.5 to 2 mm thick, and continuous in areas undisturbed by soil creep.

Trenches and a few natural exposures reveal unsorted, nonbedded layers that are 1 to 2 m thick. Each layer contains coarse fragments ranging from pebbles to boulders that are supported by a matrix of clay- to sand-size material. Clay and silica coat larger fragments below the calcic horizon. Natural exposures of unit QTa are light brown with a pinkish to reddish cast. Boulders of welded tuff, limestone, or quartzite are commonly 1 to 4 m in diameter on the uppermost piedmont slopes and in QTa deposits in bedrock hills. Boulders at the base of unit QTa, deposited on a pediment cut on the Eleana Formation in the Calico Hills and in Yucca Flat, are as much as 10 m in diameter.

At the foot of the Eleana Range in the west-central part of Yucca Flat, lenses of calcium carbonate that contain ostracodes, gastropods, and small mammal remains are interbedded with debris flow deposits of unit QTa. Two lenses, exposed in trenches cut at right angles, are as much as 2 m thick, extend at least 50 m downslope, and are at least 30 m wide along the slope contour. The upper part of both lenses contains greenish-gray clay and clasts as much as 20 cm in diameter. The location of the calcium carbonate lenses, adjacent to faults that displace the uphill side of the faults down against quartzite of the Eleana Formation, indicate that the fossiliferous carbonate lenses are sag pond deposits.

Alluvial pediments were cut on unit QTa throughout the NTS area. The pediments are defined by the concordant tops of the ridges that characterize unit QTa. Concordancy of the ridges extends across small washes that originate in bedrock hills and across some major washes. The concordant ridges extend into bedrock in a few locations in the Calico Hills, east of Jackass Flats, and on the southwest side of Bare Mountain. Benches cut on bedrock and "lines" of calcium carbonate that stain steep bedrock slopes may record the original surface of unit QTa. These features occur as scattered remnants in the ranges east of Yucca and Jackass Flats, in the Calico Hills, and on the southwest side of Bare Mountain. The benches and carbonate lines suggest that 25 to 50 m of unit QTa may have been eroded where the ranges have the greatest relief and highest slopes. Near hills that are low in relief, erosion may have been much less than 25 m.

On hillslopes that have 10-25 m of relief, QTa deposits lack any evidence of bedding. The few exposures along washes and in trenches are predominantly layers of unsorted cobbles and boulders. In Crater Flat trenches 1 and 2 and in some exposures in washes, coarse, poorly to moderately sorted alluvial gravel is present in the upper 1-3 m of unit QTa. In a few wash exposures, alluvial gravel occurs as thin beds between unsorted layers of cobbles and boulders. Numerous large boulders are present in almost all exposures of unit QTa, regardless of relief or lithology of the bedrock above the outcrops.

Subunit QTc.--Colluvium that consists of unsorted fine to coarse angular rubble was mapped separately as a subunit of unit QTa on steep slopes of Little Skull Mountain in the Lathrop Wells quadrangle (Swadley, 1983) and in the northeast corner of the Big Dune quadrangle (Swadley and Carr, 1987). Colluvium of subunit QTc is included in map unit QTa at other locations. The colluvium includes rock falls and debris flow deposits that grade downslope into unit QTa. Slightly dissected smooth slopes of subunit QTc are underlain by stage III to IV calcic horizons that are several meters thick. A and B horizons are not present.

Regional Unconformity

Where subunit Q2c overlies unit QTa in the Yucca Mountain area, a regional unconformity is present. This unconformity is defined by the soil developed on unit QTa and the dissected pediments of unit QTa, and represents a long period of erosion and nondeposition. The pediments were dissected by subparallel drainage systems throughout the Yucca Mountain area after pedimentation of unit QTa and development of a soil on the pediments. This dissection of unit QTa formed long, narrow, rounded ballenas, usually less than 20 m wide. At the upslope end of ballenas, the ridge crests merge into the pediments and ridges wider than 20 m usually have flat tops that are remnants of the pediments on unit QTa. Slopes of the valleys between ballenas are convexo-concave in contrast to steep, straight slopes of washes in younger deposits. Where not obscured by younger deposits, valleys between ballenas are rounded.

No deposits are present between unit QTa and unit Q2c near Yucca Mountain, but near the head of the Kyle Canyon (just southeast of fig. 2) alluvial fan, alluvial gravels form terraces that are intermediate in elevation between the ballenas of unit QTa and the terraces of unit Q2. The lithology, pedimentation, soils, landforms, and dissection of unit QTa are similar at both Kyle Canyon and in the Yucca Mountain area. Except for thicker soil horizons, the same aspects of unit Q2 are also similar in both areas. These similarities and the proximity of Kyle Canyon to Yucca Mountain indicate that deposits of intermediate age should also be present in the Yucca Mountain area. Deposits of intermediate age may be buried in Yucca and Frenchman Flats or removed by erosion in Mercury Valley, Crater Flat, Rock Valley, Jackass Flats, and the Amargosa Desert.

Pedimentation, soil development, and dissection of unit QTa represent a long period of erosion and nondeposition. The absence at the surface of the Yucca Mountain area of the intermediate-age deposits that are present at Kyle

Canyon suggests that intermediate-age deposits are not present in the Yucca Mountain area. The probable absence of the intermediate-age deposits in the Yucca Mountain area extends the period of erosion and nondeposition after deposition of unit QTc, and requires a regional unconformity between unit QTa and subunit Q2c.

Quaternary Surficial Deposits

Quaternary surficial deposits of the Yucca Mountain area include units Q1 and Q2, both of which have five subunits. Both units consist of alluvial sand and gravel, debris flow deposits, and eolian sand. The major differences between the two units are that the older unit, unit Q2, has moderately to well developed soils and desert pavements, whereas unit Q1 has incipiently developed soils and desert pavements are absent. Except for topographic position, all other characteristics of the two units and their subunits are similar.

Unit Q2

Unit Q2 consists of alluvial deposits, debris flow deposits, and eolian sand. Unit Q2 contains five subunits: Q2c, Q2b, and Q2a and Q2a(?), alluvial and debris flow deposits; Q2e, eolian sand ramps and sand sheets; and Q2s, alluvial sand sheets. These subunits range in age from middle to late Pleistocene. Soils in unit Q2, except for the youngest deposits, are moderately to well developed. Desert pavements are well developed except on the youngest deposits. The youngest deposits and eolian sand have a limited extent, but alluvial deposits of oldest and intermediate ages are present throughout the Yucca Mountain area. The topography, drainage, and desert pavements of all subunits are similar, but soils, lithology, and topographic position differ.

Alluvial deposits of subunits Q2c and Q2b are found in all the valleys of the NTS area and in washes in the hills and ranges. The debris flow deposits of unit Q2a have been identified only in the Calico Hills and in the Syncline Ridge area of Yucca Flat. Thin slopewash deposits with similar radiometric ages at several locations in the Yucca Mountain area are called Q2a(?) in this report, and may be equivalent in age to subunit Q2a, which has not been dated radiometrically. Subunits Q2e and Q2s have been identified only in the northern part of the Amargosa Desert, Jackass Flats, and Crater Flat.

Subunit Q2c.--Subunit Q2c consists of alluvial deposits and equal to lesser amounts of debris flow deposits. The alluvial deposits vary from pebbly sands to coarse gravels. Debris flow deposits that are exposed in trenches and in washes vary from small lenses to layers longer than 100 m.

Subunit Q2c is present throughout the NTS area. The subunit occurs as terrace deposits in larger washes within the bedrock and unit QTa, as fan deposits in a few intramontane valleys, as slopewash and talus deposits on the sides of most of the valleys on Yucca Mountain, and as fan deposits on upper to lower piedmont slopes in all valleys. Subunit Q2c forms the highest terrace along major washes on the piedmont slope and along most of the washes in the Amargosa Desert. Drill-hole data in Jackass Flats indicate a maximum thickness of 65 m, but beneath some valley floors the thickness may be greater.

Terraces that are typical of subunit Q2c are present between Sever Wash and Fortymile Wash and at and below the mouth of Topopah Wash west of Fortymile Wash. The best exposure of the youngest Q2c soil is in a trench (lat 36°51'58", long 116°13'19").

Subunit Q2c has a flat macrotopography even on steeply sloping deposits. Along much of Fortymile, Topopah, and Rock Valley Washes, overbank flood deposits and debris flow deposits form low levees. Microrelief is less than 0.2 m, except where residual boulders of unit QTa protrude through Q2c deposits. Drainage patterns on Q2c are parallel, have few or no tributaries on middle to upper piedmont slopes, and are distributary on middle to lower piedmont slopes. Most washes cut into subunit Q2c have very steep to vertical banks that have been steepened by Holocene erosion. Where banks below the terraces are undisturbed by Holocene erosion, these banks are also steep.

The Av horizon of Q2c soils is younger than the underlying soil horizons. The Av horizon is 10 to 50 cm thick, consists of clay-size to very coarse sand-size material, and is pale yellowish brown. The Av horizon has a sharp contact with the B horizon, or where the B horizon has been stripped, with the calcic horizon.

Soils of two different ages are present on subunit Q2c and can be differentiated only by uranium-trend age dating or by detailed soil investigations. Above 1,000 m elevation, both soils have a moderate- to dark-reddish-brown, argillic B horizon, that is partly silicified, and stage III to IV calcic horizons. The calcic horizons rarely have a laminated layer. Some calcic horizons locally may engulf the lower part of the argillic B horizon. At elevations below 800 m in the Amargosa Desert, both soils in Q2c have cambic B horizons and stage I to II calcic horizons.

The older soil is present at a depth of a few meters within subunit Q2c or at the surface in some locations. The older, buried soil has been identified by uranium-trend dating of samples from some trenches in the Yucca Mountain area. The older soil is probably the buried soil exposed in the west wall of Fortymile Wash just south of the road to Yucca Mountain. At the surface locally in the Yucca Mountain area, the older soil also has been identified by uranium-trend dating locally in the Yucca Mountain area. The maximum depth of burial of the older soil is approximately 7 m in Fortymile Wash. The younger soil has been identified at the surface or beneath less than 1 m of younger subunits in northeastern Jackass Flats, on Yucca Mountain, and in Crater Flat.

Subunit Q2c is present beneath terraces along washes that are incised in bedrock and unit QTa, and is also present on much of the upper piedmont slopes. Q2c is the highest surficial deposit on middle piedmont slopes, on some lower piedmont slopes and valley floors, and along most major washes incised in lower piedmont slopes and valley floors.

Desert pavements on subunit Q2c are densely packed, moderately to well sorted, and have a maximum clast size that is commonly less than 0.2 m in most places. Near bedrock hills or where unit QTa underlies Q2c at depths of less than 2 m, larger clasts may be present at the surface of subunit Q2c. Varnish ranges from very dark brown to blackish brown and from dull to shiny; it forms a thin film that usually covers most or all of the upper surfaces of desert pavement clasts.

Sand content of Q2c deposits ranges from less than 20 percent in coarse gravels to more than 90 percent in the Jackass Flats and Yucca Mountain areas, where the subunit contains sand that is reworked from subunit Q2e. Clay content is probably very low. Except in debris flow deposits, clay coatings on clasts below the soils are rare. The color in outcrop ranges from a light yellowish brown to grayish brown. Clasts in alluvial deposits are rarely more than 0.2 m in diameter. In most debris flow deposits, clasts are as much as 0.5 m in diameter, but on the two highest terraces of Fortymile Wash, debris flow deposits contain numerous clasts as much as 1 m in diameter.

Subunit Q2c consists of mostly alluvial deposits that range from pebbly sands, common east of Yucca Mountain and south of Jackass Flats, to sandy, coarse gravels. The volume of debris flow deposits may equal the volume of alluvial deposits on upper piedmont slopes and in intramontane valleys, but is usually less than the volume of alluvial deposits on and below middle piedmont slopes. Much of the alluvial material was deposited along shallow distributary washes. Along major washes, the alluvial deposits appear to be the result of channel aggradation. On steeper slopes, particularly within the ranges, slopewash deposits are abundant and may grade into debris flow deposits.

Along Fortymile Wash, debris flow deposits of subunit Q2c cap most of the three uppermost terraces (fig. 7). On the highest terrace, discontinuous patches of cobbles and boulders from debris flows overlie mostly pebbly sands and a few sandy pebble and cobble beds that are typical of subunit Q2c. The cobbles and boulders of the debris flow range from 0.1 to 1 m in diameter. At some locations on the east bank of the wash, the debris flow deposits form a levee that is 20 to 50 m wide and less than 1 m high. Remnants of the debris flows are sparse on the west bank, but are almost continuous for 10 km below the Calico Hills along the east bank. About 7 m below the highest terrace, a soil that is probably the older soil of subunit Q2c is exposed along the west bank. The soil has a stage IV carbonate horizon about 1 m thick and remnants of a red argillic B horizon. The soil on the highest terrace is the younger soil of subunit Q2c and has a stage III carbonate horizon less than a meter thick beneath the debris flow deposits.

Fortymile Wash is the only wash in the NTS area that is known to contain three terraces of Q2 age. In other washes, where only two terraces are present, Q2b is the lowermost terrace. Therefore, the lowest Q2 terrace in Fortymile Wash is considered to be Q2b and the middle terrace to be the youngest Q2c deposits (fig. 7). The middle terrace consists of cobbles and boulders that range from 0.1 to 1 m in diameter in a sandy matrix. The deposit on the middle terrace is 2-4 m thick and overlies sandy deposits similar to those that underlie the upper terrace. The upper meter of the debris flows of the middle terrace are cemented by a stage III calcic horizon.

Subunit Q2e.--Subunit Q2e is a lithofacies of subunit Q2c (fig. 8), and consists of eolian sand and reworked eolian sand that was deposited as sand ramps and sand sheets on the hillslopes that border the Amargosa Desert from the south end of Bare Mountain to Little Skull Mountain and from Ash Meadows to Yucca Wash and the center of the Calico Hills (fig. 9). The sand ramps

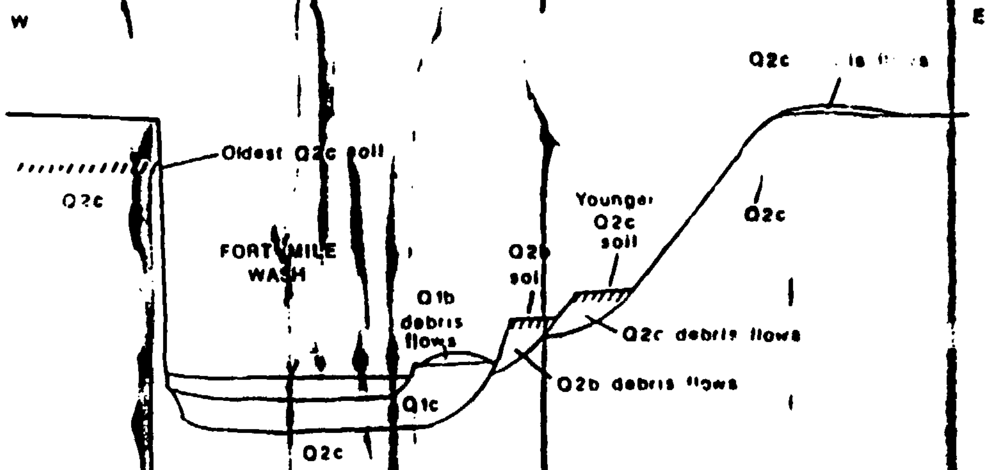

Figure 7.--Schematic cross section showing relationship of stratigraphic units and terraces in Fortymile Wash. Not to scale.

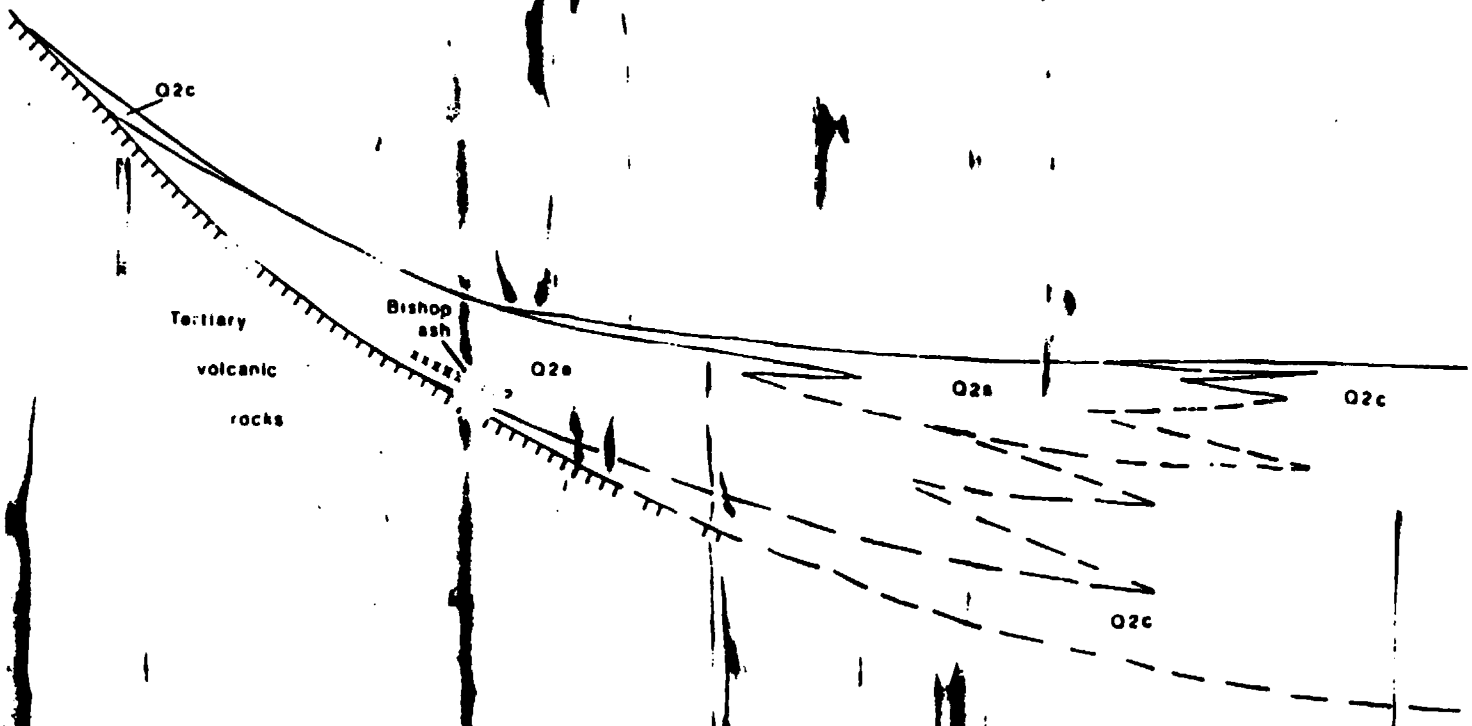

Figure 8.--Schematic diagram showing relationship of subunits Q2c, Q2e, and Q2s in Yucca Mountain area. Dashed lines are inferred.

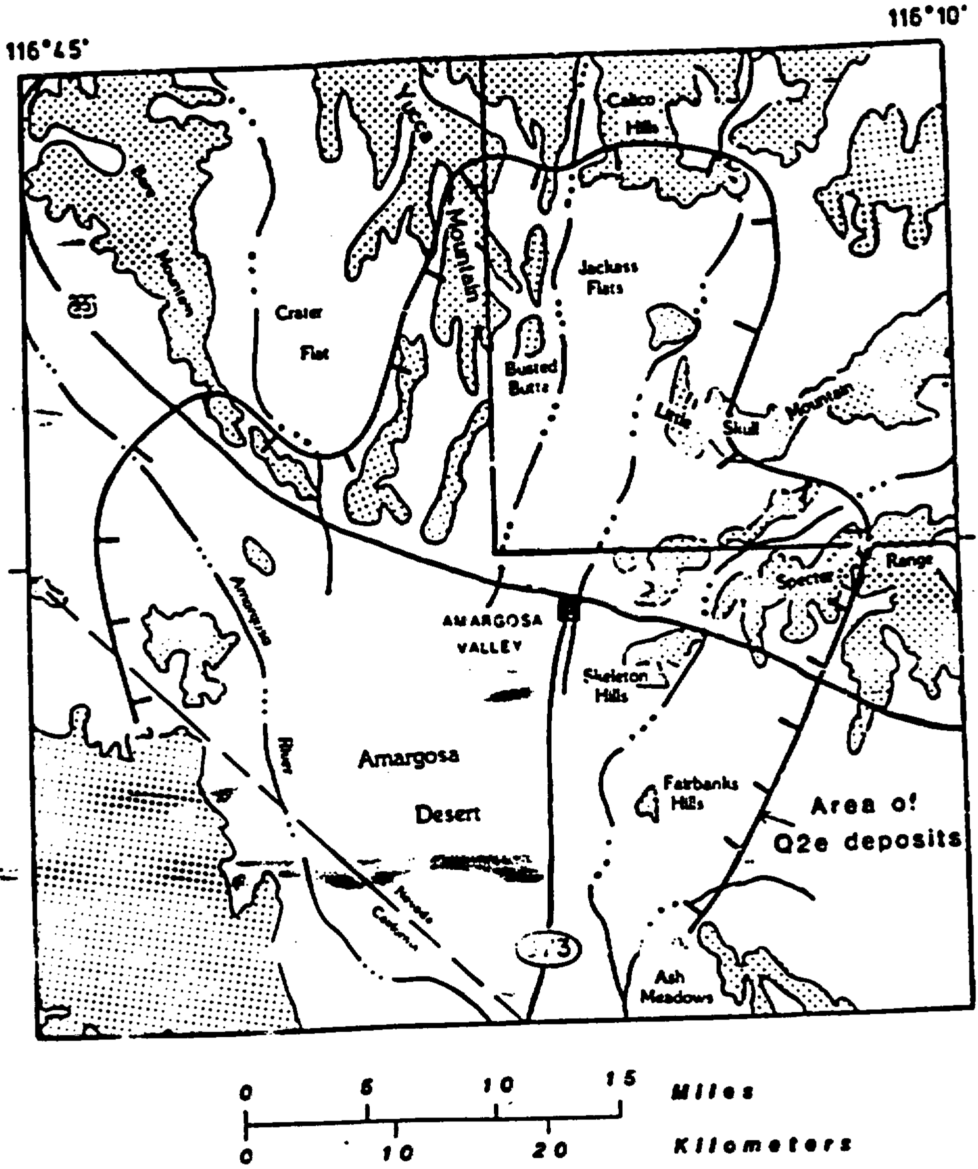

Figure 9.--Distribution of Q2e deposits. Based on the Lathrop Wells quadrangle (Swadley, 1983), the Big Dune quadrangle (Swadley and Carr, 1987), the Bare Mountain quadrangle (Swadley and Parrish, in press), author's mapping in the Topopah Spring quadrangle, and reconnaissance mapping elsewhere.

were deposited by prevailing winds from the south to southwest on any or all sides of topographic obstructions. At the southern end of Yucca Mountain, dissected ramps are present on both sides of north-south ridges. Busted Butte is surrounded by Q2e ramps. On Yucca Mountain, ramps appear to be thicker on the west faces than on the east faces of north-south ridges except for Yucca Crest. On the west side of Yucca Crest and the ridges to the west, Q2e is absent or present only as small patches and thin sheets. In the Calico Hills, Q2e was deposited as sand sheets on unit QTa and on bedrock on south-facing slopes. In the center of the Calico Hills, sheets of Q2e less than 1 m thick were deposited on pediments cut on the Eleana Formation and unit QTa. East of Topopah Wash, most sand ramps are on south- or west-facing slopes. Small, low hills of Paleozoic rocks in the central and western part of the northern Amargosa Desert are completely surrounded by ramps or may have isolated ramps on all faces. The maximum stratigraphic thickness of subunit Q2e is about 50 m. In the Striped Hills, ramps were built as much as 80 m above the piedmont slope. The best exposures of subunit Q2e are on the lower slopes of Busted Butte where washes have dissected these deposits.

Subunit Q2e is a lithofacies of subunit Q2c (fig. 8). Where subunit Q2e is underlain by subunit Q2c, the contact is less than 5 m above bedrock. Subunit Q2c also overlies subunit Q2e and occurs as tongues within Q2e. The Bishop ash (738 ka) occurs at or near the base of subunit Q2e at several locations in Jackass Flats and around the northern edge of the Amargosa Desert (Swadley, 1983; Swadley and Carr, 1987). The Bishop ash also occurs within 3 m of the base of subunit Q2c in the Calico Hills.

Macrotopography on subunit Q2e is flat between washes. Microrelief is less than 0.2 m. Drainage on subunit Q2e is poorly developed. Washes that dissect Q2e originate almost wholly from preexisting washes in bedrock. Small washes are V-shaped with steep banks in their upper parts. The lower parts of small washes and most of the larger washes have flat bottoms with steep banks. A few tributary washes south of Dune Wash and some washes on Little Skull Mountain have Q2c, Q2b, and (or) Q1c terraces inset into subunit Q2e.

Soils on subunit Q2e are typically eroded down to the calcic horizon. The A horizons vary from typical Av horizons to eolian silt and clay mixed with the underlying sand. Most Q2e soils consist of an Av horizon less than 20 cm thick that overlies a stage II to IV calcic horizon that is 0.5 to 1.0 m thick. Cambic B horizons, less than 0.5 m thick, occur locally. The variations in the development of calcic horizons suggest that some of the soils are of different ages. Dissection of the sand ramps around Busted Butte has exposed several calcic horizons within subunit Q2e. Alternating periods of eolian deposition, reworking by sheetwash, and nondeposition and soil development may account for the multiple calcic horizons in Q2e.

Calcium carbonate has also been deposited in and below the calcic horizon as root casts and as fracture fillings. Root casts vary from single roots that penetrate as deep as 2 m below the surface to dense mats less than 15 cm thick that are less than 2 m below the surface. Fracture fillings are commonly 5-10 cm thick and extend to depths of more than 4 m even though the sand next to the fracture fillings is very friable.

The topographic relationship of subunit Q2e to other deposits differs from place to place. At some locations, Q2e overlies subunit Q2c, but most of the sand ramps of Q2e at the southern end of Yucca Mountain and sand sheets of Q2e south of the Calico Hills are covered by subunit Q2c. On some ramps, subunit Q2c is inset into Q2e as terrace deposits, occurs as slopewash deposits at the foot of Q2e sand ramps, or is deposited along washes that transect the lower end of a sand ramp. Thus, subunit Q2c is both older and younger than subunit Q2e, and subunit Q2e is a lithofacies of subunit Q2c.

Desert pavement on Q2e varies from scattered and poorly packed to continuous and densely packed. Packing appears to increase with decreasing slope. The paucity of pebble- to cobble-sized clasts within most Q2e deposits indicates that pavements on Q2e are formed by coarser clasts that migrated down ramp surfaces. These clasts were derived from slope wash from bedrock or surficial deposits above the ramps. On one sand ramp south of Dune Wash, pavement clasts have migrated downslope 0.6 km from volcanic cliffs above the ramp. Clasts have maximum dimensions less than 0.2 m. Varnish is a dull, patchy film that ranges from very dark brown to brown.

The areal distribution of subunit Q2e (fig. 9) indicates that winds from the south and southwest deposited sand where air flow was perturbed by topographic obstructions. Much of the sand probably came from the Amargosa Desert, but dunes near the Funeral Range (W C Swadley, U.S. Geological Survey, oral commun., 1983) indicate that some of the sand may have come from Death Valley. Beds range from 0.1 to 1 m in thickness, and usually lack crossbedding. In some sand ramps, a single tongue of coarse slopewash material is present near the middle of the sand deposit. The tongues of coarse debris have a maximum thickness of 1 m and thin within a few hundred meters downslope to less than 0.5 m. Sand in the upper 0.5 to 1 m of Q2e contains scattered pebbles, cobbles, and boulders below some bedrock cliffs in the Yucca Mountain area. The coarse clasts are probably gravity-transported debris.

Subunit Q2s.--Subunit Q2s consists of alluvial sands and pebbly sands and is a lithofacies of subunits Q2c and Q2e (fig. 8). It is topographically lower than subunit Q2e on middle to lower piedmont slopes from the Calico Hills to the floor of the Amargosa Desert and from Yucca Mountain to the eastern edge of Jackass Flats. Subunit Q2s was derived mostly from deposits of subunit Q2e that blocked washes in the Yucca Mountain area. The maximum thickness seen in subunit Q2s is about 5 m.

The best exposures of subunit Q2s are on the upper piedmont slopes south of the Calico Hills. On the southwest side of the Calico Hills, washes that drain into Fortymile Wash expose 3-5 m of Q2s intertongued with subunit Q2c.

Most of the topographic characteristics of Q2s are like those of subunit Q2c. Where washes have dissected Q2s and the underlying deposits, the banks of these washes have shallow, rounded "rills" in Q2s that are a few meters apart.

Soils in subunit Q2s have an Av horizon like that of Q2c. B horizons are argillic, brownish red, have thin clay films on the sand grains, and are usually 50 to 80 cm thick. The argillic B horizon grades downward into a stage III to IV calcic horizon.

Subunit Q2s occurs on the lower slopes and on piedmonts downslope from Q2e, the main source for Q2s. On middle and upper piedmont slopes, Q2s is at the surface, but on the south and southwest piedmont slopes of the Calico Hills, subunit Q2s is overlain by a few meters of Q2c. On lower piedmont slopes of Jackass Flats and on the floor of the Amargosa Desert, either subunit Q2c or Q2b may overlie subunit Q2s.

Desert pavement ranges from loosely to densely packed and from well sorted to poorly sorted. Densely packed and poorly to moderately sorted pavements are present on middle to upper piedmont slopes. Loosely to moderately packed and moderately to well sorted pavements are present on middle piedmont slopes down to the floor of the Amargosa Desert. In some areas of the Amargosa Desert, the pavement is denser in surface lows that are less than a meter deep and less than 20 m across. The lows and the pavement appear to be the result of deflation. Maximum fragment sizes range from about 20 cm on upper piedmont slopes to less than 10 cm on the floor of the Amargosa Desert. Varnish is usually a very dark brown to blackish brown, dull to shiny film that covers part to all of the upper surface of pavement fragments.

Subunit Q2s is predominantly fine to medium sand. Clasts of volcanic and sedimentary rocks are usually less than 10 mm and are rarely as much as 50 mm in diameter. The larger clasts comprise less than 1 to about 5 percent of less than half the beds. Clay- or silt-size material is rarely present in sandy beds, but beds of clay or silt a few centimeters thick are locally present. Graded beds are locally present and indicate an alluvial origin for subunit Q2s. Color in fresh exposures is very light gray to very pale brownish gray. In outcrop, subunit Q2s is pale brownish gray.

<u>Subunit Q2b</u>.--Subunit Q2b consists of terrace deposits and thin sheets of alluvial fan deposits. The terrace deposits are present on strath terraces in most washes that are incised to depths greater than 3-5 m in the Yucca Mountain area. Alluvial fan deposits of subunit Q2b are present as irregular, thin sheets on piedmont slopes downslope from the mouths of incised washes and on the lower piedmont slopes of the Amargosa Desert. These sheets cannot be distinguished from Q2c except by comparison of soils. Subunit Q2b was included with subunit Q2c as subunit Q2bc on most lower piedmont slopes and the floor of the Amargosa Desert (Swadley, 1983). In major washes such as Fortymile and Topopah Washes, subunit Q2b forms the lowest terrace that has a desert pavement and an Av horizon. Terrace deposits are less than 4 m thick. Alluvial fan deposits on lower slopes probably have a similar thickness. Although much of surface is covered, the best exposures of subunit Q2b are along Fortymile Wash south of the road to Yucca Mountain. Typical terrace surfaces on Q2b deposits can be seen on the west side of Fortymile Wash just north of the road to Yucca Mountain.

Macrotopography is flat; microrelief is less than 0.2 m on lower piedmont slopes and basin floors. Terrace deposits of subunit Q2b in and near bedrock have a low slope toward the washes; on middle to lower piedmont slopes, they are nearly horizontal across the terraces. Drainage patterns on thin sheets on lower piedmont slopes are like those on subunit Q2c.

The soil on subunit Q2b has an Av horizon like that on older deposits. The B horizon is cambic and yellowish to grayish brown below elevations of about 1,200 m and argillic and light brown to pale reddish brown at higher elevations. Calcic horizons range from stage I to II at elevations below about 1,200 m to II and III at higher elevations. Desert pavement is similar to that of subunit Q2c, but is commonly less densely packed and has a duller, less complete varnish than pavements on adjacent Q2c.

Terrace deposits of subunit Q2b are topographically lower than all other Q2 subunits. Thin, alluvial fan deposits of Q2b on lower piedmont slopes and basin floors are at the same level as or overlie older deposits.

Subunit Q2b is mostly coarse alluvial gravel deposited on strath terraces or as thin sheets of alluvium in the distributary part of washes that originate in bedrock hills. Clast sizes and clay content of Q2b are like those of Q2c. In some washes just downslope from bedrock on the south side of the Calico Hills, subunit Q2b consists of scattered clasts from 10 to 50 cm in diameter that lie on strath terraces.

Terraces of Q2b are eroded only along the edges, but on piedmont slopes, Q2b may be eroded by anastamosing channels for a short distance downslope from the end of the wash responsible for deposition of the material. On lower piedmont slopes and on valley floors, Q2b is eroded only by washes that originate in bedrock or unit QTa.

Subunit Q2a.--Subunit Q2a, as originally defined (Hoover and Morrison, 1981), consists of debris flow deposits that have been identified only in the Calico Hills and between Syncline Ridge and the Eleana Range in western Yucca Flat. At these locations, subunit Q2a occurs along the washes as terrace deposits in bedrock and as sheets that overlie subunit Q2c on the uppermost piedmont slopes. Deposits at both locations are similar: (1) below drainage basins of less than 5 km^2 that originate in argillite of unit J of the Eleana Formation, (2) along washes that lack subunit Q2b, and (3) overlying subunit Q2c. The maximum thickness of subunit Q2a is 2 m.

Macrotopography is flat, but microrelief that ranges from less than 0.5 m to 1 m gives the subunit a hummocky appearance. Except for incision along pre-Q2a washes, no drainage has been developed in the subunit. The soil consists of an Av horizon, a weakly developed cambic B horizon, and a stage I calcic horizon. Desert pavement is poorly developed and very loosely packed. Varnish on pavement fragments is a patchy, dull, brown to dark-brown film.

In addition to microrelief, lithology is the major difference between Q2a and older Q2 subunits. Clasts of volcanic rock or quartzite from 0.5 to 1 m in diameter are scattered through a matrix of pebbles, sand, and silt. In the Calico Hills, most of the matrix grains are argillite; in Yucca Flat, the matrix grains are volcanic rock and argillite. Lack of bedding and the large clasts supported by a silt- to pebble-size matrix indicate a debris flow origin of subunit Q2a.

Subunit Q2a(?) occurs as slopewash deposits and local debris flows at the foot of steep slopes on Yucca Mountain and below fault scarps in Rock Valley and Crater Flat. Subunit Q2a(?) overlies subunits Q2b and Q2c at these locations. The subunit has also been recognized where it overlies older Q2 terrace deposits along Yucca and Drill Hole Washes. In mapping, subunit

Q2a(?) has been included with underlying units, because of its patchy distribution and thinness.

Deposits of Q2a(?) are similar to Q2a deposits in macrotopography, microrelief, lack of drainage development, and desert pavement. At most locations, the sand-sized matrix has a reddish-brown color that may be inherited partly from B horizons of older deposits from which it was derived. An Av horizon is present on all Q2a(?) deposits. A cambic B horizon may be present, but is not readily apparent. Calcic horizons are stage I. Deposits of subunit Q2a(?) that overlie older terrace deposits contain fewer clasts than the slopewash deposits and have a crude bedding or layering.

Subunit Q2a(?) differs from subunit Q2a in that:

1. Deposits of Q2a(?) are reddish brown, whereas those of Q2a are shades of gray to brown.

2. Deposits of Q2a(?) appear to have originated on steep slopes rather than in a single drainage basin as did deposits of Q2a.

3. Crude bedding is apparent in deposits of Q2a(?) that overlie older Q2 terrace deposits, whereas, the few exposures of Q2a seem to be a single, unbedded layer.

4. Deposits of Q2a(?) were derived mostly from volcanic rocks, whereas, Q2a was derived mostly from argillite of the Eleana Formation.

5. The volume of clasts larger than 10 mm is greater in Q2a(?) than in Q2a, but maximum sizes are greater in Q2a.

Although Q2a(?) and Q2a differ, the similarity of their stratigraphic position and topographic location, just downslope from bedrock, suggests that they are probably equivalent in age. Deposits of Q2a(?) have been dated radiometrically, but Q2a has not been dated.

Unit Q1

Unit Q1 consists of alluvial deposits, debris flow deposits, and eolian sand that are mapped in five subunits: Q1c and Q1a, predominantly alluvial gravels and sands; Q1b, debris flows and alluvial gravels; Q1s, alluvial sand sheets; and Q1e, eolian dunes and sand sheets. In comparison to units QTa and Q2, unit Q1 has been only slightly modified since it was deposited. Soils are weakly developed, desert pavements are not present, and only the oldest surfaces have been smoothed by creep and sheetwash.

Subunit Q1c.--Subunit Q1c occurs as terrace deposits, as alluvial fans and sheetwash deposits on middle to lower piedmont slopes, and as alluvial fans at the junction of tributaries with larger washes and across a few fault and terrace scarps. Terrace deposits of subunit Q1c occur in all washes that originate in bedrock or unit QTa. Alluvial fans and sheetwash deposits overlie units Q2 and QTa on middle to lower piedmont slopes. Alluvial fans of Q1c occur at the junction of tributaries with major washes and across some terrace scarps and Quaternary fault scarps. Thickness of subunit Q1c is usually less than 5 m. The best exposures of subunit Qlc are along the banks of terrace deposits in major washes, such as Fortymile Wash and Topopah Wash.

Subunit Qlc has a flat to slightly convex macrotopography. Microrelief is usually less than 0.2 m, but dissection of terraces of Qlc in larger washes can result in a greater relief. Drainage development in Qlc occurs along preexisting washes and as short distributory channels below these washes.

In gravelly deposits, the only noticeable soil horizon is a stage I calcic horizon that consists of calcium carbonate coatings on clasts. In sandy deposits, an A horizon can be detected by a slight darkening of the sand and, locally, a slight increase in calcium carbonate at a depth of 2-5 cm. Desert pavement is lacking on subunit Qlc.

Subunit Qlc varies from pebbly sands to gravels that contain boulders as much as 0.5 m in diameter. Individual beds are commonly well sorted, but clasts may vary from sand to cobbles in adjacent beds. Debris flow deposits make up less than 25 percent of the volume of subunit Qlc, but in alluvial fans at the junction of tributaries to larger washes, debris flow deposits may comprise about half of subunit Qlc. In fresh exposures, subunit Qlc is light gray; the surface is light brownish gray.

Subunit Qls.--Subunit Qls occurs as alluvial sands on middle to lower piedmont slopes and on the floor of the Amargosa Desert. The subunit is a lithofacies of subunit Qlc that was produced primarily by erosion of subunits Q2e and Q2s. The subunit overlies all Q2 subunits except Q2a and Q2u(?) and is overlain by subunit Qlb. Subunit Qls is limited to middle and lower piedmont slopes below Q2e and Q2s and to the floor of the Amargosa Desert. Maximum thickness of subunit Qls is 5 m. The best exposures of Qls are on the piedmont slopes between Little Skull Mountain and Fortymile Wash.

Topography, drainage, soils, topographic relationships, and depositional process in Qls duplicate these characteristics in subunit Qlc. In subunit Qls, the deposits range from 90 to 100 percent sand. Clasts larger than sand are commonly less than 10 cm in diameter and a have a maximum diameter of about 20 cm. A deflation pavement is usually present on subunit Qls; pebbles and larger clasts cover 20-50 percent of the surface.

Subunit Qlb.--Subunit Qlb occurs as debris flow deposits and small amounts of alluvial gravels in all washes. The best exposures of Qlb are along Fortymile Wash, north of the road to Yucca Mountain. In small washes that contain remnants of Qlc terraces, Qlb is preserved as long, convex tongues that are 5 to 10 m wide or as long, flat-topped tongues with convex sides that are 10 to 20 m wide. Maximum thickness of subunit Qlb is 3 m, but most deposits are less than 1.5 m thick. In major washes, such as Dune, Sever, Yucca, Fortymile, and Topopah Washes, subunit Qlb occurs as scattered, elongate patches of cobbles and boulders between individual channels of braided sections of these washes. The patches of cobbles and boulders usually range from 1x2 to 10x50 m, but they may be longer at the edge of a braided channel pattern. Small patches are convex across both the long and short dimensions; larger patches are convex to flat topped across the short dimension. Relief on these patches ranges from 0.3 to 1 m.

Soil development in Qlb deposits is usually weak because of the youthfulness of these deposits and because most of the upper 0.5 m is comprised of pebble- to boulder-sized clasts. Spaces between the larger clasts are empty at the surface and are partly to completely filled by sand- to clay-sized material below the surface. In some exposures, a stage I calcic horizon is present. Subunit Qlb overlies Qlc in small washes, in the upper to middle reaches of major washes, and on middle to lower piedmont slopes. In major washes and the Amargosa River, subunit Qlb locally occurs as terrace remnants less than 0.5 m below Qlc terraces.

The debris flow origin of Qlb is indicated by the lack of bedding, the predominance of cobble- to boulder-sized clasts, and by its occurrence as undissected tongues on Qlc terraces. Small tongues have noses and short levees trailing back from the noses that consist of only boulders from 0.3 to 1 m in diameter. Longer and wider tongues of Qlb have levees that trail back from the noses for most of the length of the tongues. Elongated patches 1 to 5 m wide and 5 to 50 m long of boulders occur on the surface within the larger tongues.

Subunit Qle.--Subunit Qle occurs as eolian sand that forms dunes and sandsheets in the Big Dune quadrangle and on the basalt cone and flows northwest of Amargosa Valley. Qle also forms sand sheets in the southern Yucca Mountain area and near bedrock outcrops on the east side of Jackass Flats. Big Dune is the largest outcrop of subunit Qle; it is about 5 km long, as much as 2 km wide, and approximately 100 m high. Deposits older than Qle are not exposed on Big Dune, but to the northwest and southeast of Big Dune, outcrops of Paleozoic rocks are partly covered by Q2e and Qle dunes. Sand sheets around Big Dune are less than 3 m thick. Sand dunes on lava flows of the Lathrop Wells basalt cone are 2 to 5 m high and lie on a sand sheet 2 to 3 m thick. Sand on the south side of the basalt cone has a maximum thickness of about 2 m. In the Ash Meadows quadrangle, layers of peat are interbedded in sand dunes (Mehringer and Warren, 1976) that are probably equivalent to subunit Qle.

Soil horizons are not apparent in most outcrops of subunit Qle. In the Ash Meadows area, weakly developed soils of middle Holocene age are present within dunes of subunit Qle (Mehringer and Warren, 1976). Radiometric ages, archaeological material in Holocene dunes, and soil morphology (Mehringer and Warren, 1976; Haynes, 1967) indicate that subunit Qle includes three separate periods of Holocene eolian deposition. The volume and areal distribution of Qle deposits are much smaller than for subunit Q2e. Except for a small dune on the north side of the Skeleton Hills and the sand on the Lathrop Wells basalt cone, most of subunit Qle was deposited on the basin floor of the Amargosa Desert or in areas of little topographic relief. Along Fortymile and Topopah Washes and at the mouth of the unnamed wash that drains Crater Flat, subunit Qle is deposited on Qlb and older units as small patches of rippled sand that are less than 0.5 m thick. Near sources of silt- and clay-sized materials, these particles form laminations between sand beds or are mixed into sand beds.

Subunit Qla.--Subunit Qla occurs as alluvial deposits in the bottom of active channels. In braided channels, the subunit was deposited as small elongated patches that are a few centimeters thick. In major washes, subunit Qla was deposited as channel fill, a few centimeters to 1.5 m below Qlc or Qlb terraces. About 1 km south of the road to Yucca Mountain in Fortymile Wash, subunit Qla is less than 1 m thick, and fills a channel approximately 30 m wide. Along single channels, subunit Qla usually has a relatively smooth surface for 100 to 200 m along the wash with ripples 2 to 5 cm high. Across single channels, 10 to 30 m wide, subunit Qla may have 0.5 to 1 m of relief. Subunit Qla lacks soil development. Within the hills and on upper piedmont slopes, Qla consists of well-sorted gravels that are mostly pebbles with small amounts of sand. On middle to lower piedmont slopes and on the basin floors, Qla consists mostly of sand that contains minor amounts of pebbles.

Pliocene and Quaternary Basalts

Remnants of basalt flows form part of the possible dam west of Eagle Mountain. The basalt flows overlie debris flow deposits and alluvial gravels that were derived partly from Eagle Mountain and partly from the Greenwater Range. The basalts are less than 4 km from basalts in the Greenwater Range that are 4.03-7.16 m.y. old (Luedke and Smith, 1981).

Basalts that are 3.75 and 1.1 m.y. old crop out in Crater Flat (Carr, 1982). The older group of basalts in southeastern Crater Flat is highly dissected. Unit QTa overlies the older basalts that in turn overlie older alluvium (Carr, 1982). The younger group of basalts consists of flows and cones from four eruptive centers that form a gently curved line extending north-northeast across central Crater Flat. The cones and lava flows of the younger group of basalts are dissected, but dissection is limited to ejecta layers on the cones, the brecciated tops of flows, and flow edges.

Basalt flows and a cinder cone occur about 10 km northwest of Amargosa Valley. The flows and the cone are undissected. Basalt ash is interbedded with subunit Q2c less than 1 km north of the cone. Stalactitic calcite on welded tuff cobbles that immediately underlie the basalt flow has been dated at 345 ka (Szabo and others, 1981).

Pliocene and Quaternary Spring Deposits

Spring deposits that consist of tufas and calcite veins and spring vents occur in deposits that range in age from pre-QTa to the present. The spring deposits occur in the Amargosa Desert and near outcrops of Paleozoic carbonate rocks east of Nevada State Highway 373.

Spring deposits occurred between deposition of the waterlaid sediments and deposition of unit QTa, during deposition of unit QTa, and between deposition of unit QTa and post-QTa pedimentation. Some outcrops of tufa that overlie the waterlaid sediments of Amargosa marsh in the headwaters of Carson Slough differ from tufas in the upper unit of the sediments. The tufas occur as single outcrops or a few scattered outcrops that are a few meters to 50 m in their maximum dimension and are not related to channels. Calcite veins and vents cut across the tufas. At one location, tufa that lies on the waterlaid sediments is overlain by unit QTa. At several locations, from Devils Hole to the north side of the Amargosa Desert (Winograd and Doty, 1980), calcite veins and vents in unit QTa are truncated by the pediment cut on unit QTa. At Devils Hole (Cave) No. 2, a sinkhole approximately 300 m north of Devils Hole, a small spring mound that contains tufa is enclosed within unit QTa.

Spring deposits have not been found in units Q2 and Q1, but probably occur locally in these units near modern springs. At Point of Rock Springs in the Ash Meadows area, tufas form a spring mound that covers an area of at least 10,000 m^2. Rounded ridges that are characteristic of unit QTa extend from the tufa upslope into unit QTa. The relationship of the spring deposits to Q1 and Q2 deposits in the wash below the springs is not clear.

Spring deposits are not recognizable in the lower unit of the waterlaid sediments, but the large volume of chalk and magnesium silicates in the lower unit required a large volume of spring discharge during deposition (R.L. Hay, Univ. of Southern Illinois, oral commun., 1980). Evidence of springs was probably not preserved because the waterlaid sediments were not indurated. Induration of the lower unit probably formed an aquitard above the Paleozoic aquifer that underlies most of the Amargosa Desert (Winograd and Thordarson, 1975). This aquitard would restrict the location of most of the upper unit and younger spring deposits to outcrops of Paleozoic carbonate rocks at the edge of the aquitard.

Age of Late Pliocene and Quaternary Deposits

Ages of the waterlaid sediments of Amargosa Marsh and younger surficial deposits have been determined mostly by radiometric dating methods. Most of these methods, such as ^{14}C, $^{40}K/^{40}A$, and fission-track dating, are standard methods, but the uranium-trend method used extensively on middle to late Pleistocene deposits, is relatively new. The uranium-trend method is an empirical method. This method assumes vertical migration of isotopes in a continuously open system, has a variable accuracy that is dependent on the isotopic quantities originally in the sediments, and may require calibration by other dating methods at new locations (Rosholt, 1980, 1985). The consistent determinations of similar ages for deposits and soils considered to be stratigraphically equivalent have clearly demonstrated the usefulness of this method for determining the age of surficial deposits in the Yucca Mountain area.

In this report, the Pliocene-Pleistocene boundary is considered to be 1.7 Ma (Obradovich and others, 1982). The boundary between early and middle Pleistocene is considered to be at the Brunhes-Matuyama magnetic boundary at 788 ka (Johnson, 1982). The boundary between the middle and late Pleistocene is considered to be the boundary between oceanic ^{18}O isotope stages 5 and 6 at 132 ka (Johnson, 1982). The Pleistocene-Holocene boundary is considered to be at the boundary between ^{18}O stages 1 and 2 at 11 ka (Kominz and others, 1979).

Basalt flows at the possible dam near Eagle Mountain have not been dated, but basalts in the Greenwater Range, less than 4 km to the west, have K-Ar ages between 4.03±0.12 and 7.16±0.22 Ma (Luedke and Smith, 1981). Both the basalt at the possible dam and in Greenwater Range are faulted. The proximity of the faulted basalts at the two locations suggests that the basalts are probably the same age, and that impoundment of a lake probably began less than 4-7 Ma ago.

Deposition of the lower unit of the waterlaid sediments of Amargosa marsh began prior to deposition of an included ash bed dated at 3.22±0.12 Ma by the K-Ar method (R.F. Marvin and others, U.S. Geological Survey, written commun.,

1983) and 2.95±0.42 Ma by the fission-track method (C.W. Naeser, U.S. Geological Survey, written commun., 1980). An ash bed in the lower unit, where it is unconformably overlain by the river gravels of ancestral Rock Valley Wash in SE1/4 NE1/4 sec. 19, T. 16 S., R. 50 E., has been dated at 2.1±0.4 Ma by the fission-track method (C.W. Naeser, U.S. Geological Survey, written commun., 1982). The ash bed underlies recrystallized chalk at the edge of the river gravels and is probably just below the top of the lower unit.

Fossils in the upper unit of the waterlaid sediments indicate that Amargosa marsh may have persisted into the Quaternary period. In secs. 22 and 23, T. 14 S, R. 49 E., just north of U.S. Highway 95, a small outcrop of the upper unit consists of tuffaceous sands and clays overlain by diatomaceous marl, which in turn is overlain by tufa. Richard M. Forester (U.S. Geological Survey, written commun., 1979) identified several species of ostracodes from the diatomaceous marl. Cypridopsis vidua (Muller), also identified by Forester from a sag-pond deposit in unit QTa in Yucca Flat, is known from the Pliocene and Quaternary, but is much more common in the Quaternary. Charles A. Repenning (U.S. Geological Survey, written commun., 1982) identified vertebrate fragments from the tufa and the underlying diatomaceous marls as being less than 2 m.y. old. Tooth fragments of Mammuthus sp. cf. M. columbi (Falconer), Equus sp., and a large camelid were identified. Poorly preserved fragments of a tusk and limb bones occur in the diatomaceous marl. Repenning states that Mammuthus is not known to be older than 2 Ma in North America. He states that the thickness of the enamel plates from the Mammuthus teeth suggest an age considerably less than 2 Ma. Thus, deposition of the waterlaid sediments of Amargosa marsh probably ended in early Pleistocene time.

The fossils in the upper unit verify the stratigraphic position of the 2.1 Ma-old ash bed in the lower unit. Although the recrystallized chalk above the ash bed is known only in the lower unit, the topographic position of the chalk, when compared to that of the tufas of the upper unit, which are exposed 2 km to the east, suggest that the chalk might be in the upper unit. If the ash is in the upper unit, then either a long hiatus occurred shortly after deposition of the ash and before deposition of the fossils in the upper unit, or the chronologic range of Mammuthus is incorrect. Because neither alternative seems reasonable, the 2.1 Ma-old ash is assumed to be in the lower unit of the waterlaid sediments of Amargosa marsh.

Unit QTa overlies the upper unit of the waterlaid sediments of Amargosa marsh on the west side of the Paleozoic ridge that contains Devil Hole. It also overlies the river gravels of ancestral Rock Valley Wash. Unit QTa is, therefore, younger than the 2.1 Ma-old ash in the lower unit of the waterlaid sediments and the Mammuthus remains in the upper unit, and is probably Quaternary in age.

Delicate leaves are preserved on plant casts in the tufa of the upper unit west of Devils Hole. The preservation of the leaves occurs only near the eroded edge of overlying deposits of unit QTa. Further from the edge of QTa deposits, exposed plant casts are partially dissolved and leaves are not discernible. The preservation near the edge of unit QTa and dissolution further away suggests that unit QTa was deposited shortly after the deposition of the tufa and thus preserved the leaves of the plant casts that otherwise would not have been preserved.

Unit QTa is designated as both Pliocene(?) and Pleistocene, but the faunal evidence indicates that it is probably only Pleistocene in age. In addition to the probable Pleistocene age of the upper unit of the waterlaid sediments of Amargosa marsh at the Mammuthus locality, fossils in sag-pond deposits within unit QTa in Yucca Flat also indicate a Quaternary age. Richard M. Forester (U.S. Geological Survey, written commun., 1979) reports that Cypridopsis vidua (Mulier) in the sag-pond deposits in western Yucca Flat has not been found in sediments believed to be Miocene or older, but is far more common in the Quaternary than in the Pliocene. Scottia n. sp. (sensu stricto), also found in the sag-pond deposits is known only from Pleistocene sediments in North America, and therefore, the sag-pond deposits and the overlying part of unit QTa are probably Quaternary.

The Bishop ash, 738 ka (Izett, 1982), has been found at several locations in the Yucca Mountain area at or within 5 m of the base of subunit Q2e and less than 3 m above the base of subunit Q2c in the Calico Hills just west of Fortymile Wash. The pedimentation, development of a soil, and dissection of unit QTa prior to deposition of unit Q2 and the presence of an alluvial unit between units QTa and Q2 strongly suggest that deposition of unit QTa took place significantly before 738 ka.

Although the Bishop ash (738 ka) occurs at or near the base of subunits Q2e and Q2c at all locations where the ash has been found, deposition of subunit Q2c could have begun significantly before the ash was deposited. All locations of the ash are topographically high and on or just above bedrock. These locations suggest that older deposits of subunit Q2c may be concealed at lower elevations.

Radiometric ages determined for units Q2 and Q1 are shown in table 1 (Rosholt and others, 1985; Szabo and others, 1981). The uranium-trend method determines when deposition or erosion ended, and thus, when soil formation began. Uranium-trend plots of data are linear for samples of unit Q2 that include both the B and calcic horizons. Disturbance of the vertical, open system, on which the empirical uranium-trend method is based, by biotic or tectonic processes can affect the system and may result in ages younger than the actual age (J.N. Rosholt, U.S. Geological Survey, oral commun., 1981). At the ETS trench in Jackass Flats, the soil that was sampled appears to be undisturbed, but the age of 160 k.y. is much younger than the stratigraphic position of Q2s warrants. About 20 m south of the sample site the beds from which the sample was taken are eroded at a topographic scarp. The sample age, therefore, probably indicates the end of erosion, rather than the end of deposition.

The repetition of ages determined for multiple samples of subunits Q2a(?), Q2b, and Q2c for both buried and surface deposits at different locations demonstrates the precision of the uranium-trend method. Coincidental agreement of ages at two or three locations for a single stratigraphic unit may be possible, but coincidental agreement of five or six ages in widely separated locations that vary in geomorphic position, soil development, and soil parent material seems unlikely. Similarly, the hypothesis that numerous ages of four stratigraphic units could be displaced equally by some unknown mechanism also seems unlikely.

Table 1.--Radiometric ages of Quaternary stratigraphic units in the Yucca Mountain area

Stratigraphic unit	Material	Age (ka)[1]	Method	Sample locality
Subunit Q1c	Charcoal in fluvial sand	8.3±0.075	^{14}C [2]	Amargosa River bank 6 m below surface 2 km SE of Beatty
Av horizon	Eolian silt and sand	30±30	U-trend[4]	SW Frenchman Flat trench
Av horizon[3]	Carbonate in eolian silt and sand	25±10	U-series[5]	Basalt cone 11 km WNW of Amargosa Valley
Subunit Q2a(?)	Slopewash gravel	31±10	U-trend[4]	RV-1 trench, Rock Valley
Do-----	B horizon	36±20	U-trend[4]	RV-2 trench, Rock Valley
Do-----	B horizon in slopewash gravel	37±24	U-trend[4]	RV-1 trench, Rock Valley
Do-----	B horizon in slopewash gravel	38±10	U-trend[4]	RV-2 trench, Rock Valley
Do-----	B horizon in slopewash gravel	38±10	U-trend[4]	Trench 14, Yucca Mountain
Do-----	Alluvial gravel	40±10	U-trend[4]	CF-3 trench, east-central Crater Flat
Do-----	Slopewash gravel	41±10	U-trend[4]	Trench 13, Yucca Mountain
Do-----	Alluvial gravel	47±18	U-trend[4]	Trench 2, Yucca Mountain
Do-----	B horizon in slopewash sand	55±20	U-trend[4]	Trench 14, Yucca Mountain

Table 1.--Radiometric ages of Quaternary stratigraphic units in the Yucca Mountain area--Continued

Stratigraphic unit	Material	Age (ka)[1]	Method	Sample locality
Subunit Q2b	Alluvial gravel	145±25	U-trend[4]	Trench 2, Yucca Mountain
Do-----	Alluvial gravel	160±25	U-trend[4]	Charlie Brown gravel pit, Shoshone, California
Do-----	Calcareous B horizon	180±40	U-trend[4]	RV-1 trench, Rock Valley
Do-----	Alluvial gravel	190±50	U-trend[4]	CF-3 trench, east-central Crater Flat
Do-----	Alluvial gravel	190±0	U-trend[4]	SW Frenchman Flat trench
Do-----	Alluvial gravel	200±80	U-trend[4]	SW Frenchman Flat trench
Subunit Q2s	B and calcic horizons	160±90	U-trend[4]	ETS trench, Jackass Flats
Subunit Q2c (younger soil and underlying deposits)	Alluvial gravel	240±50	U-trend[4]	Trench 13, Yucca Mountain
Do-----	K horizon	270±30	U-trend[4]	RV-1 trench, Rock Valley
Do-----	Alluvial gravel	270±30	U-trend[4]	CF-3 trench, east-central Crater Flat
Do-----	Alluvial gravel	270±35	U-trend[4]	Jackass Divide trench
Do-----	K horizon	270±90	U-trend[4]	Trench 14, Yucca Mountain
Do-----	Alluvial gravel	310±40	U-trend[4]	RV-1 trench, Rock Valley

Table 1.--Radiometric ages of Quaternary stratigraphic units in the Yucca Mountain area--Continued

Stratigraphic unit	Material	Age (ka)[1]	Method	Sample locality
Subunit Q2c (older soil and underlying deposits)	Alluvial gravel	390±100	U-trend[4]	RV-1 trench, Rock Valley
Do-----	Alluvial sand	400±50	U-trend[4]	Western SCF trench southern Crater Flat
Do-----	Slopewash sand	420±50	U-trend[4]	Trench 14, Yucca Mountain
Do-----	Alluvial gravel	430±40	U-trend[4]	Jackass Divide trench
Do-----	Alluvial gravel	480±60	U-trend[4]	Western SCF trench southern Crater Flat
Do-----	K horizon in gravel	480±90	U-trend[4]	Trench 14, Yucca Mountain

[1] One standard deviation.

[2] Analyzed by J.W. Robinson, U.S. Geological Survey, Menlo Park, California.

[3] Correlated to Av horizon by appearance.

[4] Rosholt and others, 1985.

[5] Szabo and others, 1981.

The age of subunit Qle in the Yucca Mountain area has not been determined, but numerous ^{14}C dates for charcoal and fossil seeds from sand dunes in two nearby areas indicate the probable times of accumulation. In the Ash Meadows area, three dates for charcoal in dunes and 10 dates for fossil seeds in peat interbedded with sand that is probably equivalent to Qle range from 2,940±100 to 5,320±70 yr B.P. (Mehringer and Warren, 1976). In the Corn Creek Springs area, about 35 km northwest of Las Vegas, seven charcoal samples at and near the base of dunes ranged from 4,030±100 to 5,200±100 yr B.P. (Haynes, 1967). A weakly developed soil occurs above this older material in both areas (Mehringer and Warren, 1976; Haynes, 1967). Three charcoal samples in eolian sand above the soil in the Ash Meadows area were dated between [illegible]±100 and 440±280 yr B.P. These intermediate-age deposits are overlain by a very weakly developed soil, which in turn, is locally overlain by Paiute pottery shards. Virgin Branch pottery shards that occur locally below the soil provides a maximum age of about 1,000 yr B.P. for the soil. Charcoal associated with the shards above the soil was dated at 220±100 yr B.P. (Mehringer and Warren, 1976).

On the basis of the stratigraphy in several trenches in the dunes at Ash Meadows, archaeological artifacts, and similar age dates in both the Ash Meadows and Corn Creek Springs areas, Mehringer and Warren (1976) concluded that there were three periods of eolian sand deposition during Holocene time: 5,300 to 3,000, 2,000 to 1,000 or less, and 200 yr B.P. to the present. The periods of sand deposition were separated by intervals of nondeposition and soil development from 3,000 to 2,000 and about 1,000 to 400 yr or less B.P. Similar periods of deposition and soil development in subunit Qle in the Yucca Mountain area are likely, because of the proximity of the Ash Meadows and Corn Creek Springs areas to Yucca Mountain.

At the numerous locations where subunits Qlc or Qls and Qle occur together, Qle always overlies Qlc or Qls. The minimum age of Qlc and Qls is, therefore, probably greater than 5,300 yr B.P. Where subunits Qle and Qlb occur together, sand sheets of Qle less than 0.5 m thick overlie Qlb. The stratigraphic position of Qlb above Qlc and Qls and the thinness of Qle overlying Qlb suggest that Qlb may be younger than the oldest period of Qle deposition, 5,300 to 3,000 yr B.P., and older than the youngest period of Qle deposition, or older than 1,000 yr B.P.

Subunit Qla probably corresponds to a period of arroyo erosion that began about 1840 throughout the southwestern United States (Antevs, 1955). In the Syncline Ridge area, a juniper tree, dated by dendrochronology, began growing in 1858 on a Qlc terrace. Erosion of the terrace by a Qla wash to a depth of [illegible] m exposed and killed a large root of the juniper tree in 1928.

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NAME Printed or typed	DATE IN	DATE OUT	Branch Chief	Author	Technical Reviewer	BTR Log-in	GTE	GMS	GMU	Other (Specify)	BTR Chief	Chief Geologist	Director	SIGNATURE (or initials[9])
Branch	6/24/87	6/24/87	X											William D Johnson
R.R. Shroba	6/24/87	7/14/87			X									RRS
~~[illegible]~~										–				
W. C. Swadley	8-20-87	9-2-87			X									W C Swadley
Hoover	9-3-87	10/9/87		X										DL Hoover
Earle Cressman	10/9/87	10/30/87												E Cressman
~~V. Glanzman~~ Author	10/30/87	11/5/87												DL Hoover
V. Glanzman	11/6/87	11/13/87												Virginia Glanzman
Branch	12/7/87	12/7/87	X											[illegible]
CTR	12/8/87	12/8/87												
DOE	11/6/87	5/26/89												for Ginny Glanzman
CTB Chief	5/30/89	5/30/89									x			Dian [illegible] acting
Dv Dir	6/7/89	14 June 1989								approve		x	x	

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SEE NUMBERED FOOTNOTES ON BACK OF THIS SHEET • CONTINUE ON ADDITIONAL FORMS IF NECESSARY

Prog. Mgr.: Raup

NNWSI-USGS-QMP-3.04, R1
Attachment 1
Page 1 of 1

NNA.900917.0061

Technical Reviewer's Appraisal Form
for NNWSI Publications

Title of Paper: Preliminary description of ~~Late Pliocene~~ and Quaternary Late Pliocene stratigraphy ~~of~~ at Yucca Mountain and vicinity, Nye County, Nevada

Authors(s): D. L. Hoover

Publication outlet and report number (if known): Open-File Report

Technical Reviewer: Ralph R. Shroba Date: July 14, 1987

Reviewer's title: Geologist

Recommendation (based on technical content):

- /_/ Publish as is
- /_/ Publish with minor technical revisions (as noted below or in attached memo)
- /X/ Publish only with major technical revisions (as noted below or in attached memo) and re-review
- /_/ Not suitable for publication in present form (reasons must be given in attached memo)

Memo attached: /X/ Yes /_/ No

Comments:

Ralph R. Shroba
Technical Reviewer's Signature

NNWSI-USGS-QMP-3.04, R1
Attachment 1
Page 1 of 1

Technical Reviewer's Appraisal Form for NNWSI Publications

Title of Paper: Description of Quaternary surficial deposits in the Yucca Mountain area, Nye County, Nevada

Authors(s): D. L. Hoover

Publication outlet and report number (if known): Open-file report

Technical Reviewer: W C Swadley Date: 9-2-87

Reviewer's title: Geologist

Recommendation (based on technical content):

☐ Publish as is

☒ Publish with minor technical revisions (as noted below or in attached memo)

☐ Publish only with major technical revisions (as noted below or in attached memo) and re-review

☐ Not suitable for publication in present form (reasons must be given in attached memo)

Memo attached: ☒ Yes ☐ No

Comments:

W C Swadley
Technical Reviewer's Signature

Technical Reviewer's Appraisal Form
for NNWSI Publications

Title of Paper: Preliminary Description of Quaternary and Late Pliocene surficial deposits ~~in the~~ at Yucca Mountain ~~area~~ and vicinity, Nye County, Nevada

Authors(s): D. L. Hoover

Publication outlet and report number (if known): Open-file report

Technical Reviewer: Earle Cressman Date: 10/30/87

Reviewer's title: Geologist

Recommendation (based on technical content):

☐ Publish as is

☑ Publish with minor technical revisions (as noted below or in attached memo)

☐ Publish only with major technical revisions (as noted below or in attached memo) and re-review

☐ Not suitable for publication in present form (reasons must be given in attached memo)

Memo attached: ☑ Yes ☐ No

Comments: see attached memo

Technical Reviewer's Signature

UNITED STATES GOVERNMENT

memorandum

DATE: July 14, 1987

REPLY TO ATTN OF: Ralph Shroba, geologist, Branch of Central Regional Geology RRS

SUBJECT: Review of manuscript on the surficial deposits of the Yucca Mountain area and vicinity

TO: Dave Hoover

After carefully reviewing your manuscript on the surficial deposits of the Yucca Mountain area and vicinity, I feel that it will need extensive technical revision and re-review before it will be suitable for publication as a Survey open-file report.

The following is a brief summary of the major comments that I have made on the manuscript and on the attached pages.

- The manuscript contains:
  - numerous statments regarding the genesis, stratigraphy, paleoclimate, and history of the surficial deposits that are unsubstantiated by data in the manuscript or in published reposts. Some of these statements are incorrect
  - little if any discussion of (1) key assumptions or (2) alternate interpretations
  - much speculation, particularily in the section on climatic inferences
  - numerous interpretations and inferences that are oversimplified and inadequately qualified
  - some obvious contradictions
  - numerous ambiguous phrases and sentences
  - several out-of-date oral communications that do not accurately reflect the current interpretations and findings of those cited.
- The manuscript lacks:
  - figures that illustrate key stratigraphic relationships discussed in the text

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(REV. 1-80)
GSA FPMR (41 CFR) 101-11.6
5010-114

- reference to, and discussion of, several recent reports and oral communications with other NTS investigators that clearly pertain to the interpretations presented in the manuscript
- explanations of terms, especially soils terminology, that are not used as defined in standard references
- a statement in the introduction to the effect that the findings and interpretations in the manuscript were developed prior to 1986(?) and do not reflect those of recent reports and discussions with other NTS investigators.

o In general, it was difficult to determine if many of the statements in the manuscript were based chiefly on observations, interpretations and inferences, or mere speculation.

o Many of the interpretations and inferences, particularily those pertaining to past climatic conditions, that are based on insufficient, equivocal, and (or) irrelevant data should be deleted or adequately qualified.

Refer to the text and the attached pages for additional comments.

If I can be of help in the revision and (or) the re-review of this manuscript, please contact me.

Copies to:
G. A. Izett
R. B. Raup
I. J. Witkind

Hoover's NTS surficial deposits manuscript

comment number	Page Number	Comment
1	5	reworked = ? If the debris flows are reworked are they still
		debris flows? For clarity, debris-flow deposits should be used instead
		of debris flows. I find it hard to believe that unit QTa
		consists chiefly of debris-flow deposits. Basically, QTa
		is made of poorly sorted, coarse-grained deposits that
		lack original depositional landforms. The QTa
		that I have seen appears to be poorly sorted alluvium.
2	5	55 m = max unit thickness or thickness of flows?
3	5	This material could be older and or younger than
		the waterlain sediments.
		There is virtually no age control for deposit of unit Q1. How can
4	6	you make a definitive statement that this unit is of
		Holocene age? Some of the Q1c could be of latest Pleistocene
		age. Some of the fan alluvium at Silver Lake, CA
		is about 11 ka. (Wells and others, 1987).
		Your stratigraphy needs to be spelled out in a footnote.
5	1	Your units appear to be time stratigraphic units and your
		subunits (actually mapping units) are allostratigraphic
		units. Indicate the type of units with respect to the
		North American Stratigraphic code.
6	∴	The use of the term lithofacies is confusing. Actually all 5
		subunits of Q1 are lithofacies of unit Q1
7	6	I find it very hard to believe that all of Q1b is
		debris-flow deposits and no alluvium.
8	6	Not so. Part of unit Q2c was deposited between the
		deposition of unit QTa and subunit Q2c.
9	8	Inconsistent use of Yucca Mtn area. Your fig 2
		of the Yucca Mtn area includes areas within
		100 km or more of Yucca Mountain
10	15	What about Scott and Bonk (1989)?

comment number	page number	Comment
11	16	As used here, the term Quaternary stratigraphy has little meaning. Do you mean ......sequence of surficial deposits....
12	17	You should cite Carr (1982?), Sinnbeck and Easterling (1983) or Crowe or Turrin oral communication. Crowe will tell you that the Lathrop Wells cinder cone could be in the 20,000 year range
13	18	Considering the data and the assumptions, I feel that many of your interpretations are tentative.
14	19	The ¶ needs to be expanded and clarified. Probably what you should say was that you used informal local designations for your map units because there are no nearby areas with well dated surficial deposits. All mappers of surficial deposits use one or more criteria for the identification and local correlation of surficial deposits
15	19	This "method", which is actually not a method, was not defined in your 1981 report, so you should define it here.
16	17,20	In order to be meaningful to the readers these characteristics need to be explained in more detail (in sentence form); put in an appendix at the end of the report.
17		A clear distinction should be made between lithologic units and stratigraphic units. Most of the units that you are referring to are seen lithologic units whose stratigraphic relations in many areas are inferred.
18	20	In 5 years of soils work, the thickest Av horizon I have seen is ~20-25 cm thick. Covington is not a soils person why not cite Taylor (1986).
19	20,21	B and calcic horizons are not mutually exclusive. Many B horizons are calcic horizons (eg Bk).
	23	Cambic horizons are not limited to Pleistocene deposits.

Comment number	page number	Comment
21	23	Cambic B horizons are established on the basis of color, structure, and in some cases the amount of $CaCO_3$. The amount of very fine sand or silt has no bearing on designating a cambic horizon. Moreover, if there is any evidence of clay translocation, the horizon is argillic.
22	25	Considering that bedrock lithologies tend to influence the physical properties of the surficial deposits, I feel that at least the dominant lithologies should be mentioned.
23	25	northwest -- not clear; what do you mean?
24	25	continuous -- not clear; what do you mean?
25	39	Calcic horizons and B horizons are not mutually exclusive. Either ① define what you mean by B horizon, or ② specify cambic or argillic B horizons
26	39	Previously you said the QTa was composed of debris flows. Here you imply that it also consists of fluvial deposits. Is "Lake Amargosa" a bonafide term in the literature or is it one of your informal terms that you are capitalizing?
27	43	It's entirely possible that the deposition of some of the oldest Q2 deposits occurred relatively soon after the deposition of the youngest of the QTa deposits.
28	4	Come on Dave! If they have similar radiometric ages then they should be considered to be equivalent in age. Don't you believe the radiometric ages?
29	44	Are valleys different from and larger than, washes?
30	46	If these units are so different, as indicated, then VT dating is unnecessary to distinguish these deposits.

comment number	page number	Comment
31	47	It's not easy to distinguish between poorly sorted alluvium and debris flows, therefore why "go out on a limb" and make this guesstimate?
32	51	The "mixture bit" sounds like a typical A horizon to me.
33	53	This is confusing. Somewhere make it very clear ~~which subunits are "lithofacies" of what subunits.~~ ~~I was left with the impression~~ that each of the subunits are lithofacies of a unit (e.g. Q2a, Q2b, Q2c, Q2e, and Q2s are lithofacies of unit Q2). It sure would help to have a figure showing "lithofacies" relationships. I talked with Dave Fullerton. The best he could tell, you have allostratigraphic units and subunits. He said that the subunits should be lithofacies of a given unit and not lithofacies of each other. ∴ Therefore, subunit Q'2e being should not be referred to be a lithofacies of subunit Q2c.
34	54	Check with Geologic Names in CTR. You may have to refer to the Bishop ash as a bed of Bishop ash or a Bishop ash bed.
35	55	Somewhere make it clear that washes refer to "valleys" rather than stream beds as defined in AGI glossary.
36	56	Insert into or downstream of?
37	57	Does not Q2a contain any deposits other than debris-flow deposits (such as slopewash)?
38	57	No alluvium in the Q2a deposits?
39	58	I suggest deleting this ¶. It lacks the necessary qualifications and it is very speculative.
40	58	I suggest including these deposits in subunit Q2a. You make a strong pitch on how similar they are.

comment number	page number	Comment
41	58	Do debris flows and slopewash have similar deposition processes?
42	59	Entrenchment is not the same as incision. What is your evidence for entrenchment?
43	59	Qlc is probably chiefly alluvium along with a minor amount of debris-flow deposits.
44	60	This term is not in Peterson's (1981) glossary.
45	60	What is the significance of maximum thickness. Typical thickness is more informative.
46	60	"May" sounds like you have never looked at these deposits. Either the microrelief does or it does not locally exceed 0.2 m.
47	61	Have you looked at enough exposures of Qlc to cite the less than 25 percent value?
48	61	Why not just floor of the Amargosa Desert?
49	62	By definition, voids are empty.
50	63	These criteria only suggest a possible debris flow origin. They support, but in themselves do not prove, a debris-flow origin.
51	64	Qze lacks dune form.
52	64	This cone is actually composed of scoria.
53	64	Or is some of Qle at least 25,000 years old
54	66	Ren Thompson said that the basalt west of Eagle Mountain is probably 4-4.5 Ma, and definitely not as old as 7 Ma.
55	67	Contact B Crowe. Ashes from the ~1 Ma crater center and the Lathrop Well volcanic center can not be distinguished on the basis of chemistry. The ashes in the faults are much younger than 1 Ma.
56	68	probably not preserved or not preserved probably..."
	82	This is an unwarranted assumption given the limestone bedrock at Kyle Canyon.

(5)

comment number	page number	Comment
58	82	Make it clear that you are referring to a unit considered by D.L. Hoover to be equivalent to unit Q2. J. Sowers didn't use NTS terminology for her stratigraphic units.
59	80	For each area that you correlate with add a figure showing inferred correlations and names of units at NTS and correlative units in other areas. If you don't include these figures I strongly suggest that you delete this entire section.
60	86	You have made many assumptions, state them.
61	86	What are these values based on? Why English and metric units.
62	87	Are present-day plants diagnostic indicators of temperature ranges of spring water or will they grow in water of almost any temperature?
63	87	Unit Q1a is not made up entirely of debris-flow deposits. It also contains a lot of alluvium.
64	87	"Decreased stability" may promote or favor instability and/or mass movement, but it may or may not be sufficient to cause or initiate movement.
65	87	There are a lot of assumptions and feed-back mechanisms that you are not discussing.
66	89	I think I know what you are referring to. I'd be careful in making a climatic interpretation without a careful review of the literature. I have seen excellent "book-like" cleavage at Silver Lake playa (~280 m elev) near Baker, CA. Stone Weathering is more pronounced with proximity to the playa. The weathering features you describe do occur at

comment number	page number	Comment
		lower elevations, in some cases they appear to be related to salt weathering, and they may be due in part to the physical properties of the weathered rock.
67	89	Your interpretations are incredibly simplistic. There are feed-back mechanisms and threshold conditions that you are not discussing. One of these is the influence of decreasing permeability due to accumulation of silt and/or clay and CaCO3. Deflation of unit QTa and the partial dissolution you mention could have occurred without an increase in ppt or actually with a decrease in ppt if the permeability of the surface material decreased with soil development. These effects in the nearby Mojave Desert are discussed in the literature. I suggest that you back off on unqualified and unsubstantiated speculations like this one.
68	90	The dominant grain size of a deposit is influenced not only by the grain size of the sediment source but also by the mode of deposition and the amount of energy in the transporting and depositing system. Much of the silt and clay from eroded deposits could have been transported into the Amargosa Desert.
69	90	It's hard to follow the logic of this ¶. It contains unsubstantiated statements and unqualified and unwarranted inferences/conclusions.
70	94	Solution features are more readily distinguished in strongly developed calcic horizons and may be indistinguishable in weakly developed ones.

comment number	Page number	Comment
71	94	The Arkley equation doesn't apply to the gravelly soils of the NTS. Talk to E.M. Taylor for more details. If you would look at her thesis you would see that she did not try to predict past precipitation with the Arkley equation. Your ppt values are meaningless.
72	96	Are <u>all</u> of the statements in this section substantiated by factual data, not speculation, that was presented in the preceding pages of this report?
73	97	Biomass means amount of living material, which would include both plants and animals. Actually, it's the amount and type of vegetation that influences slope stability.
74	1	Although the title emphasizes "stratigraphy", not much of the report is devoted to stratigraphic relationships. Moreover, the report doesn't even have one single figure illustrating stratigraphic or "facies" relationships
75	1, 19	Much of the criteria you use to identify deposits are not true stratigraphic criteria or criteria intrinsic to the deposits, except for VI, lithologic properties. It appears that you have allostratigraphic units ~~meaning~~ in North American Stratigraphic Code. If you refer to the subunits as lithofacies ~~(of these superposed units and not of each other)~~ you should do a better job of characterizing the inherent physical (lithologic) properties of the subunits and show how the subunits differ one from another.

comment number	page number	Comment
		in published reports. I strongly suggest that this section and some of the other sections contain much material that previous reviewers, such as John Whitney, have recommend to be deleted, qualified, modified, or documented.
77	5	Both Emily Taylor and I feel that much of what you are calling debris flows is poorly sorted alluvium. Convince us and the readers by presenting data that substantiate your interpretations.
78	5	Considering that many of the statements in this report are not supported by data, I strongly suggest that many of the "probably statements" should be changed to "may have", etc.; indicate → suggests,
79	5	I strongly suggest that you retain only well documented climatic inferences.
80	1	This report is too long; shorten text by at least one third.

Comments [illegible]

Aug 17, 1987

Comments on 8/87 Version of Hoover ms

page	¶	Sentence	Comment
1	2	2	I disagree
1	2	1	only partial list of landforms
1	2	3	semiconical = what?
*=	2 ①	2	Dave's interpretation that much of QTa is debris flows is unwarranted. Both E Taylor and I feel that much of QTa is alluvium, only some of it is debris-flow deposits. (1) deposits should be referred to as debris-flow deposits rather than debris flows. (2) Dave should definite what he means by debris flows so that readers will know that some or much of the material that he is calling debris flows was not deposited by this mechanism; (3) He would be wise to describe units QTa, Q2ia, and Q1b as alluvium and debris-flow deposits and not indicate mostly debris flows and some alluvium. Also his term "reworked debris flows" is confusing, e.g., if they were reworked by water then they are alluvium.
2	2	3	only one [illegible]?
-	2	5	"Residual" is confusing. These boulders were transported
*3 2 ②	2 2	1st last	INCORRECT use of the term unconformity. An unconformity has to be bounded on both upper and lower sides by rock or surficial material.
3	1	2	doesn't belong in abstract. Delete
*4 3 ③	1 2	2 2	Incorrect use of the term lithofacies. Subunits Q2e and Q2s are lithofacies of unit Q2 not subunit Q2c,
4	1	1	what about eolian sand that blankets areas outside of work
4	2	1st	what mean by probably. Their they are or they are not
6	1	2nd to last	Sand ramp is an informal term that need to be fixed.
20	1		Not clear

page	¶	Sentence	Comments
28	7	5	Not so. Argillic B preserved at >1 site. Talk with E. Taylor.
*28 ④	1	3rd from last	Although Dave indicates that CaCO3 ranges are maximum for entire soil (on p. 14). Statements like this are very ~~misleading because the reader is~~ left with the impression that the entire horizon is stage IV.
29		2	Are boulders ≥ few m's ~~in diameter~~ common?
30	2	3	Upper ~1 M of QTa in CF-1 is a debris flow like deposit on poorly sorted alluvium that overlies >1.5 m of moderately well sorted alluvium.
30	2	last	not so
*61 32 ⑧	2	last 2	Misleading. Somers doesn't use the terms QTa and Qx2. Why not cite her thesis?
35 28	1	3	Neither Taylor or Shroba have seen a ~~40 cm~~ 50 ~~Av in the Base~~ 25 or possibly 30 cm is the thickest that Shroba has seen.
34	1 2	2 2	Is this and other trenches shown on one of your maps?
40	2	2	Confusing
~~*42~~ 52	~~2~~	1	~~Incorrect use of the term!~~ Maps?
4	2	1	Qzb only consists of scattered clasts?
45	3		Confusing
48	1	last	which slopewash deposits?
*48 ①	2		Incorrect use of the term unconformity
4	4	2nd from last	Shroba and Taylor suggest delete ...and, locally, ...2-5 cm ⊙
5	4	1	duplicate = ?
51	1	1	What mean by "reworked debris flows"?
5	2	1	Dam or what?
5	1	last	Many folk put end of Holocene at 10 ka.
60	1	3	Given ±0.4 Ma on date of ash there may not have been much of a hiatus between deposition of the ash and the start of the Quaternary.

page	¶	sentence	Comments
60	3	1st	Lavas could have been protected by sediment that were removed prior to the deposition of QTa. This sentence should be reworded.
62	1	last	"May indicate"
62	2	1st	"displaced equally" not clear
66	1	3	add: "eolian sand considered to be equivalent to" Qle
67	⑧ 1	2	Qle on Qlc or Q1s doesn't establish a minimum age for these deposits because some of it is modern
67	1 ⑨	1st	Q1b may or may not be older than the youngest episode of deposition of eolian sand.
71 ⑩			E.H. Taylor's thesis on Yucca Mtn. soils is not cite. This is a major omission.

THE FOLLOWING YMP-USGS DOCUMENT(S) HAVE BEEN

REVIEWED, AND RESEARCH WAS CONDUCTED TO

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INSTRUCTIONS: *Place an "X" into each appropriate "[ ]" and/or provide comments which will explain why this is the* "Best Available Copy."

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Additional Comments: ______________________

Virginia M. Glanzman
Record Source

11/17/89
Date

United States Department of the Interior
GEOLOGICAL SURVEY
BOX 25046 M.S. 913
DENVER FEDERAL CENTER
DENVER, COLORADO 80225

IN REPLY
REFER TO:

September 3, 1987

Memorandum

To: I. J. Witkind

From: W. C. Swadley

Subject: Description of Quaternary surficial deposits in the Yucca Mountain area, Nye County, Nevada by D. L. Hoover

As requested, the subject manuscript has been reviewed. Several general comments are listed below. More specific corrections or suggestions are shown on the manuscript in red or are included on a list attached to the manuscript and keyed by number to the paragraph concerned.

General Comments:

1. Two questions raised by Shroba's review have not been resolved and, I think, still require some revision. The first involves describing an unburied weathering surface as an unconformity. I have suggested changes where this occurs but my suggestions are essentially the changes proposed by Shroba that were not accepted by Hoover before. The second is the use of the term lithofacies. Shroba's review questioned whether subunits can be lithofacies of each other, or whether each subunit should be a lithofacies of the major unit. No changes were made by the author, but should be.

2. The use of the symbol Q2a(?) for a subunit correlated with subunit Q2a seems very questionable to me. I doubt if it will pass GNU.

Comments [illegible]

Abstract

① Does this mean the present surfaces [illegible] and [illegible] are erosional surfaces? [illegible]
[illegible] early Holocene and older surficial deposits includes about every thing

② This seems too abrubt. Suggest adding a lead in sentence like: Surficial deposits described in this report range from Pliocene marsh sediments [illegible] to modern alluvium.

③ Doesn't seem important enough for abstract

④ Not an unconformity unless buried

Text

① Overstated. How about:
~~These~~ data provide a basis from which approximate age of faults that offset surficial deposits of the Yucca Mt. area may be determined.

~~ⓐ This seems meaningless. The junction of the piedmont slope ~~and~~ with the bedrock hills is a line. You need something like "the angle formed at the junction of the piedmont ~~slope~~ the ~~surface~~ & the adjacent bedrock surface."~~

② Seems awkward to throw in specific lithologies here when reader hasn't been told what rocks are present at Yucca Mt. ∴ suggested addition above

③ "pre-Paintbrush Tuff" ~~is~~ will be meaningless to the reader — say mid-Tert. or whatever.

④ These two sentences seem to conflict.

③ I don't think this says it. How about:
Correlation characteristics were devised because no suitable Quaternary stratigraphy had been established for the study area or for nearby areas ~~that~~ could be correlated with the NTS area. The detailed Quaternary section ~~defined~~ described for the Searles Lake, Calif. area by Smith — ~~Smith~~ and others — was not comparable because the sediments ~~deposits~~ of Searles Lake were deposited in

a different environment; the detailed stratigraphy established by Haynes (—) for the Tule Spr., Nev., area was not comparable because ~~the~~ the deposits of that area were deposited during a much shorter time span than those of NTS area.

⑥ Meaning you can have one and not the other?; outcrops are discontinuous? or ?

⑦ Very vague sentence! everywhere? similar?

⑧ If you say "a possible dam" in sentence two, you have to hedge here

⑨ What does "reworked gravel" mean, If it's alluvium, call it alluvium.

⑩ These silica lenses are enclosed in a hard, dense laminar ± carbonate that probably contains secondary silica.

⑪ Subunit of what? Pliocene(?) + Quat Deposits? or QT. Fig. 4 seems to make QT_9 + QT_3 equal.

⑫ There are areas in northern Dome Mt quad and in Big Dune quad where this isn't true. Also the QTa in Lathrop Wells quad east of Skeleton Hills has boulders, but not necessarily large ones.

⑫ What you describe is a weathering ~~surface~~ contact, not ~~an~~ unconformity. It's not an unconformity until ~~it is~~ buried by a younger unit. How about: The dissected surface of ----, alluvial pediment remnants and the soil on unit QTa indicate a lengthy period of erosion and weathering following the deposition of QTa and prior to the deposition of unit Q2. Or. Where buried by unit Q2, the dissected surface of ---- alluvial ----, and the soil ---- mark ~~a~~ a regional unconformity in the NTS area.

⑬ All ballenas are rounded (preceding sentence). In the narrow ones, rounding has advanced to the crest; on wide ones a flat top is still ~~[illegible]~~ preserved along the crest.

⑭ without some amplification this seems meaningless to me

⑮ "Also" suggests solution + deposition — of pediment soil yet no pediment soil is mentioned for "first" solution + deposition!

⑯ First "solution + deposition", second, or both?

⑰ Is Jane[illegible]'s thesis complete? — cite in references?

⑱ Awkward sentence, How about
Pedimentation and dissection of the ~~unit~~ deposits equivalent to ~~unit~~ QTa in Kyle Canyon are similar to ~~those~~ that of QTa at Yucca Mount. Other characteristics (specify what may be?) of deposits equivalent to QTa + Q2 also are similar to those at Yucca Mt. Considering the proximity (?) of Kyle Canyon to Y. Mt. and assuming similar climates for the two areas, the sequence of deposits at Kyle ~~Canyon~~ suggest alluvial deposits intermediate between QTa and Q2 should be present at Yucca Mt.

⑲ The middle surface has a "deposit" or a "deposit" — then the third sentence describes the soil of the "debris flow" which has not been mentioned before. Fix.

⑳ This ¶ seems poorly organized. Try coming up with a topic sentence that tell the reader where you are trying to go. Maybe make two ¶'s — one on Q2e – Q2c relations and one on Bishop occurrences — or reduce the jumble between these two things.

㉑ Much Q2s in NW Big Dune is not noticeably down slope from Q2c

㉒ Where is the valley floor of the [illegible] ?

㉓ What means "in or near bedrock" ? Rest of sentence not clear either.

㉔ This is impossible. It sounds as if the depositing wash stopped at the uphill edge of the deposit and is now eroding the upper part of the deposit. The stream must have extended the full length of the deposit or it wouldn't be there.

㉕ This is not a difference between the deposits.

㉖ Although subunit Q2a(?) is similar to subunit Q2a in lithology (or whatever), it is described partly in this report.

㉗ Q2a(?) is described as being slopewash and debris flow deposits. - I don't think of slopewash as forming terrace deposits. If the terraces were deposited by debris flows, why are they bedded?

㉘ How equivalent? Time equivalent? I don't think anything given here supports that.

㉙ Reorganize Q2a(?) section – seems upside down

㉚ Same problem here as with other "unconformity" (item ⑫) — an unburied pavement or soil is not an unconformity — it is a weathering surface

㉛ This is hard to follow. How about:
These pavements are commonly disturbed where they are adjacent to steep-walled washes that contain (?) Q1 deposits. This area of disturbed pavement suggests that the pavement was well developed prior to dissection and has subsequently been disrupted (by soil creep (?)) at the lip of the wash. If the pavement had developed after dissection the pavement would probably extend somewhat beyond the break in slope at the edge of the wash.

If this is the correct line of reasoning!

㉜ I would be very reluctant to describe Q1b as debris flow deposits without much qualifying. How about poorly sorted alluvium that may be in part debris flow deposits?

㉝ Seems to me some of the largest Q1c deposits are none of these, but are simply alluvial fans on the lower part of the piedmont slopes.

(34) If this can't be moved up and still be [illegible], then the sentence needs to be ~~[illegible]~~ reorganized

(35) I don't understand this sentence

(36) If reworked, probably not debris flows

(37) Below meaning downslope from? If it's beyond the wash how did Q1b get there?

(38) The fact that the tongues are preserved and undissected is not relevant

(39) Don't follow the connection between the part before but and after.

(40) Source couldn't have been lacking or the stuff couldn't be there

(41) Seems very awkward to stick these two rather unrelated thoughts into one sentence with but between. How does the first "but" the second?

(42) Sentence not clear. Are sedimentary [illegible] indicated during deposition?

(43) It doesn't explain it very well to me. Try rewrite

Figure 7 ① Add scale

② No indication of what red line means
(red line = incomplete?)

③ Don't label lat. & long. points
within map

Comments on Hoover's Quaternary Stratigraphy Report

The name will have to be changed to "Preliminary Description of Late Pliocene and Quaternary Surficial Deposits at Yucca Mountain and Vicinity, Nye County, Nevada" [or must we now use "Bullfrog County?"] assuming <u>this</u> is the title agreed on with DOE for milestone #1395

I find nothing major wrong with this report, but much of the wording is ambiguous and needs tightening.

Earl Cressman

(1. Strange wording; why not "Sedimentation founded on Holocene and older surficial deposits"?

(2) Needs a lead-in as suggested by Smalley

3. "Deposits" is too vague

4. Is Early Pleistocene a formal term?

5. [illegible] this is not a common term, it shouldn't be used in the abstract.

6. I don't understand; Do you mean upper slopes, then near the crests, are 10-15% whereas lower slopes are 20-50° (not in my AGI glossary)

7. Sand ramp is not a common term. Define or give a reference

8. Rewrite. "Valley side of a fault block" doesn't make sense. I suspect that you have omitted a word.

9. Poor term. Do you mean less mature?

(10. A map showing the location of [illegible] would be helpful

11. I don't understand the parentheses. Expand them or delete

12. Not clear to me whether or not this is a direct quote from Peyton. If it is a direct quote, why did you delete the "is" after [illegible] location on p. 15?

13. [illegible]

14 Aren't the channels in the lower unit but filled with the upper unit?

(15 – No gravels sand or [illegible] shown on any of the illustrations.

16 This section needs to be rewritten for clarity. I think my suggestions would help.

17 If it was breached early, there wouldn't have been a lake! Thus the suggested changes

18 "Related to" is nearly meaningless unless you give the relationship

19 Here, and elsewhere, the description of each unit should begin with a

→ definition of the unit.

20 This sentence gives me trouble, mostly because I'm not sure what is meant by "above."

21 Reword: If it was the older, it can't be overlain by anything older.

22 This is what I picture from the description:

I doubt if this is what is meant.

23 I can't picture the relations described here. Why not delete the paragraph? The plates aren't part of QT9 anyway.

24 According to p. 25, line 6, also overlain by QT9

25 Can't be both parallel and dendritic

26 Why aren't the "unlabelled layers" Qal?

27 "Roughly parallel..." an imprecise description. I think you could delete the material in brackets with no loss of meaning and some increase in clarity.

28 I agree with Sundby and Shroba that this should not be called an unconformity. The sense of 3 to 1 (col author) should be convincing.

29 If they have flat tops, are they ballenas?

30 Would be more accurate to say "When not obscured by younger deposits, valleys betw ballenas are rounded"

31 Give the observations that lead to your conclusions

32 If it could have occurred either during or after, it isn't worth saying. Give evidence for deposition of sediments before deposition of Q2

33 Start out with a summary description of unit Q2.

34 Reword as "Subunits are similar in — — and but dissimilar in — — "

35 Here and elsewhere(!) begin by defining the subunit

36 What are the land forms? This paragraph might be better placed at the end of the section

37 This is no doubt clear to you, but inasmuch as subunit Q2b's relationship to Q2c has not yet been described, it isn't clear to me.

38 You give evidence for its being younger but not for its being "much" younger (whatever that means)

39 is this a soil within Q2c or is it at the top and covered by a younger unit? This is not at all clear in your discussion

40 As written, the cobbles are described as overlying Q2c, but I doubt if this is what you mean.

41, Here and on p. 36 & 37 the positions of the soils are not clear to me. Are they on or in Q2c? I gather here that the latter is the case, but on p. 36-37 I [illegible] it is for [illegible]. This must be clarified

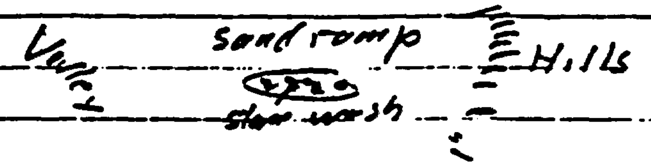
42 Not clear. Reword.

43 Spell out the implications as to relative ages. All of this sounds as if Q2e is older than Q2c, but this isn't what is shown in fig. 4.

44 Don't you mean "by slopewash from bedrock"? Slopewash is a process, not a source. "Alluvium" is a poor choice of words.

45 Strange: How do you explain the lack of crossbedding?

46 From the description I picture



Is this what is meant? If not, revise.

47 I realize that you discuss ages in a separate section, but I would like to see radiometric ages given here and anywhere else that you mention dated materials.

48? What evidence is there for "as much as 10 m"?

49 "Below" could be interpreted as underneath.

50 Give the evidence. What features of the pavement indicate deflation?

51 [illegible] the grains on clasts [illegible]?

52 Crossbedding itself indicates no such thing; it depends on the nature of the crossbedding.

53 In the first sentence, Q2b is said to represent as strath terrace deposits, does this sentence implies that Q6 would also include alluvial fan deposits. Revise the first sentence along the lines I've suggested

54. But Q2b itself comprises basin deposits. Wrong preposition?

55. This confused me because up to here I'd been taught that Q2b consists of basin deposits, so I'm wondering about this and the first sentence of the section.

56. Were scattered clasts mapped as Q2b? Do scattered clasts a unit make?

57. I don't understand. The problem is the expression "below the drainage basins".

58. The matrix isn't volcanic rock and argillite; it is grains (of whatever size) of volcanic rock and argillite.

59. Poor expression. Below can mean (and commonly does) beneath. Here, again, I would have you give the radiometric ages: at the very least, refer to the table or page that gives the data.

60. Describe the unit before you describe the outcrops. What gives the unit its unity? By definition, a unit must be analyzable as a whole, so describe it.

61. Ambiguous as written. Is it correct as changed?

62. I don't understand. Reword.

63. Data don't provide proofs; they do support.

64. I don't recall peat being mentioned earlier in the text. Did I miss it? Do Mehringer and Warren (1976) state that

probable equivalence? If not, you should. Why do you use B.P. instead of a (or convert to ka)?

Illustration

Figure 1 is very poor. It could be deleted with no loss to the paper.

Figure 2 & 3. Both quads and the land net are referred to in the text. Although the land net is too big a job in the time available, but quads mentioned in the text should be shown with fig 2 or 3

Figure 4 I would like to see radiometric ages plotted into this diagram if time permits.

In general, the figures are not referred to in the text; they should be put to better use (then, again, if time permits)

DOCUMENT REVIEW CONTINUATION SHEET

REVIEWER'S COMMENTS			RESOLUTION			REVIEW DISPOSI	
ITEM NO	PAGE NO	COMMENTS	ACCEPT	REJECT	REASON	ACCEPT	
③	29	Section [illegible] N., R. 6 E. does not appear to be on the Ryan quad (at least not on the 1952 version). Are the township and range specifications correct, or should this be the Eagle Mtn. (15 minute) quad, or is there a newer map with a revised coordinate system?			Q.3. Page 29, paragraph 3, line 3. Ryan should be changed to Eagle Mountain.		
④	32	The discussion of the relationship of the "carbonate and silica plates" in the QTg unit near the Eleana Range does not seem clear. Is there any evidence for age of these (i.e., overlain by QTa deposits like most of the QTg deposits)? The statement saying that these appear to have been "deposited by ground water" is also unclear -- is there any indication whether this ground water is from the water table or from a perched-water zone? As written, the discussion seems to leave more questions unanswered than provide information. If possible, a sketch or photo of the deposits and additional discussion may help clarify.			Q.4. Page 32, paragraph 2. Insert sentences at end of paragraph. "A few residual boulders from unit QTa are present on ridge crests near carbonate plates. On a few ridges, unit QTa overlies unit QTg downslope from where the carbonate plates are present at the edge of unit QTg. Although no clear relationship between the carbonate plates and unit QTa was observed, the position of the carbonate plates with respect to unit QTg and unit QTa suggests that the carbonate plates are older than unit QTa."		
⑤	73	U-series date shown may not be accurate. Winograd et al. (1985; Science, vol 227, pages 519-521, footnote 3) indicate that to rule out initial detrital thorium-230 contamination, the Th-230 to Th-232 ratio must be greater than 20. This same problem was noted in the presentation by D. Muhs (USGS) at the Calcite-Silica Peer Review meeting. Szabo et al. (1981) show that the ratio for the sample listed in this report is 1.99 for the calcite portion and 1.13 for the residual portion. Thus, it would seem that this date and its [illegible] are questionable as initial contamination cannot be ruled out.			Q.5. My purpose in reporting these data was to compile all available data applicable to the stratigraphy. At [illegible] time [illegible] were compiled (198[illegible] or 1984). I was not aware of the U-series date problem. The date should be kept until it can be determined whether it is valid, rather than rule it out simply on the basis of observations on other samples.		

An argument might be made that the debris flow deposits might have been deposited by water floods or mud floods, but the larger clasts supported by a fine matrix argues against these processes. The numerous instances of transport of boulders from 4-10 m in diameter down 1-2 km of piedmont slope and as much as 1 m in diameter down 10-50 km of piedmont slope strongly suggests transport by debris flows rather than a less viscous, less dense medium. The lack of sorting of larger clasts (except for boulders larger than 1 m in diameter) beyond 2-3 km downslope from bedrock also suggests debris flows rather than water or mud.

Finally, the preservation of delicate leaf casts at the top of the upper unit of the waterlain sediments of Amargosa marsh by unit QTa indicates that unit QTa was deposited very shortly after deposition of the upper unit. Although I am forbidden to discuss the subject in this report, the disappearance of Amargosa marsh followed immediately by deposition of unit QTa indicates that the wet climate that maintained Amargosa marsh (and probably heavy vegetation in the hills) rapidly became drier which should have caused a substantial decrease in vegetation in the hills thereby making large quantities of material accumulated during the existence of Amargosa marsh available for the debris flow deposits of unit QTa.

Given the above, I can only conclude that the majority of unit QTa is debris flow deposits.

2. Incorrect use of unconformity—corrected

3. Lithofacies is used correctly (see attached AGI definition)

CEI states that either lithofacies or depositional facies (per Strat. Comm. code) can be used. Q2e and Q2s are mappable subdivisions of Q2c that are distinguished by lithology and are enclosed within the boundaries of Q2c. The same applies to Q1c and Q1s.

Replies to numbered questions on W C Swadley review

Abstract

1. Yes. All but Q1b, Q1e, and Q1s.
2. This is an abstract. The first sentence has been rewritten.
3. Agree.
4. Statement deleted.

Text

1. Rewritten
2. Agree
3. Agree
4. Paragraph rewritten
5. Rewritten
6. Rewritten
7. Rewritten
8. Sentence changed--The alluvial barrier was present, but whether it was breached by the Amargosa River before a lake could be impounded is uncertain.
9.. OK
10. Rewritten
11. Fig. 4 and subunit QTc corrected
12. Rewritten
12. (As numbered by WCS) Rewritten
13. Rewritten
14. Amplified
15. Rewritten

16. Not certain about meaning of question, but obviously solution followed by immediate redeposition occurred together. Otherwise, solution alone would have removed the carbonate from the area.

17. This is my observation, but was brought to my attention by Janet Bowers —reference deleted

P. 32--bottom (no no.) If a small area was being discussed, I wouldn't bother, but absence of deposits between QTa and Q2 in such a large area should be discussed

18. Rewritten

19. Rewritten

20. Rewritten

21. Corrected

22. Rewritten

23. Rewritten

24. Rewritten

25. It is a difference, but not in the sense of the other differences. Sentence moved to text.

26. Reworded

27. I have not described these deposits as terrace deposits, but as deposits that overlie older terrace deposits. I don't think that these Q2a(?) deposits are terrace deposits, but am uncertain

28. In age. Stratigraphic position overlying Q2b and Q2c (sentence added) justifies this conclusion

29. Done

30,31. Section on regional unconformity deleted. Age of Q2a(?) and possible late Pleistocene age of some Q1c by others makes this section uncertain

32. Changed to alluvial gravels and debris flow deposits

11/5/87

To: Earle Cressman
From: D.L. Hoover
Subject: Your review of Quaternary stratigraphy report

Replies to your numbered comments are attached. Where a comment in the text without a number needed a reply, I added "a" after the numbered comment immediately before the text comment. For the most part, I accepted your suggestions. Where I did not, I have explained why. My revisions are in red on a fresh copy of the report.

I have no disagreement with deleting figure 1. It was put in for lay readers. The quadrangle index has been added as figure 3. Addition of land nets to the figures is not possible for two reasons: (1) the figures will be page-size and are already crowded and (2) time available. On figure 4, the problem is which age to use for each unit. For ash-beds, this is not much of a problem, but for U-series and U-trend ages, do you use ranges, all the ages, average the ages, or average some ages after discarding "unreasonable" ages? By the time agreement was reached by those who have an interest, the deadline would be long past. These choices are the reason that I have compiled all the ages in table 1. Readers will see a general agreement for each stratigraphic unit and will be free to use their own choice.

The title on the schedule change request, "A preliminary description of Quaternary surficial deposits, etc." is incorrect for several reasons. When this title was chosen, I was not consulted.

1. "Preliminary" is incorrect. The stratigraphy has been in use for 9 years and has been published on 3 quadrangles (1 in press) and was used on two additional quadrangles that are completed. Although some aspects of soils and depositional environments are questioned by others, there has not been any question of the basic stratigraphy or the general descriptions that I am aware of. Therefore, the work is hardly preliminary.

   From the schedule change request, I gather that Hayes used "preliminary" to make room for changes caused by further work. It is unlikely that changes in the basic stratigraphy will be made and only details of description will be changed. Dropping "preliminary" will still leave room for new work.

   In regard to my own work, "preliminary" is also incorrect. First, a description of the stratigraphy was made earlier by Hoover and others (1981). Second, because this will be my last description, the use of "preliminary" for my work is not correct.

2. "Description" is not totally correct. The report describes more than the deposits--it relates the deposits to each other, incorporates and interpretes part of the depositional history, and summarizes evidence for the ages of the units. A description provides a mental image of what the described object looks like--the report is more than a description.

3. "Quaternary" is incorrect, inasmuch as several pages are used to describe late Pliocene deposits. Also the wholly Quaternary age of unit QTa is uncertain.

4. "Surficial deposits" is incorrect because the term does not apply to the waterlaid sediments of Amargosa marsh. I used stratigraphy in my title to get around this problem.

Finally, the title on the schedule change request is only ink on paper, not words chiseled in granite. In the interest of clarity and accuracy, I suggest that the title be changed to "Late Pliocene and Quaternary stratigraphy of etc." so that the title will properly reflect what is in the report.

Replies to numbered comments

1. Sentence changed. I want to emphasize the smoothing of alluvial fans in the older deposits. Pedimentation OK on p. 2, why not here with change to alluvial fans?
2. Rewritten with lead sentence.
3. Rewritten
4. Change to lc
5. Deleted
6. Rewritten
7. Look under ramp(snow). The term, when separated into two words, is self descriptive. I first used dunes, but was told by Whitney that the proper term was sand ramps. Rest of sentence rewritten.
8. Rewritten
9. Reworded
[illegible]. Figure 4 added
11. Added because of previous review. Now deleted
12. Quotation form was suggested by Pat Poole. Changes made because of previous reviews have been restored.
13. Rewritten
14. Rewritten
15. The illustrations will all be page size. No way to get land net on even if there was time. Fig. 4 will show quadrangle locations.
16.17. Para. completely rewritten
18. Rewritten
19. First sentence rewritten to define unit.
20. Rewritten
20a. Next para. Conglomerite, not conglomerate. The rock is metamorphosed to the point that it breaks across both the large clasts and the matrix sand grains. Therefore, conglomerite.
21. Reworded
22. Your concept is exactly what is meant. Deposition of QTg quartzite clasts in shallow troughs on the pediment, cementation of QTg, deposition of QTa, and then dissection has resulted in a small scale inverted topography.
23. Rewritten to show relationship of plates to QTg.
[illegible]. Rewritten
25. Dendritic deleted
26. You can call the layers "beds", but I want to call attention to the contrast of these "beds" with the alluvial beds that are usually moderately to well sorted and a few cm to less than 1 m thick. I have used layer to emphasize this contrast.
27. Deleted
28. Rewritten to conform with AGI definition of unconformity
29. Dendritic deleted
30. Rewritten—comments 28-30 are incorporated in complete rewrite of this section.
31-2. Subject of this para. is deleted
32a. Para. under "Quaternary Surficial Deposits" incorporated under "Regional Unconformity" and replaced by new para.
33. Definition added
34. Rewritten
35. Reworded to define unit.
36. Rewritten
37. Rewritten
38. "Much" deleted

39. Rewritten
40. Rewritten
41. Rewritten
42. Rewritten
43. Para. rewritten.
44. Rewritten. Above is the correct word. Higher than would not restrict the location. Topographically higher or topographically above is also less restrictive and probably overdone.
45. No explanation—just recording observations.
46. Rewritten
47. Para. rewritten
48. 10 m deleted
49. Rewritten
50. Evidence added
51. Rewritten
52. Rewritten
53. 2nd sentence of para. rewritten
54. Typo corrected
55. Rewritten
56. Too small to map, but strath terrace and scattered clasts are recognizable by their topographic position as Q2b. In a few washes, the scattered clasts grade into terrace deposits.
57. Phrase deleted
58. Rewritten
59. Rewritten
60. Q1 defined
60a. (p. 51) As written, lithofacies is not relevant. Sentence added.
61. Rewritten
62. Para. rewritten
63. Rewording accepted
64. You are correct. Description of Q1e changed to add peat.

bcc: CRGB file
CRGB RF
Circ RF ✓
VMGlanzman:br

December 8, 1987

Mr. Carl P. Gertz, Project Manager
Waste Management Project Office
Nevada Operations Office
U.S. Department of Energy
P. O. Box 98518
Las Vegas, Nevada 89193-8518

Dear Mr. Gertz:

A draft of the report, "Preliminary Description of Quaternary and Late Pliocene Surficial Deposits at Yucca Mountain and Vicinity, Nye County, Nevada," by D.L. Hoover is enclosed for review in your office and approval for release. This report represents level 2 milestone M395 under WBS 1.2.3.2.3.1.G, and will be released as a U.S. Geological Survey open-file report.

By carbon copy of this letter, copies of the draft are also being sent to the Chief, Regulatory and Site Evaluation Branch; Chief, Technology Development and Engineering Branch; and the Technical Information Officer, NVO.

Sincerely yours,

Virginia M. Glanzman
Technical Publications Editor
Central Regional Geology Branch
for L.R. Hayes, Chief
Branch of NNWSI

Enclosure

cc: G.M. Plummer, AMA/NVO
M.B. Blanchard, R&SE Branch/NVO
L.P. Skousen, TD&E Branch/NVO
L.R. Hayes, USGS
R.B. Raup, USGS
R. Belyea, SAIC/LV

SAIC
Science Applications International Corporation

L89-SED-KFB-175
WBS # 1.2.1.2.0
QA

April 17, 1989

Carl P. Gertz, Project Manager
Yucca Mountain Project Office
U.S. Department of Energy
Nevada Operations Office
P.O. Box 98518
Las Vegas, NV 89193-8518

Attention: Jerry Lorenz

Subject: Contract #DE-AC08-87NV10576
Document Review Comment Disposition Action Item #88-578

Dear Mr. Gertz:

Attached are Document Review Sheets for a document sent to Science Applications International Corporation for comment disposition. The major comment resolutions have been accepted .

Action Item #	Title
88-578	"Preliminary Description of Quaternary and Late Pliocene Surficial Deposits at Yucca Mountain and Vicinity, Nye County, Nevada," by D. L. Hoover.

If there are any questions, please contact Kathryn Brennan at extension 7827.

Sincerely,

SCIENCE APPLICATIONS
INTERNATIONAL CORPORATION

John D Waddell

John D. Waddell, Manager
Systems Engineering Department

JDW:KFB:lcr

101 Convention Center Dr., Ste. 407, Las Vegas, NV 89109 (702) 295-1204
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Mill

USGS-OFR-8X-XXX

USGS-OFR-8X-XXX

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PRELIMINARY DESCRIPTION OF QUATERNARY AND LATE PLIOCENE SURFICIAL DEPOSITS AT YUCCA MOUNTAIN AND VICINITY, NYE COUNTY, NEVADA

By

D.L. Hoover

Open-File Report 8X-XXX

Prepared in cooperation with the
Nevada Operations Office
U.S. Department of Energy
(Interagency Agreement DE-AI08-78ET44802)

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

Denver, Colorado
19XX

USGS-OFR-8X-XXX USGS-OFR-8X-XXX

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PRELIMINARY DESCRIPTION OF QUATERNARY AND LATE PLIOCENE SURFICIAL DEPOSITS AT YUCCA MOUNTAIN AND VICINITY, NYE COUNTY, NEVADA

By

D.L. Hoover

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PRELIMINARY DESCRIPTION OF QUATERNARY AND LATE PLIOCENE SURFICIAL DEPOSITS AT YUCCA MOUNTAIN AND VICINITY, NYE COUNTY, NEVADA

by

D.L. Hoover

ABSTRACT

The Yucca Mountain area, in the south-central part of the Great Basin, is in the drainage basin of the Amargosa River. The mountain consists of several fault blocks of volcanic rocks that are typical of the Basin and Range province. Yucca Mountain is dissected by steep-sided valleys of consequent drainage systems that are tributary on the east side to Fortymile Wash and on the west side to an unnamed wash that drains Crater Flat. Most of the major washes near Yucca Mountain are not integrated with the Amargosa River, but have distributary channels on the piedmont above the river.

Landforms in the Yucca Mountain area include rock pediments, ballenas, alluvial pediments, alluvial fans, stream terraces, and playas. Early Holocene and older alluvial fan deposits have been smoothed by pedimentation. The semiconical shape of alluvial fans is apparent at the junction of tributaries with major washes and where washes cross fault and terrace scarps. Playas are present in the eastern and southern ends of the Amargosa Desert.

Fossils in a sag pond deposit within unit QTa in Yucca Flat suggest that much of the unit is Quaternary. Terrace deposits, intermediate in age between units QTa and Q2, in the Kyle Canyon area of the Spring Mountains have not been found in the Yucca Mountain area. The sequence of events following deposition of unit QTa and prior to deposition of unit Q2 suggest that unit QTa was deposited significantly before the Bishop ash, 738 ka, was deposited near the base of unit Q2.

Unit Q2 is present throughout the Yucca Mountain area and consists of five subunits: subunit Q2c, alluvial sand and gravel and lesser amounts of debris flow deposits; subunit Q2e, eolian sand; subunit Q2s, alluvial sand; subunit Q2b, alluvial gravel and debris flow deposits; and subunit Q2a, debris flow deposits. Subunits Q2e and Q2s are lithofacies of subunit Q2c. Slopewash deposits in the Yucca Mountain area have a stratigraphic position like that of subunit Q2a, but differ from Q2a in several characteristics and are designated subunit Q2a(?) in this report.

The presence of the Bishop ash at or near the base of subunits Q2e and Q2c at several locations in the Yucca Mountain area indicates that deposition of unit Q2 began before 738 ka. Radiometric ages indicate that a soil within subunit Q2c began development about 425 ka. Surface soils began development on subunit Q2c about 270 ka; on subunit Q2b, about 175 ka; and on subunit Q2a(?), about 40 ka.

Unit Q1 was deposited mostly in washes throughout the Yucca Mountain area. The unit consists of subunit Q1c, alluvial gravel; subunit Q1s, alluvial sand that is a lithofacies of subunit Q1c; subunit Q1e, eolian sands; subunit Q1b, debris flow deposits and minor amounts of alluvial gravels; and subunit Q1a, alluvial sand and gravel. Charcoal within subunit Q1c has been dated at 8.3 ka. Charcoal, fossil seeds, and archaeological material have established three periods of deposition for subunit Q1e: 5,300 to 3,000; 2,000 to 1,000 or less; and 200 yr B.P. to the present. Deposition of subunit Q1a probably began about 1840.

Basalts in Crater Flat have ages of 3.75 Ma, 1.1 Ma, and less than 345 ka. Most of the spring deposits in the Amargosa Desert range in age from pre-QTa to pre-Q2 in age. Spring deposits that are Q2 and Q1 in age are probably restricted to the vicinity of modern springs.

INTRODUCTION

The U.S. Geological Survey began geological, geophysical, and hydrological investigations of Yucca Mountain, Nevada, in 1978. The purpose of these investigations is to provide data for the evaluation of Yucca Mountain as a potential nuclear-waste repository site. This report describes Late Pliocene and Quaternary deposits in the vicinity of Yucca Mountain. Age determinations for these deposits are summarized. The report provides a basis from which the approximate age of faults that displace surficial deposits in the Yucca Mountain area can be determined.

Physiography

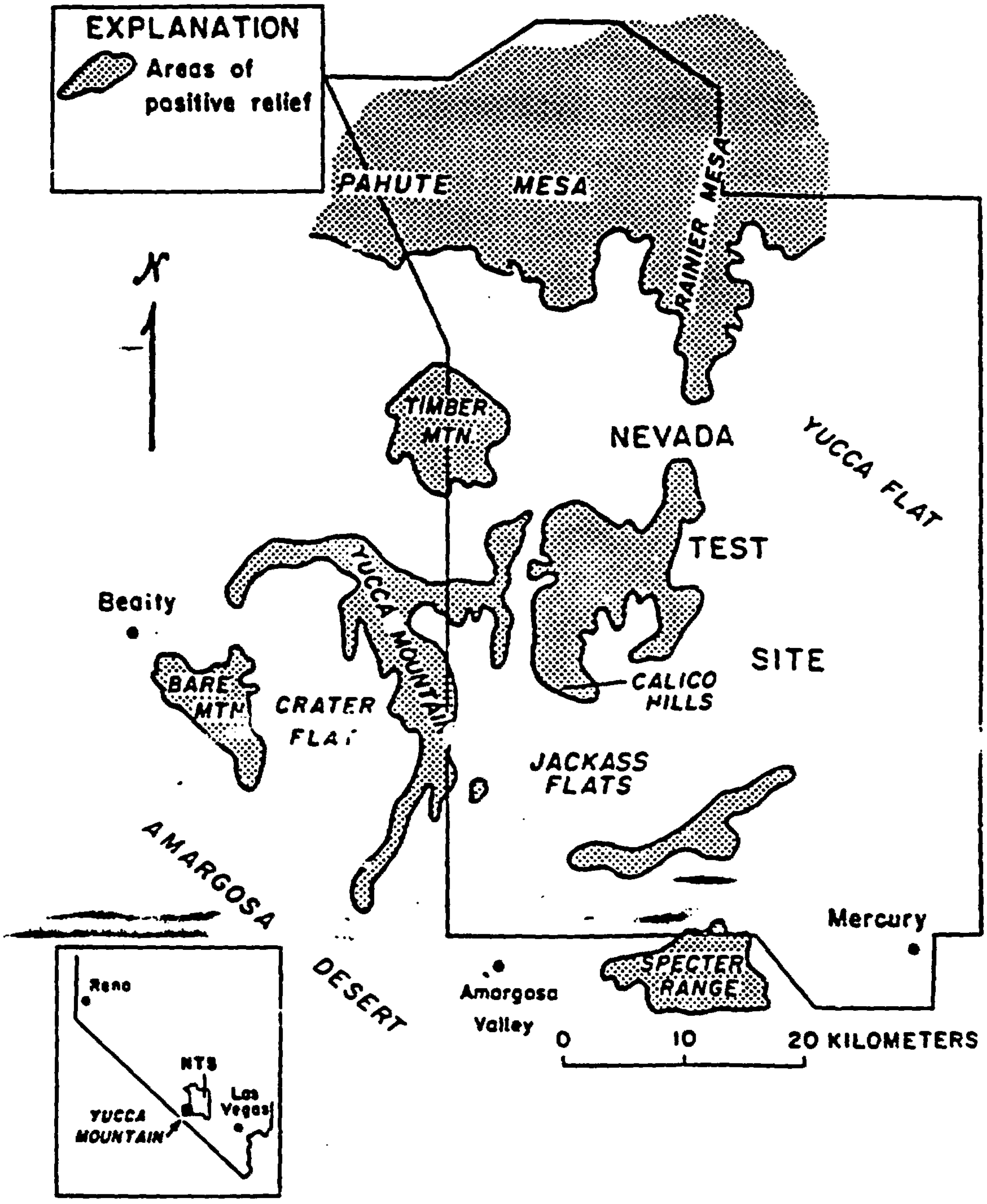
Yucca Mountain (fig. 1) is in the south-central part of the Great Basin subprovince of the Basin and Range physiographic province. In the Yucca Mountain area, elevations range from approximately 610 m on the Amargosa River at the southern end of the Amargosa Desert to approximately 2,345 m on Pahute Mesa. Within 100 km of Yucca Mountain (fig. 2), elevations range from -80 m in Death Valley to 3,368 m on Telescope Peak in the Panamint Range on the west (just southwest of fig. 2) and 3,633 m on Charleston Peak in the Spring Mountains (just southeast of fig. 2). The elevation of the piedmont angle (at the junction of the piedmont slope with the bedrock hills) at Yucca Mountain ranges from 865 m at the southernmost ridge to approximately 1,050 m at the head of Yucca Wash. Maximum elevation of Yucca Mountain is 1,783 m at the northern end.

FIGURE 1.--NEAR HERE

FIGURE 2.--NEAR HERE

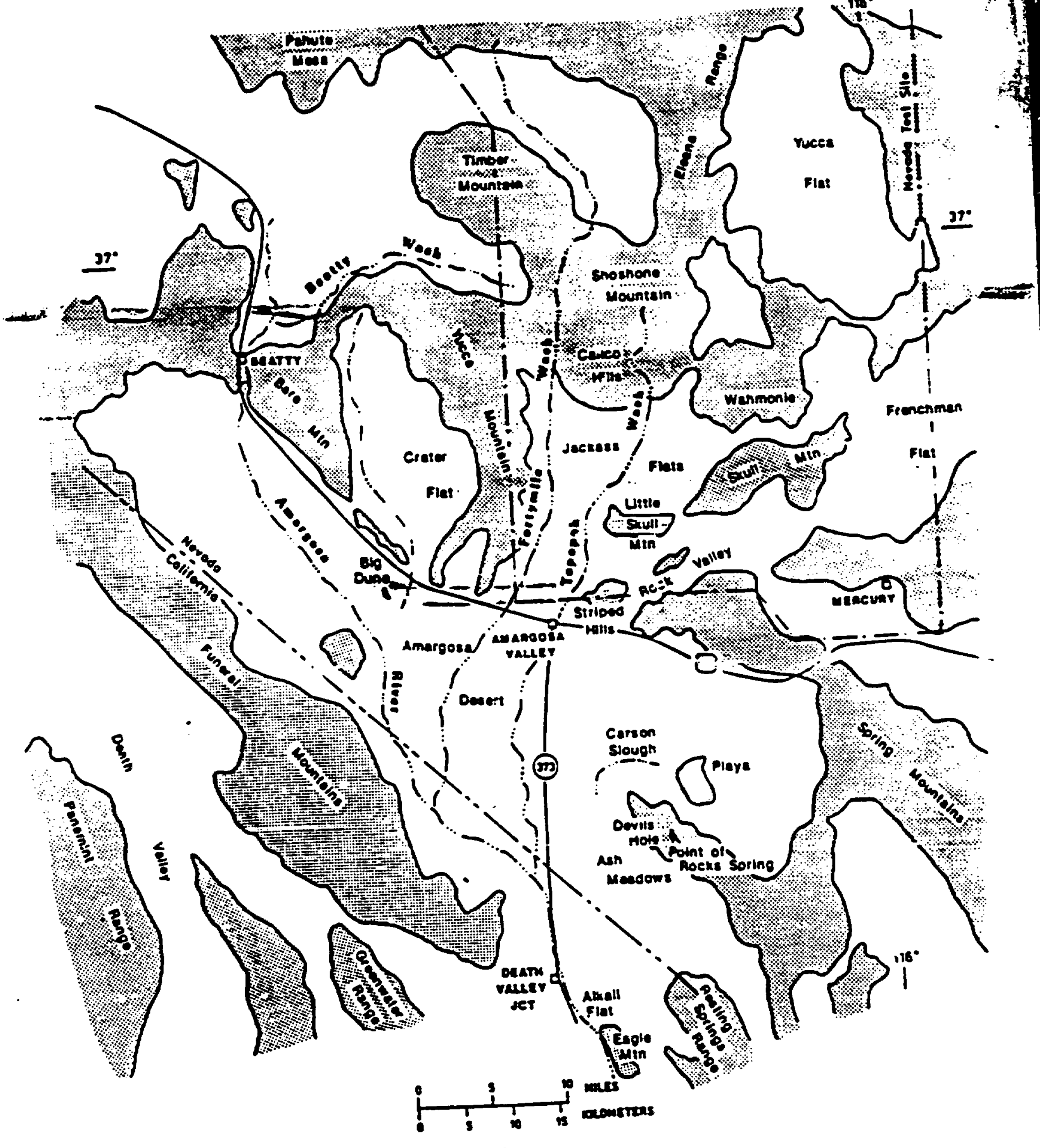
A geologic map of the potential repository site at Yucca Mountain (Scott and Bonk, 1984), a report on the Quaternary faults at and near Yucca Mountain (Swadley and others, 1984), and a report on the structural features and tectonic history of part of the southern Great Basin (Carr, 1984) describe the structural features of Yucca Mountain and the surrounding area. The reader is referred to these reports for descriptions of the structural features mentioned in this report. Landform terminology in this report is in accordance with Peterson's (1981) classification for the Basin and Range province.

Figure 1.--Index map showing location of Nevada Test Site and Yucca Mountain.



EXPLANATION
Areas of positive relief
PAHUTE MESA
RAINIER MESA
N
TIMBER MTN.
NEVADA
TEST
SITE
YUCCA FLAT
YUCCA MOUNTAIN
Beatty
BARE MTN
CRATER FLAT
CALICO HILLS
JACKASS FLATS
AMARGOSA DESERT
Amargosa Valley
SPECTER RANGE
Mercury
0
10
20 KILOMETERS
Reno
NTS
Las Vegas
YUCCA MOUNTAIN

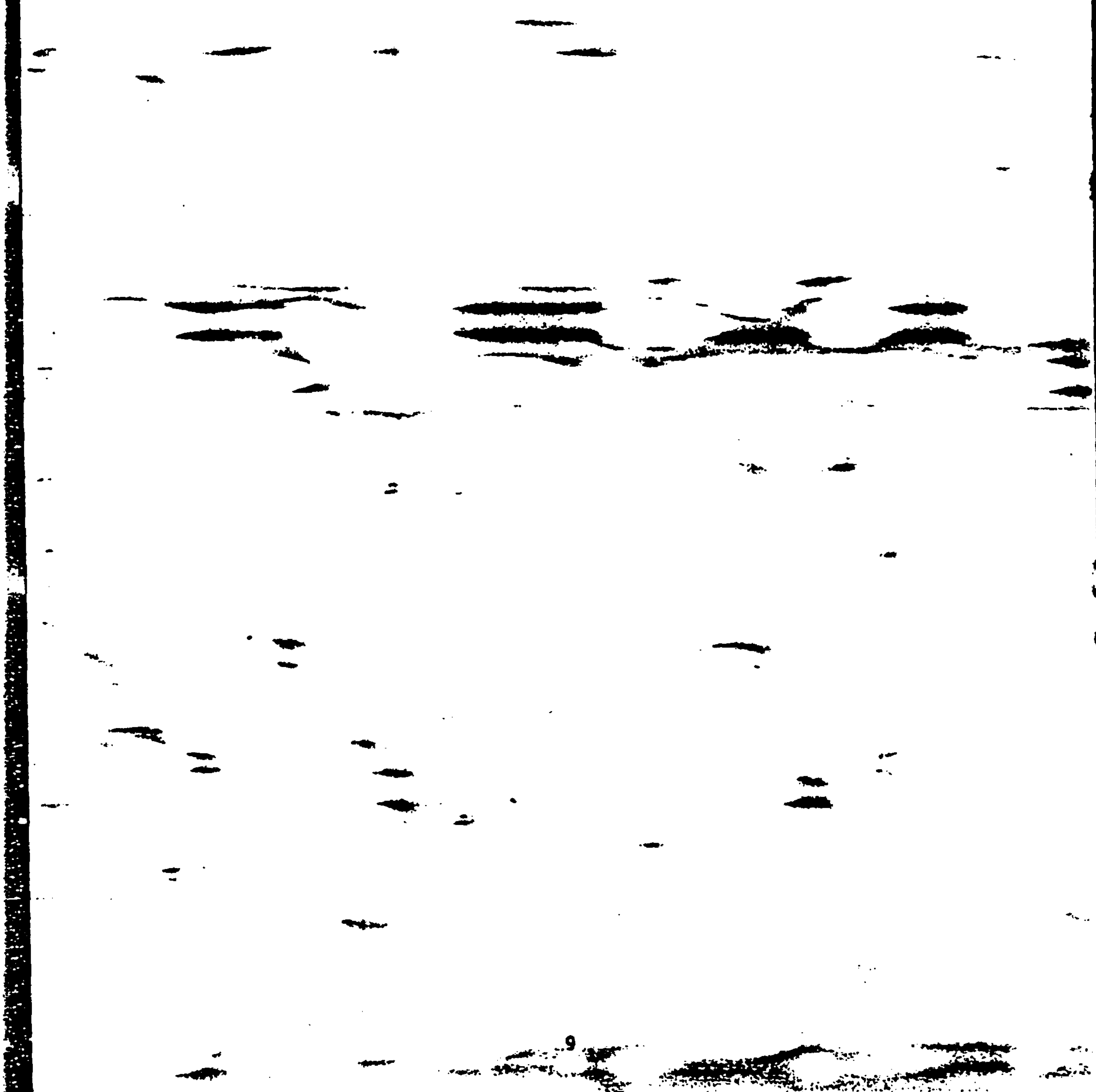
Figure 2.--Bedrock geologic map of Yucca Mountain region.

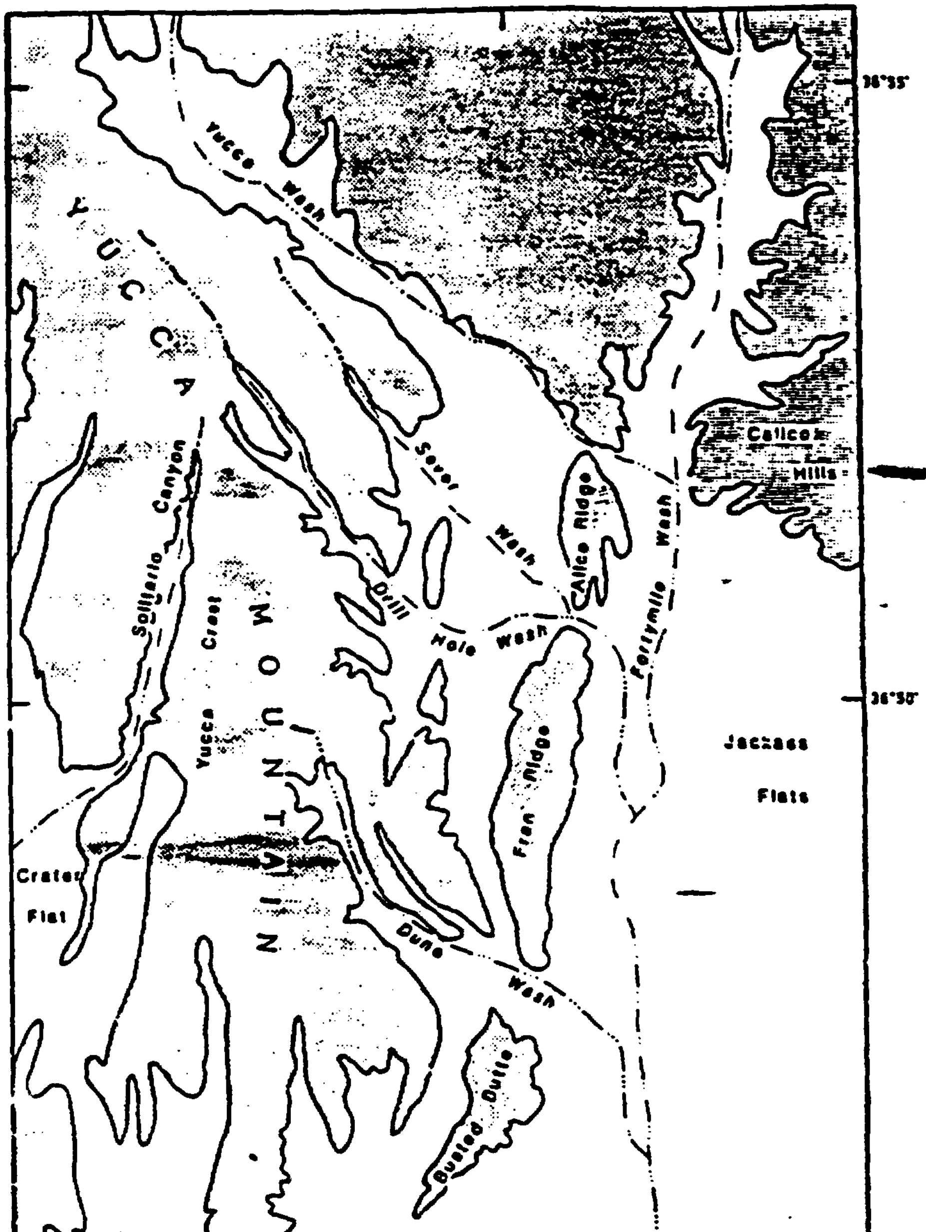

Pahute Mesa
116°
Eleana Range
Yucca Flat
Nevada Test Site
Timber Mountain
37°
Beatty Wash
Shoshone Mountain
37°
BEATTY
Yucca Mountain
Calico Hills
Wahmonie
Frenchman Flat
Bare Mtn
Crater Flat
Jackass Flats
Skull Mtn
Fortymile Wash
Topopah Wash
Little Skull Mtn
Amargosa
Nevada
California
Big Dune
Rock Valley
MERCURY
Striped Hills
Amargosa Desert
AMARGOSA VALLEY
Funeral Mountains
Amargosa River
Death Valley
Carson Slough
Playa
373
Spring Mountains
Panamint Range
Devils Hole
Point of Rocks Spring
Ash Meadows
Greenwater Range
DEATH VALLEY JCT
Alkali Flat
Eagle Mtn
Resting Springs Range
116°
0 5 10 MILES
0 5 10 15 KILOMETERS

The Yucca Mountain area is in the drainage basin of the Amargosa River, which has its headwaters in the western part of Pahute Mesa and drains through the Amargosa Desert and Tecopa Basin into Death Valley (fig. 1). Yucca Mountain consists of one main and several subsidiary, tilted fault blocks of Tertiary volcanic rocks that are typical of the Basin and Range province. West-facing fault scarps on the main fault block have maximum slopes of 60 percent in Solitario Canyon (Scott and Bonk, 1984). A dendritic drainage system was deeply eroded before Quaternary time into the east-facing dip slopes and along faults in the main fault block. Slopes on the main fault block are 10-15 percent near the crests and 20-50 percent on the sides. Small valleys vary from V-shaped with remnants of surficial deposits along the lower valley sides and as thin, narrow deposits in the valley bottoms to flat-bottomed valleys underlain by surficial deposits. The largest valleys, Dune, Drill Hole, and Sever Washes (fig. 3), have sand ramps and alluvial deposits on the valley sides that have slopes of 10 percent and are bordered by terraces underlain by surficial deposits. These terraces are 50 to 300 m wide and have downstream slopes of 3-8 percent.

FIGURE 3.--NEAR HERE.

Figure 3.--Physiographic features of Yucca Mountain and vicinity.




36°55'
Yucca Wash
YUCCA MOUNTAIN
Sever Wash
Calico Hills
Alice Ridge
Fortymile Wash
Solitario Canyon
Yucca Crest
Drill Hole Wash
36°50'
Jackass Flats
Fran Ridge
Crater Flat
Dune Wash
Busted Butte

The sides of ridges that are formed by subsidiary fault blocks have lower slope angles than the sides of ridges formed by the main fault block on both fault scarps and dip slopes. The drainage systems of the subsidiary fault blocks are short, first- and second-order washes that are V-shaped and shallower than washes on the main fault block. The lower slope angles and the lesser development of tributaries in these drainage systems, when compared to those of the main fault block, are the result of lower relief and shorter dip slopes on the subsidiary fault blocks. South of the Dune Wash drainage basin, a few deep V-shaped drainages are present along north-south trending faults, and do not have tributaries.

Most of the washes that drain east-southeast to east on Yucca Mountain and adjacent fault blocks are consequent washes developed on dip slopes. Valleys that drain to the north or south and valleys at the north end of Yucca Mountain that drain southeast were developed along faults (Scott and Bonk, 1984; Carr, 1984). Although faults are not exposed in Yucca Wash, a geomagnetic anomaly suggests that a probable Miocene structural boundary may have influenced the distribution of older rocks, and thus the location of Yucca Wash (Carr, 1984).

The drainage basin of the Amargosa River above Beatty (fig. 2) is deeply incised in volcanic rocks. Fortymile Wash, Topopah Wash, Rock Valley Wash, Carson Slough, and the unnamed wash that drains Crater Flat are the major tributaries of the Amargosa River between Beatty and the southern end of the Amargosa Desert. East of Rock Valley Wash and Carson Slough, drainage is into the playa at the eastern end of the Amargosa Desert. South and west of the Amargosa River and north of Eagle Mountain, tributaries originating in the Funeral Mountains are much smaller than tributaries north of the river. Although Crater Flat, Fortymile Wash, Topopah Wash, and the unnamed wash that drains Crater Flat are deeply incised on middle to upper piedmont slopes, these washes are not integrated with the Amargosa River. On the lower piedmont slopes south of U.S. Highway 95, these washes are distributary and their runoff reaches the Amargosa River only during times of flooding. Rock Valley Wash and the drainage basin of Carson Slough are integrated with the Amargosa River.

Major landforms in the Yucca Mountain area include rock pediments, ballenas, fan and alluvial pediment remnants[1], alluvial fans, stream terraces, and playas. The only rock pediment near Yucca Mountain is on argillite of the Eleana Formation in the center of the Calico Hills. Rounded, subparallel ridges, called ballenas, are common on the oldest surficial deposits near bedrock hills. On piedmont slopes between bedrock hills and on the basin floor of the Amargosa Desert, deposits of coalescing alluvial fans of different ages form nearly flat remnants between washes. Most of these fan deposits have been modified by creep and slopewash into smooth alluvial pediments. Because of fan coalescence and alluvial pedimentation, the semiconical topographic expression of alluvial fan cones is absent on most piedmont slopes. Small, semiconical fans are present at the junction of tributaries and larger washes in valleys in the Yucca Mountain area. Just west of Fran Ridge, Drill Hole Wash has a large, low semiconical fan just above the junction with Sever Wash. Steep semiconical fans are present below fault scarps, along the east front of Bare Mountain and along terrace scarps east of Beatty. Major washes have stream terraces that extend from near the head of the wash down to where the washes become distributary on the lower part of the piedmont slope. A playa defines the end of a closed drainage system at the eastern end of the Amargosa Desert. Alkali Flat, at the south end of the Amargosa Desert, is a late Pleistocene playa that has been breached by the Amargosa River (fig. 2).

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[1] Peterson (1981) uses the term pediment for a surface eroded on unconsolidated material on the piedmont slope. In this report, the adjective, alluvial, is added to avoid confusion with rock pediments by readers unfamiliar with Peterson's terminology.

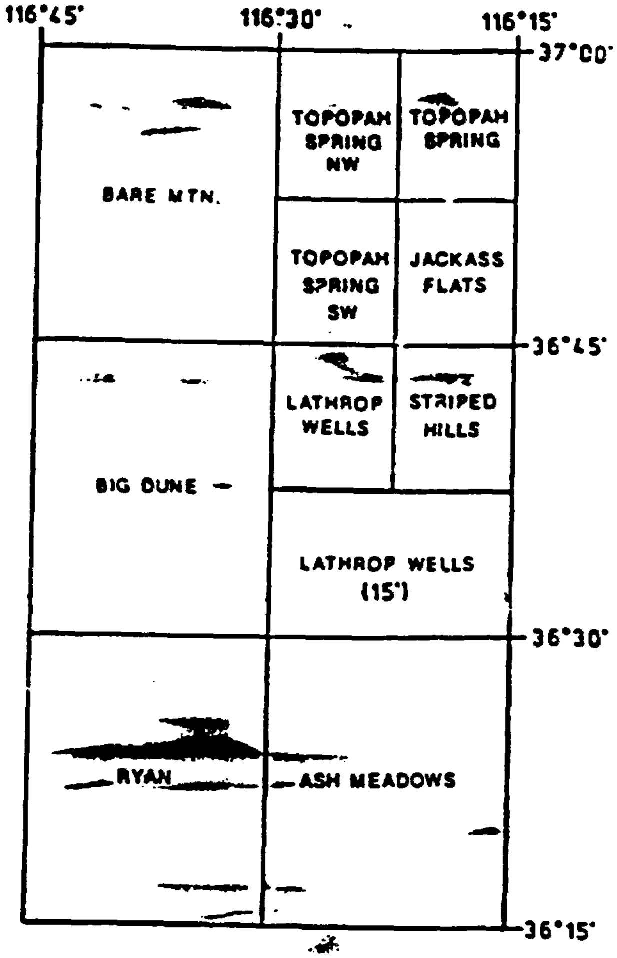
Although calderas north of Yucca Mountain and northwest-trending faults alter the north-south pattern of ranges and valleys that are typical of the Great Basin, the general physiography and types of landforms in the Yucca Mountain area are similar to other areas of the Great Basin. The dimensions and topographic relationships of the landforms in Quaternary deposits in the Yucca Mountain area and in the Amargosa Desert do not differ greatly from those of similar landforms in the closed basins of Frenchman and Yucca Flats and appear to be relatively unaffected by the presence of the Amargosa River.

Previous Work

The bedrock geology of the NTS area has been published in a series of geologic maps at a scale of 1:24,000 (fig. 4). In the Yucca Mountain area, these maps include Topopah Spring NW (Christiansen and Lipman, 1965), Topopah Spring SW (Lipman and McKay, 1965), Topopah Spring (Orkild and O'Connor, 1970), Jackass Flats (McKay and Williams, 1964) and Lathrop Wells (McKay and Sargent, 1970). The geology of the Bare Mountain 15-minute quadrangle was mapped by Cornwall and Kleinhampl (1961). The Quaternary deposits as shown on these quadrangles were simplified and based mostly on clast size and geomorphic position.

FIGURE 4.--NEAR HERE

Figure 4.--Index map of the Yucca Mountain area showing outlines of quadrangle maps.


116°45'
116°30'
116°15'
37°00'
36°45'
36°30'
36°15'
TOPOPAH SPRING NW
TOPOPAH SPRING
BARE MTN.
TOPOPAH SPRING SW
JACKASS FLATS
LATHROP WELLS
STRIPED HILLS
BIG DUNE
LATHROP WELLS (15')
RYAN
ASH MEADOWS

Fernald and others (1968) mapped the surficial deposits of Yucca Flat for engineering purposes on the basis of depositional processes and fragment size. Units QTa, Q2, and Q1 were first described in the Syncline Ridge area of western Yucca Flat (Hoover and Morrison, 1980), which has Quaternary deposits similar to those in the Yucca Mountain area. Correlation characteristics and the stratigraphy of Quaternary surficial deposits in the NTS area were described by Hoover and others (1981). Swadley (1983) mapped the Quaternary deposits in the Lathrop Wells quadrangle and Swadley and Carr (1987) mapped Quaternary deposits in the Big Dune quadrangle. Field mapping of the Quaternary deposits in most of the Topopah Spring 15-minute quadrangle by the author was included in a map of the Quaternary geology of the Yucca Mountain area compiled by Swadley and others (1984).

Waterlaid sediments in the Amargosa Desert were first mapped in a reconnaissance investigation of the hydrology of the Amargosa Desert (Walker and Eakin, 1963). Denny and Drewes (1965) mapped these sediments as playa and spring deposits in the Ash Meadows quadrangle. Swadley (1983) mapped the recrystallized chalk caprocks and claybeds separately in the Lathrop Wells quadrangle. The waterlaid sediments have also been mapped in the Big Dune quadrangle (Swadley and Carr, 1987). Mapping of the NE1/4 of the Ash Meadows 15-minute quadrangle by Pexton (1985) established the stratigraphy of the waterlaid sediments and the relationship of these deposits to younger surficial deposits. Studies of the basalts in Crater Flat (Crowe and Carr, 1980) provided the stratigraphic relationships of these basalts to Quaternary and older surficial deposits.

IDENTIFICATION OF QUATERNARY SURFICIAL DEPOSITS

Multiple criteria, called correlation characteristics (Hoover and others, 1981) are used for identification and correlation of surficial deposits in the NTS area. Correlation characteristics are used because Pliocene and Quaternary sediments in nearby areas could not be identified in the NTS area. The detailed Pliocene and Quaternary section of the Searles Lake area in California (Smith, 1979; Smith and others, 1983) was not comparable, because it was deposited in a different environment than the NTS deposits. The Quaternary deposits of the Tule Springs area near Las Vegas (Haynes, 1967) were deposited in a different environment, and over a much shorter time span. The correlation characteristics (see Hoover and others, 1981 for definitions) are:

- I. Topography
  - A. Macrotopography
  - B. Microrelief
- II. Drainage
  - A. Pattern and development direction
  - B. Cross-sectional shape
  - C. Depth
- III. Soils
  - A. A and B horizons
    - 1. Color
    - 2. Secondary clay, carbonate, and silica content
    - 3. Thickness
  - B. Calcic horizon
    - 1. Stage (Gile and others, 1966)
    - 2. Thickness

IV. Topographic relationships to other depositional units

V. Desert pavement

   A. Packing and sorting

   B. Maximum fragment size

   C. Rock varnish color and luster

VI. Lithology

   A. Sand and clay content

   B. Color

   C. Maximum fragment size and frequency

   D. Ratio of clast lithologies

The order of these characteristics reflects their decreasing importance in the identification of a stratigraphic unit. Except for the order of listing, these characteristics are the same as described by Hoover and others (1931).

The use of soil properties to identify stratigraphic units was limited to macroscopic differences in the A, B, and calcic horizons that are easily identifiable by geologists unfamiliar with the descriptions and techniques of soil science. These differences include the presence of vesicular A and cambic B horizons, and the presence and the degree of development of argillic B and calcic horizons. The soil-horizon designations used in this report differ somewhat from those defined by the Soil Conservation Service (Soil Survey Staff, 1975), and are defined in the following paragraphs.

Vesicular A (Av) horizons are surface horizons that contain numerous vesicles that are 1-10 mm in diameter. Av horizons are formed in a layer of silty sand that underlies a desert pavement. Most Av horizons overlie an unconformity at the top of the underlying B or calcic horizon. This unconformity is indicated by: (1) the presence of similar Av horizons on either B or calcic horizons of a single stratigraphic unit, and (2) an abrupt decrease in secondary carbonate in some soils between the Av and the underlying B horizon.

Cambic and argillic B horizons are present on most Pleistocene and older surficial deposits. Cambic B horizons are distinguished on the basis of better developed structure and (or) stronger colors than the underlying horizon. Cambic B horizons lack significant clay accumulation, but a few, thin clay coatings on sand grains and larger fragments are present in some cambic B horizons. Most cambic B horizons are yellowish brown. Argillic B horizons have significant clay accumulations as indicated by abundant clay films. Most argillic B horizons are reddish brown, and contain more clay than the underlying horizon. Some argillic B horizons are indurated by abundant secondary calcium carbonate and locally by secondary silica. Most cambic and argillic B horizons are less than 50 cm thick.

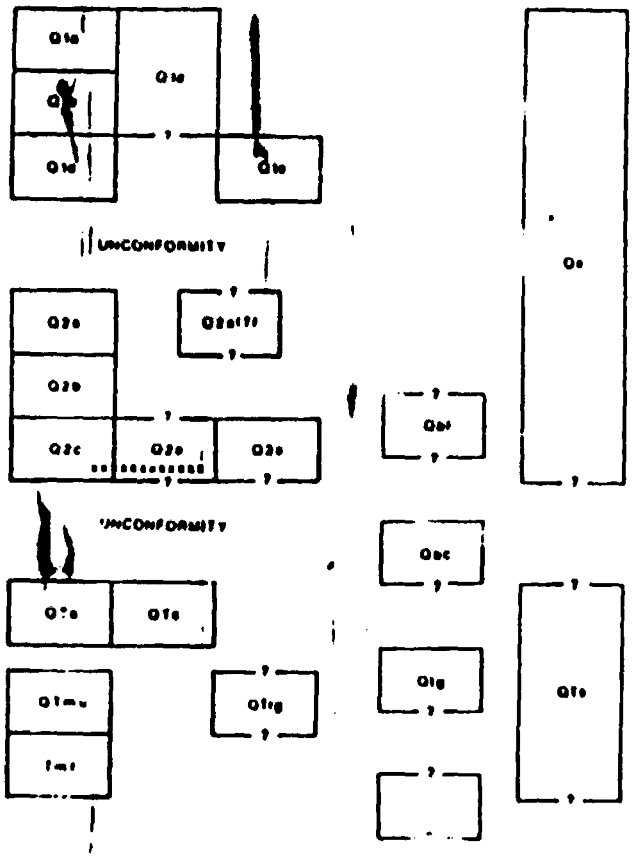
Calcic horizons are characterized by the deposition of abundant calcium carbonate and locally by some secondary silica. The calcic horizons referred to in this report include the Cca, calcic, and petrocalcic horizons of the Soil Survey Staff (1975) and the K horizon of Gile and others (1965). Thicknesses of calcic horizons in this report include the entire thickness of visible secondary carbonate which ranges from less than 0.1 to greater than 1.5 m. The morphological characteristics of secondary carbonate in calcic horizons were used to assign stages as defined by Gile and others (1966). Calcic horizons range from stage I films and coatings on the bottoms of clasts in early Holocene and late Pleistocene deposits to thick, plugged, stage IV horizons in early Pleistocene deposits. The carbonate stages that are reported are the maximum stage developed in the entire calcic horizon (Gile and others, 1966). Carbonate-rich laminae, characteristic of strongly developed stage IV horizons, are common in early Pleistocene and older deposits, but they occur only locally in some middle Pleistocene deposits. Pisolites and brecciated and recemented laminae occur in a few locations in early Pleistocene and older deposits.

STRATIGRAPHY

Stratigraphic units in the Yucca Mountain area range from Precambrian to Holocene. Metamorphic and sedimentary rocks from Precambrian to Mississippian in age and volcanic rocks of Miocene and Pliocene age form the hills and ranges of the Yucca Mountain area. Sedimentary rocks of Miocene and early Pliocene age are present in the Funeral Mountains, at the southern and eastern ends of the Amargosa Desert, and in Crater Flat. All of these rocks are highly deformed and densely faulted. In contrast, the waterlaid sediments in the Amargosa Desert and younger surficial deposits are relatively undeformed and are faulted in only a few places. Late Pliocene and Quaternary deposits in the Yucca Mountain area include the waterlaid sediments of Amargosa marsh, unit QTa, unit Q2, which has five subunits, and unit Q1, which also has five subunits (fig. 5).

FIGURE 5.--NEAR HERE

Figure 5.--Correlation chart of late Pliocene and Quaternary stratigraphic units in the Yucca Mountain area. Query indicates that stratigraphic position of base and (or) top is uncertain.



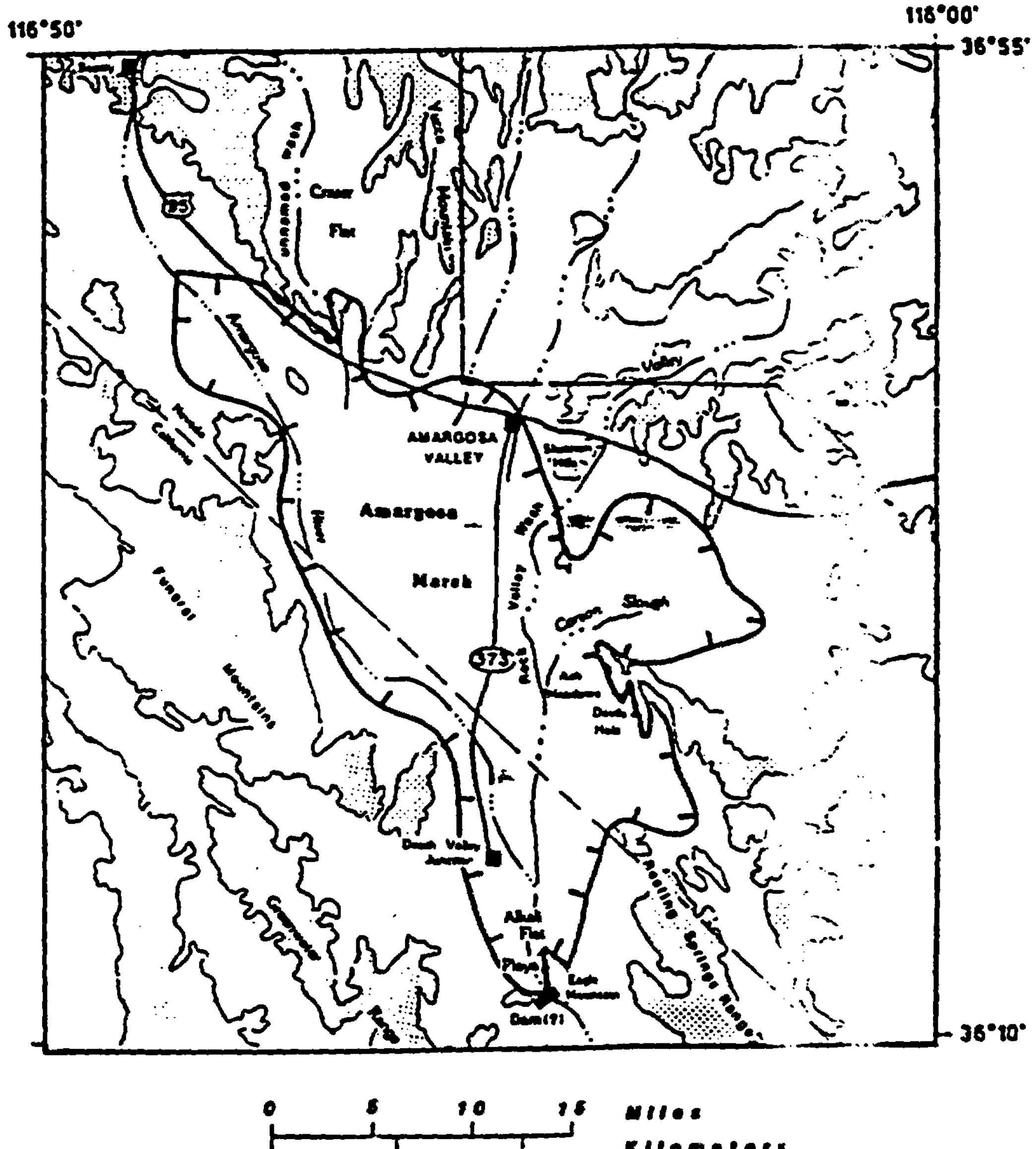
Q1a - Alluvial deposits	Holocene	Quaternary
Q1b - Debris flow deposits and alluvial deposits		
Q1c - Alluvial deposits		
Q1e - Eolian deposits		
Q1s - Alluvial sheet sand deposits		
Qs - Spring deposits		
Q2a - Debris flow deposits	Pleistocene	
Q2a(?) - Alluvial deposits		
Q2b - Alluvial deposits		
Q2c - Alluvial deposits		
Q2e - Eolian deposits		
Q2s - Alluvial sheet sand deposits		
Qbl - Lathrop Wells basalt		
ss - Bishop ash		
Qbc - Basalt of Crater Flat 1.1 Ma		
QTa - Debris flow deposits and alluvial deposits	Pleistocene and Pliocene(?)	Quaternary and Tertiary
QTc - Colluvium		
QTg - Pediment gravel of Syncline Ridge area		
QTmu - Upper unit, waterlaid sediments of Amargosa Marsh	Pleistocene(?) and Pliocene	
QTrg - River gravels of ancestral Rock Valley Wash		
QTs - Spring deposits	Pliocene	Tertiary
Tml - Lower unit, waterlaid sediments of Amargosa Marsh		
Tbc - Basalt of Crater Flat, 3.75 Ma		

Pliocene and Quaternary(?) Deposits

Waterlaid Sediments of Amargosa Marsh

Th~~at~~e waterlaid sediments of Amargosa marsh consist of clays, limestones, and tufas that crop out in much of the Amargosa Desert south of lat 36°30' and west of long 116°10'. Scattered outcrops are present along the Amargosa River northwest to lat 36°40', between U.S. Highway 95 and the hills that form the southern edge of Crater Flat, and at the southern end of Crater Flat along the unnamed wash that drains Crater Flat. Driller's logs (Walker and Eakin, 1963) indicate that the waterlaid sediments underlie most of the Quaternary surficial deposits between the Skeleton Hills and the Amargosa River south of U.S. Highway 95. The sediments were deposited in an area called Amargosa marsh in this report (fig. 6). These sediments are referred to as the waterlaid sediments of Amargosa marsh. Amargosa marsh had an area of approximately 1,250 km^2.

FIGURE 6.--NEAR HERE


116°50'
116°00'
36°55'
36°10'
95
Crater
Flat
Amargosa
Nevada
California
AMARGOSA
VALLEY
Amargosa
Marsh
Valley
Wash
Carson
Slough
Funeral
Mountains
373
Ash
Meadows
Devils
Hole
Death Valley
Junction
Alkali
Flat
Playa
Eagle
Mountain
Dam(?)
Resting
Springs Range
Greenwater
0
5
10
15
Miles
Kilometers

Pexton (1985) divided the waterlaid sediments of Amargosa marsh into a lower and an upper unit separated by a disconformity. The lower unit was further divided and mapped as four lithofacies: three units that are mostly argillaceous and a fourth unit of sheet limestones that overlies and interfingers with two of the argillaceous lithofacies; the "lake" deposits and the paludal deposits. The lower unit, as described by Pexton (1985), consists of:

Undifferentiated Pliocene "lake" deposits (unit Tld):

Mostly brown to green, illitic and montmorillonitic claystones with soft to hard limestone beds, pods, and nodules that contain minor dolomite. Thin sandstone beds are sparse. Clay beds pinch and swell noticeably over short distances and grade into limestone with inclusions of irregular clay masses. Claystones contain only small amounts of magnesium silicate clays. Evaporites were not observed, but masses of selenite and thenardite blooms are found at the surface. Abundant rootmarkings. Contains two ash-fall tuffs. Deposited in floodplains, swamps, ponds, and playas.

Pliocene playa deposits (unit Tp[illegible]

Mostly buff to brown, hard, blocky claystones that are predominantly magnesium silicate clays with some authigenic potassium feldspar. Some claystones have pelletal textures. Minor, hard, white dolomite sheets grade into soft, white limestone. Calcium carbonate breccia masses (caliche-breccia) found near Carson Slough contain interstitial magnesium silicate clays. Contains one ash-fall tuff. Probably deposited in a seasonally flooded playa.

Pliocene paludal deposits (unit Tpa):

Mostly white, chalky limestones with minor amounts of sandstone and claystones. Claystone occurs as irregular masses of illitic to montmorillonitic clay within chalky limestones. Limestone contains gastropods, bivalves, and ostracodes. Probably deposited in spring-fed marshes and ponds.

Pliocene sheet limestones (unit Tll):

White to light gray, dense, recrystallized, fenestral limestone sheets. Contains rootmarks and occasional plant casts that resemble plants growing in runoff from springs. Probably deposited in isolated ponds.

The disconformity that separates the lower and upper units has been recognized in the Carson Slough and Rock Valley Wash drainage basins and in the area southwest of Devils Hole. The disconformity is marked by channels that are 3 to 10 m deep and a few meters to a few tens of meters wide. Between Carson Slough and Rock Valley Wash, the channels have a low gradient to the south. South of Carson Slough along the west side of the ridge of Paleozoic rocks that contains Devils Hole, the channels have a slightly steeper gradient to the west. At the south end of this ridge, the channels have a gentle gradient to the southwest.

The upper unit fills the channels cut into the lower unit. The base of the upper unit is marked by coarse sands or gravels. In the Carson Slough and Rock Valley Wash drainage basins, basal sands contain sparse pebbles as much as 2 cm in diameter. Along the west side of the ridge south of Carson Slough, similar sands and local gravels are present in lenses at the base of the upper unit. West of Devils Hole and south of the Paleozoic ridge, the base of the upper unit contains beds of limestone gravel as much as a meter thick. Clasts of the gravels are mostly less than 20 cm in diameter.

Above the basal clastic deposits, the upper unit is mostly white, soft limestone that contains minor amounts of siltstone and claystone. Clay minerals are mostly illite and montmorillonite, but magnesium silicate minerals are also present (Pexton, 1985). Beds are mostly less than 1 m thick.

The deposits of the upper unit are capped by tufa. The tufa is brown to orangish brown in outcrop and medium gray to pale yellowish gray on a fresh surface. The tufa consists of limestone and sandy limestone that preserves casts and moulds of plants and algal structures. Where the plant casts and moulds are well preserved, they contain a triangular reed and two broad-leafed plants that closely resemble plants that grow in the runoff from modern springs. The tufa is usually 1-2 m thick near the head of the channels and thins downslope. In sec. 26, T. 17 S., R. 50 E., the tufa covers an area about 1 km^2 and is 2-4 m thick. Although Pexton (1985) mapped the tufas separately from the underlying sediments of the upper unit, the association of the tufas with the sediments and the channels of the disconformity indicate that the tufas are a lithofacies of the upper unit.

The upper unit is not continuous. The association of the channels of the disconformity and the upper unit, similar lithologies throughout the upper unit, and a similar elevation of the disconformity noted by Pexton (1985) from Carson Slough and Rock Valley Wash to the area southwest of Devils Hole indicates that these deposits were probably deposited at the same time by the same processes.

West of the area mapped by Pexton (1985), a large outcrop of sediments similar to the upper unit may also be the upper unit. The outcrop covers an area about 6 by 3.5 km in the Ash Meadows quadrangle in T. 17 and 18 S., R. 49 E. in Nevada and T. 26 and 27 N., R. 5 E. in California between Nevada State Highway 373 and the Amargosa River. Diatomite and white, soft limestone and claystone are capped by tufa. Sand less than 20 cm thick occurs at the base of the deposit. The sand contains very sparse pebbles that are less than 10 mm in diameter. At the southern end, a lobate shape of the deposit suggests filled channels like the channels filled by the upper unit about 10 km to the east.

Outcrops in the Big Dune quadrangle resemble both the lower and upper units. Along the Amargosa River, claystones and limestones resemble sediments of the lower unit. In the Big Dune quadrangle in secs. 22 and 23 (estimated), T. 14 S., R. 48 E., pebbly tuffaceous sands underlie claystone and diatomite that resemble similar sediments in the upper unit. These sediments are capped by tufa in which mammalian fossils occur. Tufas on the south and west sides of this outcrop appear to occur in channels that slope to the south. In sec. 19, T. 14 S., R. 49 E., claystone and remnants of tufa are exposed south of the hills that bound Crater Flat on a terrace or pediment along the unnamed wash that drains Crater Flat.

In southern Crater Flat in the Big Dune quadrangle in secs. 12 and 13, T. 14 S., R. 48 E. and secs. 7 and 18, T. 14 S., R. 49 E., tufas are interbedded with sand and gravel. Tufas and limestone also form erosional mounds. Along the unnamed wash, where it drains east-southeast, gravel beds dip 5°-15° south to southeast, and are interbedded with tufas. In a trench exposure, the gravel on the north edge of the wash grade vertically from poorly sorted at the base of a bed to well-sorted at the top and laterally from poorly sorted on the north to well sorted to the south. The gravels in the trench are interbedded with pebbly sands. A yellowish to orangish, iron-oxide stained band from 5 to 15 cm thick, which slopes slightly to the south, cuts across bedding of the sands and gravels that have a slightly greater dip to the south. South of the wash, tufa and white, soft limestone form eroded mounds that appear to have been deposited along a north-south line of springs.

In the southern part of the Lathrop Wells quadrangle, Swadley (1983) mapped calcareous clays and silts and dense limestones that are continuous with outcrops mapped by Pexton (1985) as the lower unit of the sediments of Amargosa marsh. Swadley's (1983) unit QTld is equivalent to Pexton's (1985) units Tld, Tpl, and Tpa; Swadley's unit QTll is equivalent to Pexton's sheet limestones, unit Tll. The upper unit was not recognized by Swadley (1983), but areas of calcified vegetal mats in sec. 19 and 30, T. 16 S., R. 50 E. may be the upper unit.

The deposits needed to interpret the early history of Amargosa marsh are concealed by the waterlaid sediments and by younger deposits, but some evidence suggests that at least part of Amargosa marsh may have been occupied by a lake early in its history. The evidence consists of a possible dam at Eagle Mountain and possible beach terraces near the dam, near Devils Hole, and at the north end of the limestone ridge that contains Devils Hole.

The possible dam at Eagle Mountain was formed by older, deformed gravels, alluvial fans, and basalt that may have provided barriers on either side of Eagle Mountain to runoff from Amargosa marsh. Between Eagle Mountain and the Resting Springs Range to the east, older, deformed gravels and alluvial fans provided a barrier that still exists. West of Eagle Mountain, alluvial fans and faulted younger basalts formed a similar barrier. The basalts are probably the same basalts as in the Greenwater Range, less than 5 km from these basalts. The barrier west of Eagle Mountain has been breached by the Amargosa River. When this breaching occurred is uncertain, but the breaching was probably early in the history of Amargosa marsh.

Faint traces of possible beach terraces are present on the basalt at the possible dam, on Paleozoic carbonate rocks near Devils Hole, and at the north end of the limestone ridge that contains Devils Hole. In the Ryan quadrangle, in sec. 30, T. 24 N., R. 6 E., a bench that is 3-5 m wide is cut in basalt almost completely around a knob that is about 5 m higher than the bench. The bench does not coincide with any apparent lithologic changes and is overlain by 0.3-0.6 m of fine-grained material. The fine-grained material could be eolian in origin, but it is not present on other nearby outcrops of basalt. The bench is about 45 m above the waterlaid sediments at an altitude of approximately 652 m.

In the Ash Meadows quadrangle, in sec. 36, T. 17 S., R. 50 E., about 1/2 km west of Devils Hole, a bench is cut across the bedding of Cambrian limestone at an altitude of approximately 737 m. This bench may be an old terrace at the junction of washes in adjacent drainage basins, but similar benches are not present adjacent to other nearby, similar junctions of washes in the limestone. In sec. 23, T. 17 S., R. 50 E. and sec. 19, T. 17 S., R. 51 E., benches about 15 m wide are cut in the limestone at elevations of 725-745 m, and are partly covered by waterlaid sediments of Amargosa marsh. The benches cut across bedding and appear to be unrelated to lithologic differences or faults. The topographic setting and location of the benches make differential weathering or stream erosion unlikely. A few limestone clasts on these benches are highly rounded, but are too deeply pitted by weathering to determine their origin.

River Gravels of Ancestral Rock Valley Wash

The river gravels of ancestral Rocky Valley Wash consist of coarsely crossbedded pebbly sands and sandy gravels that underlie a north-south ridge just west of Rock Valley Wash in the Ash Meadows and Lathrop Wells quadrangles. The outcrops can be traced from sec. 30, T. 17 S., R. 50 E. north for approximately 10 km to the SE 1/4 sec. 19, T. 16 S., R. 50 E. The best exposures are in the SW 1/4 NE 1/4 sec. 19, T. 17 S., R. 50 E., where crossbedding and the relationship to the lower unit of the sediments of Amargosa marsh are well exposed.

Crossheds are 5-20 cm thick in beds that are 0.3-0.6 m thick. Clasts of volcanic rock as large as 10 cm are scattered in a sandy matrix that is cemented by calcite. A few beds are sandy gravel. Clasts are mostly silicic volcanic rocks, but minor amounts of basalt are present.

The crossbedded sand and gravel fill a channel 1.5 km wide and as much as 5 m deep. Remnants of sheet limestones of the lower unit of the sediments of Amargosa marsh form part of the east bank of the channel. The parallelism of the channel with Rock Valley Wash for at least 10 km indicates that the channel is probably an ancestral Rock Valley Wash.

Slopes and ridgetops above the crossbedded sands are covered by deposits that contain boulders of basalt and other volcanic rocks as much as 0.5 m in diameter. These boulders are probably from the next younger unit, unit QTa.

Pliocene(?) and Quaternary Deposits

Unit QTg

Unit QTg consists of thin-bedded gravels that fill shallow valleys of a dissected pediment between the Eleana Range and Syncline Ridge in western Yucca Flat (fig. 2). The gravels are composed of quartzite, conglomerite, and siliceous argillite derived from the Eleana Range. Clasts are angular, platy, and prismatic, have a maximum dimension 0.7 m, and have thicknesses that are 20 to 50 percent of the maximum dimension. In contrast, the overlying unit QTa contains numerous boulders of Tertiary welded tuff that have diameters of 1 to 10 m, are subangular to subrounded, and are roughly equidimensional. The gravels of unit QTg are as much as 5 m thick near the Eleana Range and 22 m thick near Syncline Ridge beneath units QTa and Q2 (Hoover and Morrison, 1980).

The pediment beneath the gravels is defined by a nearly planar surface that covers approximately 17 km^2 between the Eleana Range and Syncline Ridge. The pediment is cut on gently to steeply dipping quartzite and clayey argillite of the Eleana Formation (Mississippian and Devonian) and on Tippipah Limestone (Permian(?) and Pennsylvanian). Where unit QTg is present on ridges near the Eleana Range, it is overlain in most places by unit QTa. These ridges are 10 to 20 m wide and have rounded to flat tops. The contact between the Eleana Formation and the gravels dips into the ridges. The upper part of the gravels is thoroughly cemented by dense calcium carbonate. At the base of the gravels on one ridge, a trench exposes soft, pulverent to nodular calcium carbonate. The soft carbonate forms 50 percent or more of the matrix in both the gravels and the weathered rock of the underlying Eleana Formation in a zone approximately 0.7 m thick.

Plates of calcium carbonate occur as residual deposits at the edge of the gravel and on the Eleana Formation along the ridges upslope from the edge of the gravel. The carbonate plates can be traced to a thrust fault in the Eleana at the east foot of the Eleana Range. The plates are siliceous near the thrust fault. The carbonate and silica plates and the carbonate in the gravel appear to have been deposited by ground water seeping out of the thrust fault and into the gravel.

Unit QTa

Unit QTa consists of predominantly debris flow deposits and small amounts of alluvium. Unit QTa is present at the periphery of all basins in the NTS area, around isolated bedrock hills in the Amargosa Desert, and as erosional remnants in valleys in the hills and ranges. Unit QTa lies unconformably on Precambrian to Paleozoic sedimentary rocks, on Tertiary volcanic and sedimentary rocks, and on the waterlaid sediments of Amargosa marsh. In the Calico Hills and between Syncline Ridge and the Eleana Range in Yucca Flat, unit QTa was deposited on unit QTg and pediments that were cut on argillite of unit J of the Eleana Formation. In most areas, exposures of unit QTa are less than 2 km from the hills and ranges. In a few places, such as Rock Valley Wash near the Skeleton Hills and in Crater Flat, exposures are 10 km or more from the ranges. The maximum observed thickness of unit QTa is approximately 55 m.

Natural exposures of unit QTa are sparse. The best developed soils and landforms that are typical of unit QTa occur between Yucca Mountain and Alice Ridge, just south of Yucca Wash (fig. 3). Debris flow deposits and poorly sorted alluvial gravel that may have been reworked from debris flows are exposed in Crater Flat trenches 1 (lat 36°48'14", long 116°29'50") and 2 (lat 36°46'59", long 116°30'38") and in some of the deeper washes near these trenches.

Unit QTa crops out as elongate, well-rounded ridges called ballenas. The ballenas are separated by washes that form parallel to subparallel drainage systems. The washes, where not filled by unit Q2 or dissected by Holocene erosion, have rounded cross sections. Relief on the ridges ranges from 1 to 25 m; the macrotopography is rounded. Microrelief is flat except where erosion during the pedimentation of unit QTa has left residual cobbles and boulders protruding above the desert pavement. Within 1-2 km of bedrock hills, residual boulders are as much as 10 m in diameter. At distances of 5 km, residual boulders are less than 1 m in diameter. Along Rock Valley Wash south of U.S. Highway 95, basalt boulders from Skull Mountain, more than 30 km away, are commonly 0.5 to 1 m in diameter. Residual boulders are rarely present on deposits younger than unit QTa.

Soils on unit QTa typically consist of an Av horizon and a calcic horizon. The Av horizon on unit QTa overlies the calcic horizon or, where present, an argillic B horizon. The Av horizon is formed in material that is probably much younger than the underlying deposits. Thickness of the Av horizon ranges from 10 to 40 cm. The B horizon has been eroded from most QTa soils. Only one area, just south of Yucca Wash and west of Alice Ridge, has been found with an argillic B horizon intact in a QTa soil. At this location, the argillic B horizon is dark reddish brown, contains abundant clay, and is approximately 50 cm thick. Secondary silica increases downward in the B horizon. Where the argillic B horizon is preserved, the calcic horizon has engulfed the lower part of the B horizon and consists of laminar layers that enclose lenses of pale-brown opaline silica that are as much as 5 cm thick. The laminar layers that enclose these silica lenses are dense, hard, and probably contain secondary silica. Calcic horizons of unit QTa are stage II to III at elevations of about 700 m in the Ash Meadows area and stage IV above 900 m in the Yucca Mountain area. Stage IV calcic horizons are 2 to 3 m thick. Laminar layers are present in most stage IV calcic horizons. Pisolites and brecciated and recemented laminar layers occur in a few locations.

On the uppermost part of piedmont slopes, interfluves of unit QTa between washes that head in the bedrock hills, are topographically above units Q2 and Q1. Deposits of QTa are also present at drainage junctions within bedrock hills, as erosional remnants on pediments, and as the highest erosional terrace along major washes within bedrock hills. On Yucca Mountain, remnants of unit QTa are present on steep slopes 20-50 m above the bottoms of some washes. Terraces and dissected hills of unit QTa are present on lower piedmont slopes along Rock Valley Wash from U.S. Highway 95 south to about lat 36°30'. At distances of 5 km or more from bedrock hills, unit QTa is buried by younger surficial deposits on most piedmont slopes.

Desert pavement on unit QTa is very densely packed and poorly to moderately sorted. Maximum fragment size in the pavement is about 20 cm, but residual boulders, which range from 0.5 to as much as 10 m in diameter, commonly protrude above the pavement. Varnish on pavements and residual boulders is shiny brownish black to black, 0.5 to 2 mm thick, and continuous in areas undisturbed by soil creep.

Trenches and a few natural exposures reveal unsorted, nonbedded layers that are 1 to 2 m thick. Each layer contains coarse fragments ranging from pebbles to boulders that are supported by a matrix of clay- to sand-size material. Clay and silica coat larger fragments below the calcic horizon. Natural exposures of unit QTa are light brown with a pinkish to reddish cast. Boulders of welded tuff, limestone, or quartzite are commonly 1 to 4 m in diameter on the uppermost piedmont slopes and in QTa deposits in bedrock hills. Boulders at the base of unit QTa, deposited on a pediment cut on the Eleana Formation in the Calico Hills and in Yucca Flat, are as much as 10 m in diameter.

At the foot of the Eleana Range in the west-central part of Yucca Flat, lenses of calcium carbonate that contain ostracodes, gastropods, and small mammal remains are interbedded with debris flow deposits of unit QTa. Two lenses, exposed in trenches cut at right angles, are as much as 2 m thick, extend at least 50 m downslope, and are at least 30 m wide along the slope contour. The upper part of both lenses contains greenish-gray clay and clasts as much as 20 cm in diameter. The location of the calcium carbonate lenses, adjacent to faults that displace the uphill side of the faults down against quartzite of the Eleana Formation, indicate that the fossiliferous carbonate lenses are sag pond deposits.

Alluvial pediments were cut on unit QTa throughout the NTS area. The pediments are defined by the concordant tops of the ridges that characterize unit QTa. Concordancy of the ridges extends across small washes that originate in bedrock hills and across some major washes. The concordant ridges extend into bedrock in a few locations in the Calico Hills, east of Jackass Flats, and on the southwest side of Bare Mountain. Benches cut on bedrock and "lines" of calcium carbonate that stain steep bedrock slopes may record the original surface of unit QTa. These features occur as scattered remnants in the ranges east of Yucca and Jackass Flats, in the Calico Hills, and on the southwest side of Bare Mountain. The benches and carbonate lines suggest that 25 to 50 m of unit QTa may have been eroded where the ranges have the greatest relief and highest slopes. Near hills that are low in relief, erosion may have been much less than 25 m.

On hillslopes that have 10-25 m of relief, QTa deposits lack any evidence of bedding. The few exposures along washes and in trenches are predominantly layers of unsorted cobbles and boulders. In Crater Flat trenches 1 and 2 and in some exposures in washes, coarse, poorly to moderately sorted alluvial gravel is present in the upper 1-3 m of unit QTa. In a few wash exposures, alluvial gravel occurs as thin beds between unsorted layers of cobbles and boulders. Numerous large boulders are present in almost all exposures of unit QTa, regardless of relief or lithology of the bedrock above the outcrops.

Subunit QTc.--Colluvium that consists of unsorted fine to coarse angular rubble was mapped separately as a subunit of unit QTa on steep slopes of Little Skull Mountain in the Lathrop Wells quadrangle (Swadley, 1983) and in the northeast corner of the Big Dune quadrangle (Swadley and Carr, 1987). Colluvium of subunit QTc is included in map unit QTa at other locations. The colluvium includes rock falls and debris flow deposits that grade downslope into unit QTa. Slightly dissected smooth slopes of subunit QTc are underlain by stage III to IV calcic horizons that are several meters thick. A and B horizons are not present.

Regional Unconformity

Where subunit Q2c overlies unit QTa in the Yucca Mountain area, a regional unconformity is present. This unconformity is defined by the soil developed on unit QTa and the dissected pediments of unit QTa, and represents a long period of erosion and nondeposition. The pediments were dissected by subparallel drainage systems throughout the Yucca Mountain area after pedimentation of unit QTa and development of a soil on the pediments. This dissection of unit QTa formed long, narrow, rounded ballenas, usually less than 20 m wide. At the upslope end of ballenas, the ridge crests merge into the pediments and ridges wider than 20 m usually have flat tops that are remnants of the pediments on unit QTa. Slopes of the valleys between ballenas are convexo-concave in contrast to steep, straight slopes of washes in younger deposits. Where not obscured by younger deposits, valleys between ballenas are rounded.

No deposits are present between unit QTa and unit Q2c near Yucca Mountain, but near the head of the Kyle Canyon (just southeast of fig. 2) alluvial fan, alluvial gravels form terraces that are intermediate in elevation between the ballenas of unit QTa and the terraces of unit Q2. The lithology, pedimentation, soils, landforms, and dissection of unit QTa are similar at both Kyle Canyon and in the Yucca Mountain area. Except for thicker soil horizons, the same aspects of unit Q2 are also similar in both areas. These similarities and the proximity of Kyle Canyon to Yucca Mountain indicate that deposits of intermediate age should also be present in the Yucca Mountain area. Deposits of intermediate age may be buried in Yucca and Frenchman Flats or removed by erosion in Mercury Valley, Crater Flat, Rock Valley, Jackass Flats, and the Amargosa Desert.

Pedimentation, soil development, and dissection of unit QTa represent a long period of erosion and nondeposition. The absence at the surface of the Yucca Mountain area of the intermediate-age deposits that are present at Kyle Canyon suggests that intermediate-age deposits are not present in the Yucca Mountain area. The probable absence of the intermediate-age deposits in the Yucca Mountain area extends the period of erosion and nondeposition after deposition of unit QTc, and requires a regional unconformity between unit QTa and subunit Q2c.

Quaternary Surficial Deposits

Quaternary surficial deposits of the Yucca Mountain area include units Q1 and Q2, both of which have five subunits. Both units consist of alluvial sand and gravel, debris flow deposits, and eolian sand. The major differences between the two units are that the older unit, unit Q2, has moderately to well developed soils and desert pavements, whereas unit Q1 has incipiently developed soils and desert pavements are absent. Except for topographic position, all other characteristics of the two units and their subunits are similar.

Unit Q2

Unit Q2 consists of alluvial deposits, debris flow deposits, and eolian sand. Unit Q2 contains five subunits: Q2c, Q2b, and Q2a and Q2a(?), alluvial and debris flow deposits; Q2e, eolian sand ramps and sand sheets; and Q2s, alluvial sand sheets. These subunits range in age from middle to late Pleistocene. Soils in unit Q2, except for the youngest deposits, are moderately to well developed. Desert pavements are well developed except on the youngest deposits. The youngest deposits and eolian sand have a limited extent, but alluvial deposits of oldest and intermediate ages are present throughout the Yucca Mountain area. The topography, drainage, and desert pavements of all subunits are similar, but soils, lithology, and topographic position differ.

Alluvial deposits of subunits Q2c and Q2b are found in all the valleys of the NTS area and in washes in the hills and ranges. The debris flow deposits of unit Q2a have been identified only in the Calico Hills and in the Syncline Ridge area of Yucca Flat. Thin slopewash deposits with similar radiometric ages at several locations in the Yucca Mountain area are called Q2a(?) in this report, and may be equivalent in age to subunit Q2a, which has not been dated radiometrically. Subunits Q2e and Q2s have been identified only in the northern part of the Amargosa Desert, Jackass Flats, and Crater Flat.

Subunit Q2c.--Subunit Q2c consists of alluvial deposits and equal to lesser amounts of debris flow deposits. The alluvial deposits vary from pebbly sands to coarse gravels. Debris flow deposits that are exposed in trenches and in washes vary from small lenses to layers longer than 100 m.

Subunit Q2c is present throughout the NTS area. The subunit occurs as terrace deposits in larger washes within the bedrock and unit QTa, as fan deposits in a few intramontane valleys, as slopewash and talus deposits on the sides of most of the valleys on Yucca Mountain, and as fan deposits on upper to lower piedmont slopes in all valleys. Subunit Q2c forms the highest terrace along major washes on the piedmont slope and along most of the washes in the Amargosa Desert. Drill-hole data in Jackass Flats indicate a maximum thickness of 65 m, but beneath some valley floors the thickness may be greater.

Terraces that are typical of subunit Q2c are present between Sever Wash and Fortymile Wash and at and below the mouth of Topopah Wash west of Fortymile Wash. The best exposure of the youngest Q2c soil is in a trench (lat 36°51'58", long 116°13'19").

Subunit Q2c has a flat macrotopography even on steeply sloping deposits. Along much of Fortymile, Topopah, and Rock Valley Washes, overbank flood deposits and debris flow deposits form low levees. Microrelief is less than 0.2 m, except where residual boulders of unit QTa protrude through Q2c deposits. Drainage patterns on Q2c are parallel, have few or no tributaries on middle to upper piedmont slopes, and are distributary on middle to lower piedmont slopes. Most washes cut into subunit Q2c have very steep to vertical banks that have been steepened by Holocene erosion. Where banks below the terraces are undisturbed by Holocene erosion, these banks are also steep.

The Av horizon of Q2c soils is younger than the underlying soil horizons. The Av horizon is 10 to 50 cm thick, consists of clay-size to very coarse sand-size material, and is pale yellowish brown. The Av horizon has a sharp contact with the B horizon, or where the B horizon has been stripped, with the calcic horizon.

Soils of two different ages are present on subunit Q2c and can be differentiated only by uranium-trend age dating or by detailed soil investigations. Above 1,000 m elevation, both soils have a moderate- to dark-reddish-brown, argillic B horizon, that is partly silicified, and stage III to IV calcic horizons. The calcic horizons rarely have a laminated layer. Some calcic horizons locally may engulf the lower part of the argillic B horizon. At elevations below 800 m in the Amargosa Desert, both soils in Q2c have cambic B horizons and stage I to II calcic horizons.

The older soil is present at a depth of a few meters within subunit Q2c or at the surface in some locations. The older, buried soil has been identified by uranium-trend dating of samples from some trenches in the Yucca Mountain area. The older soil is probably the buried soil exposed in the west wall of Fortymile Wash just south of the road to Yucca Mountain. At the surface locally in the Yucca Mountain area, the older soil also has been identified by uranium-trend dating locally in the Yucca Mountain area. The maximum depth of burial of the older soil is approximately 7 m in Fortymile Wash. The younger soil has been identified at the surface or beneath less than 1 m of younger subunits in northeastern Jackass Flats, on Yucca Mountain, and in Crater Flat.

Subunit Q2c is present beneath terraces along washes that are incised in bedrock and unit QTa, and is also present on much of the upper piedmont slopes. Q2c is the highest surficial deposit on middle piedmont slopes, on some lower piedmont slopes and valley floors, and along most major washes incised in lower piedmont slopes and valley floors.

Desert pavements on subunit Q2c are densely packed, moderately to well-sorted, and have a maximum clast size that is commonly less than 0.2 m in most places. Near bedrock hills or where unit QTa underlies Q2c at depths of less than 2 m, larger clasts may be present at the surface of subunit Q2c. Varnish ranges from very dark brown to blackish brown and from dull to shiny; it forms a thin film that usually covers most or all of the upper surfaces of desert pavement clasts.

Sand content of Q2c deposits ranges from less than 20 percent in coarse gravels to more than 90 percent in the Jackass Flats and Yucca Mountain areas, where the subunit contains sand that is reworked from subunit Q2e. Clay content is probably very low. Except in debris flow deposits, clay coatings on clasts below the soils are rare. The color in outcrop ranges from a light yellowish brown to grayish brown. Clasts in alluvial deposits are rarely more than 0.2 m in diameter. In most debris flow deposits, clasts are as much as 0.5 m in diameter, but on the two highest terraces of Fortymile Wash, debris flow deposits contain numerous clasts as much as 1 m in diameter.

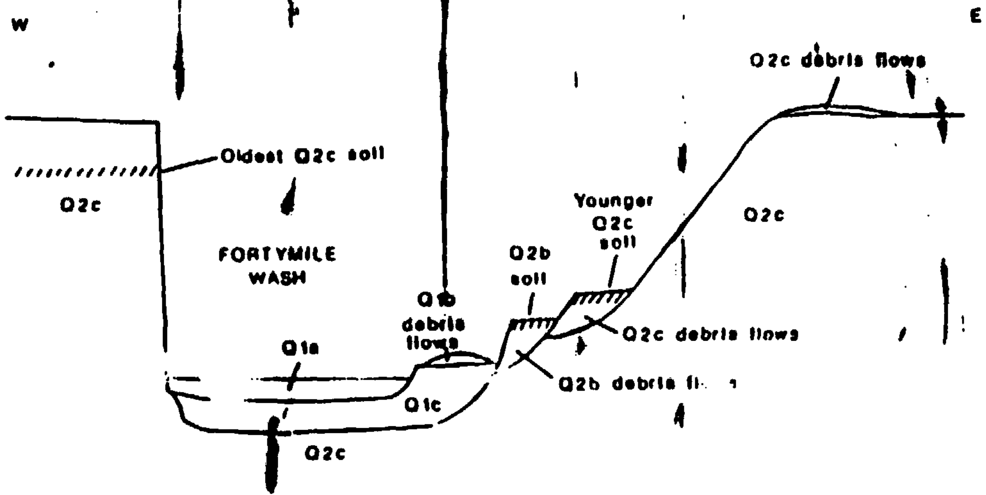
Subunit Q2c consists of mostly alluvial deposits that range from pebbly sands, common east of Yucca Mountain and south of Jackass Flats, to sandy, coarse gravels. The volume of debris flow deposits may equal the volume of alluvial deposits on upper piedmont slopes and in intramontane valleys, but is usually less than the volume of alluvial deposits on and below middle piedmont slopes. Much of the alluvial material was deposited along shallow distributary washes. Along major washes, the alluvial deposits appear to be the result of channel aggradation. On steeper slopes, particularly within the ranges, slopewash deposits are abundant and may grade into debris flow deposits.

Along Fortymile Wash, debris flow deposits of subunit Q2c cap most of the three uppermost terraces (fig. 7). On the highest terrace, discontinuous patches of cobbles and boulders from debris flows overlie mostly pebbly sands and a few sandy pebble and cobble beds that are typical of subunit Q2c. The cobbles and boulders of the debris flow range from 0.1 to 1 m in diameter. At some locations on the east bank of the wash, the debris flow deposits form a levee that is 20 to 50 m wide and less than 1 m high. Remnants of the debris flows are sparse on the west bank, but are almost continuous for 10 km below the Calico Hills along the east bank. About 7 m below the highest terrace, a soil that is probably the older soil of subunit Q2c is exposed along the west bank. The soil has a stage IV carbonate horizon about 1 m thick and remnants of a red argillic B horizon. The soil on the highest terrace is the younger soil of subunit Q2c and has a stage III carbonate horizon less than a meter thick beneath the debris flow deposits.

FIGURE 7.--NEAR HERE

Fortymile Wash is the only wash in the NTS area that is known to contain three terraces of Q2 age. In other washes, where only two terraces are present, Q2b is the lowermost terrace. Therefore, the lowest Q2 terrace in Fortymile Wash is considered to be Q2b and the middle terrace to be the youngest Q2c deposits (fig. 7). The middle terrace consists of cobbles and boulders that range from 0.1 to 1 m in diameter in a sandy matrix. The deposit on the middle terrace is 2-4 m thick and overlies sandy deposits similar to those that underlie the upper terrace. The upper meter of the debris flows of the middle terrace are cemented by a stage III calcic horizon.

Figure 7.--Schematic cross section showing relationship of stratigraphic units and terraces in Fortymile Wash. Not to scale.


W
E
Q2c debris flows
Oldest Q2c soil
Q2c
FORTYMILE WASH
Younger Q2c soil
Q2c
Q2b soil
Q1b debris flows
Q1a
Q2c debris flows
Q2b debris flows
Q1c
Q2c

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
*GS931008315215.030	CARBON AND OXYGEN ISOTOPE ANALYSES OF CAVITY- AND FRACTURE-COATING CALCITE AND SOIL CARBONATE FROM DRILL HOLES AND OUTCROPS, MAY '89 - OCT. '93. ACQN/DEVL LOCATION : USGS, DENVER, CO	05/15/89-10/31/93	NWM-USGS GCP-16,R3, CARBONATE CARBON AND OXYGEN ISOTOPE ANALYSES.	A	Y	P
*GS931108315215.031	STRONTIUM ISOTOPES IN CARBONATE DEPOSITS AT CRATER FLAT, NV, BY B.D. MARSHALL, K. FUTA, Z.E. PETERMAN, AND J.S. STUCKLESS. ACQN/DEVL LOCATION : USGS, DENVER, CO.	01/01/90-12/31/90	TO HELP CHARACTERIZE THE ORIGINS AND ESTIMATE THE AGES OF SOME HYDROGENIC DEPOSITS, DATA FROM STRONTIUM ISOTOPE ANALYSES OF CARBONATES ARE COMPARED. SAMPLE DATA FROM SOILS, VEINS, EOLIAN DUST, AND PALEOZOIC BASEMENT TAKEN SOUTH AND WEST OF YM ARE COMPARED TO SIMILAR SAMPLE DATA FROM EAST OF YM AND TO TERTIARY AQUIFER WATER. SR ISOTOPE RATIOS VS FREQUENCY ARE PRESENTED IN HISTOGRAMS.	D	N	P
*GS931108315215.033	FLUID INCLUSION TEMPERATURES FROM DRILL HOLES USW G-1 AND G-2, OCT. 92 - SEPT. 93. ACQN/DEVL LOCATION : HARVARD UNIV., CAMBRIDGE, MA	10/01/92-09/30/93	NWM-USGS GCP-27,R0, DETERMINATION OF TEMPERATURE AND SALINITY FROM MINERAL-HOSTED FLUID INCLUSIONS.	A	Y	P
*GS931108315215.034	CARBON 14 AGES FROM DRILL HOLES USW G-1, G-2, GU-3, AND G-4, APRIL 92 - JAN. 93. ACQN/DEVL LOCATION : LLNL, LIVERMORE, CA UNIV. OF COLORADO, BOULDER, CO	04/01/92-01/31/93	DATA WERE ACQUIRED BY DR. T. STAFFORD OF THE UNIVERSITY OF COLORADO. CARBONATE CARBON WAS EXTRACTED BY STANDARD 14C PROCEDURES AND THE 14C CONTENT WAS DETERMINED BY AMS AT LAWRENCE LIVERMORE NATIONAL LABORATORIES.	A	Y	P

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
*GS931108315215.035	OXYGEN STABLE ISOTOPE ANALYSES OF OPAL FROM DRILL HOLES AND OUTCROPS, JUNE 92 - AUG. 92. ACQN/DEVL LOCATION : ASU, TEMPE, AZ	06/01/92-08/31/92	DATA WERE ACQUIRED BY DR. L. KNAUTH OF ARIZONA STATE UNIV. DR. KNAUTH IS AN APPROVED QA VENDOR. DATA ACQUIRED BY STEPWISE FLUORINATION OF OPALINE SILICA TO REMOVE EXTRANEOUS WATER PRIOR TO EXTRACTION OF THE SILICATE OXYGEN.	A	Y	P
*GS931208315215.036	STABLE ISOTOPE COMPOSITION OF SOIL CO2, MARCH 93 - SEPT. 93. ACQN/DEVL LOCATION : USGS, DENVER, CO	03/01/93-09/30/93	NWM-USGS GCP-33,R0, EXTRACTION OF SOIL GAS CO2 FOR STABLE ISOTOPE ANALYSIS AND GCP-16,R3, CARBONATE CARBON AND OXYGEN STABLE ISOTOPE ANALYSES.	A	Y	P
*GS931208315215.037	ISOTOPIC STUDIES OF YUCCA MOUNTAIN SOIL FLUIDS AND CARBONATE PEDOGENESIS, BY T. MCCONNAUGHEY, K. WICKLAND, AND J. WHELAN. ACQN/DEVL LOCATION : USGS, DENVER, CO	09/01/93-12/17/93	STUDY OF ISOTOPIC COMPOSITIONS OF SECONDARY MINERALS PRECIPITATED FROM FLUIDS PERCOLATING THROUGH SOILS, FRACTURES, AND FAULTS, AND ORGANISMS LIVING IN THOSE FLUIDS, TO INFER THE ISOTOPIC COMPOSITIONS OF THE PARENT FLUIDS. TO INCREASE ACCURACY OF THIS PROCESS ISOTOPIC COMPOSITIONS OF MODERN SOIL FLUIDS ARE COMPARED, WHERE POSSIBLE, WITH MODERN CARBONATE PRECIPITATES.	D	Y	P

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
Activity - 8.3.1.8.5.1.2						
*GS931008318512.009	40AR/39AR AGE OF THE LATHROP WELLS VOLCANIC CENTER, YUCCA MOUNTAIN, NEVADA, BY BRENT D. TURRIN, DUANE CHAMPION, AND ROBERT J. FLECK ACQN/DEVL LOCATION : USGS, DENVER, CO	01/01/88-10/31/89	PALEOMAGNETIC AND 40AR/39AR ANALYSES WERE USED TO PRODUCE ISOCHRON AND INVERSE-ISOCHRON PLOTS AND IDEOGRAMS SHOWING INTEGRATED PROBABILITY DISTRIBUTION OF 40AR/39AR.	D	N	P
Activity - 8.3.1.9.2.1.1						
*GS930908319211.001	NEW RADIOMETRIC AGES RELATED TO ALTERATION AND MINERALIZATION IN THE VICINITY OF YUCCA MOUNTAIN, NYE COUNTY, NEVADA, BY EDWIN H. MCKEE AND JOEL R. BERGQUIST. ACQN/DEVL LOCATION : USGS, MENLO PARK, CA	01/01/86-12/31/90	AGE ANALYSIS OF K-AR AND 40AR/39AR DATA AND DESCRIPTION OF THE GEOLOGIC SETTING.	D	N	P
Activity - 8.3.1.9.2.1.4						
*GS931208319214.002	OIL AND GAS EXPLORATION NEAR YUCCA MOUNTAIN, SOUTHERN NEVADA, BY J. GROW, C. BARKER, AND A. HARRIS. ACQN/DEVL LOCATION : USGS, DENVER, CO	10/01/92-12/15/93	NON-YMP INFORMATION WAS REVIEWED INCLUDING INFORMATION OBTAINED FROM WILDCAT WELLS DRILLED IN 1991 IN THE AMARGOSA VALLEY, CONODONT ALTERATION INDICES, THERMAL MATURITY, AND ORGANIC GEOCHEMICAL ASSESSMENTS, TO COMPARE THE OIL AND GAS POTENTIAL OF YUCCA MOUNTAIN WITH THE PRODUCING AREA IN RAILROAD VALLEY.	D	N	P

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
Activity - 8.3.1.14.2.2.1						
*SNL02030193001.012	MECHANICAL PROPERTIES DATA (ULTRASONIC VELOCITIES, STATIC ELASTIC PROPERTIES, & UNCONFINED STRENGTH) FOR DRILLHOLE UE25 NRG-5 SAMPLES FROM DEPTH 847.2 FT. TO 896.5 FT.	08/13/93-11/30/93	STANDARD LABORATORY ROCK MECHANICS PROCEDURES AS PER TP-219: "UNCONFINED COMPRESSION EXPERIMENTS AT 22 DEGREES C AND A STRAIN RATE OF 10E-5 S-1.", ASTM STM D2845-90: "LABORATORY DETERMINATION OF PULSE VELOCITIES AND ULTRASONIC CONSTANTS OF ROCK."	A	Y	P
	ACQN/DEVL LOCATION : NER, INC., WHITE RIVER JUNCTION, VERMONT					
*SNL02030193001.013	MECHANICAL PROPERTIES DATA (ULTRASONIC VELOCITIES, STATIC ELASTIC PROPERTIES, UNCONFINED STRENGTH, TENSILE STRENGTH, & POROSITY) FOR DRILLHOLE UE25 NRG-2B SAMPLES FROM DEPTH 2.7 FT. TO 87.6 FT.	09/23/93-11/30/93	STANDARD LABORATORY ROCK MECHANICS PROCEDURES AS PER TP-219: "UNCONFINED COMPRESSION EXPERIMENTS AT 22 DEGREES C AND A STRAIN RATE OF 10E-5 S-1.", ASTM STM D3967-92: "SPLITTING TENSILE STRENGTH OF INTACT ROCK CORE SPECIMENS.", ASTM STM D2845-90: "LABORATORY DETERMINATION OF PULSE VELOCITIES AND ULTRASONIC ELASTIC CONSTANTS OF ROCK.", & ASTM STM D854-92: "TEST METHOD FOR SPECIFIC GRAVITY OF SOILS."	A	Y	P
	ACQN/DEVL LOCATION : NER, INC., WHITE RIVER JUNCTION, VERMONT					

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
Activity - 8.3.1.14.2.2.2						
**SNL02030193001.001	MECHANICAL PROPERTIES DATA (ULTRASONIC VELOCITIES, STATIC ELASTIC PROPERTIES, & UNCONFINED STRENGTH) FOR DRILLHOLE USW NRG-6 SAMPLES FROM DEPTH 22.2 FT. TO 328.7 FT.	04/01/93-05/14/93	STANDARD LABORATORY ROCK MECHANICS PROCEDURES AS PER TP-219 "UNCONFINED COMPRESSION EXPERIMENTS AT 22 DEGREES C AND A STRAIN RATE OF 10E-5 S-1."	A	Y	C
	ACQN/DEVL LOCATION : NER INC., WHITE RIVER JUNCTION, VERMONT					
**SNL02030193001.002	MECHANICAL PROPERTIES DATA (ULTRASONIC VELOCITIES, STATIC ELASTIC PROPERTIES, UNCONFINED STRENGTH, TRIAXIAL STRENGTH, TENSILE STRENGTH, & AVERAGE GRAIN DENSITY) FOR DRILLHOLE USW NRG-6 SAMPLES FROM DEPTH 22.2 FT TO 427.0 FT.	04/01/93-06/23/93	STANDARD LABORATORY ROCK MECHANICS PROCEDURES AS PER TP-219 "UNCONFINED COMPRESSION EXPERIMENTS AT 22 DEGREES C AND A STRAIN RATE OF 10E-5 S-1.", ASTM STM D3967-92 "SPLITTING TENSILE STRENGTH OF INTACT ROCK CORE SPECIMENS", ASTM STM D2845-90 "LABORATORY DETERMINATION OF PULSE VELOCITIES AND ULTRASONIC ELASTIC CONSTANTS OF ROCK".	A	Y	C
	ACQN/DEVL LOCATION : NER INC., WHITE RIVER JUNCTION, VERMONT					
**SNL02030193001.003	MECHANICAL PROPERTIES DATA (ULTRASONIC VELOCITIES, STATIC ELASTIC PROPERTIES, UNCONFINED STRENGTH, TENSILE STRENGTH, & AVERAGE GRAIN DENSITY) FOR DRILLHOLE UE-25NRG#2 SAMPLES FROM DEPTH 170.4 FT. TO 200.0 FT.	04/01/93-07/07/93	STANDARD LABORATORY ROCK MECHANICS PROCEDURES AS PER TP-219: "UNCONFINED COMPRESSION EXPERIMENTS AT 22 DEGREES C AND A STRAIN RATE OF 10E-5 S-1.", ASTM STM D3967-92: "SPLITTING TENSILE STRENGTH OF INTACT ROCK CORE SPECIMENS", ASTM STM D2845-90: "LABORATORY DETERMINATION OF PULSE VELOCITIES AND ULTRASONIC ELASTIC CONSTANTS OF ROCK".	A	Y	C
	ACQN/DEVL LOCATION : NER, INC.,WHITE RIVER JUNCTION, VERMONT					

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
**SNL02030193001.005	MECHANICAL PROPERTIES DATA (ULTRASONIC VELOCITIES, STATIC ELASTIC PROPERTIES, UNCONFINED STRENGTH, TENSILE STRENGTH, & AVERAGE GRAIN DENSITY) FOR DRILLHOLE UE-25NRG#3 SAMPLES FROM DEPTH 15.4 FT. TO 297.1 FT.	06/18/93-09/13/93	STANDARD LABORATORY ROCK MECHANICS PROCEDURES AS PER TP-219: "UNCONFINED COMPRESSION EXPERIMENTS AT 22 DEGREES C AND A STRAIN RATE OF 10E-5 S-1.", ASTM STM D3967-92: "SPLITTING TENSILE STRENGTH OF INTACT ROCK CORE SPECIMENS", ASTM STM D2845-90: "LABORATORY DETERMINATION OF PULSE VELOCITIES AND ULTRASONIC ELASTIC CONSTANTS OF ROCK."	A	Y	C
	ACQN/DEVL LOCATION : NER, INC., WHITE RIVER JUNCTION, VERMONT					
*SNL02030193001.006	MECHANICAL PROPERTIES DATA (ULTRASONIC VELOCITIES, STATIC ELASTIC PROPERTIES, UNCONFINED STRENGTH, TENSILE STRENGTH, & AVERAGE GRAIN DENSITY) FOR DRILL HOLE UE-25NRG#2A SAMPLES FROM DEPTH 90.0 FT. TO 254.5 FT.	08/13/93-10/08/93	STANDARD LABORATORY ROCK MECHANICS PROCEDURES AS PER TP-219: "UNCONFINED EXPERIMENTS AT 22 DEGREES C AND A STRAIN RATE OF 10E-5 S-1.", ASTM STM D3967-92: "SPLITTING TENSILE STRENGTH OF INTACT ROCK CORE SPECIMENS.", ASTM STM D2845-90: "LABORATORY DETERMINATION OF PULSE VELOCITIES AND ULTRASONIC ELASTIC CONSTANTS OF ROCK."	A	Y	C
	ACQN/DEVL LOCATION : NER, INC., WHITE RIVER JUNCTION, VERMONT					
*SNL02030193001.007	MECHANICAL PROPERTIES DATA (ULTRASONIC VELOCITIES, STATIC ELASTIC PROPERTIES, TRIAXIAL STRENGTH, & AVERAGE GRAIN DENSITY) FOR DRILL HOLE UE-25NRG#3 SAMPLES FROM DEPTH 263.3 FT. TO 265.7 FT.	06/18/93-09/20/93	ASTM STM D2845-90: "LABORATORY DETERMINATION OF PULSE VELOCITIES AND ULTRASONIC ELASTIC CONSTANTS OF ROCK.", ISRM "SUGGESTED METHODS FOR DETERMINING THE STRENGTH OF ROCK MATERIALS IN TRIAXIAL COMPRESSION: REVISED VERSION", 1983	A	Y	C
	ACQN/DEVL LOCATION : NER, INC., WHITE RIVER JUNCTION, VERMONT					

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
*SNL02030193001.008	MECHANICAL PROPERTIES DATA (ULTRASONIC VELOCITIES, STATIC ELASTIC PROPERTIES, TRIAXIAL STRENGTH, & AVERAGE GRAIN DENSITY) FOR DRILL HOLE USW NRG-6 SAMPLE 416.0 FT.	04/01/93-06/18/93	ASTM STM D2845-90: "LABORATORY DETERMINATION OF PULSE VELOCITIES AND ULTRASONIC ELASTIC CONSTANTS OF ROCK.", ISRM "SUGGESTED METHODS FOR DETERMINING THE STRENGTH OF ROCK MATERIALS IN TRIAXIAL COMPRESSION: REVISED VERSION", 1983	A	Y	C
	ACQN/DEVL LOCATION : NER, INC., WHITE RIVER JUNCTION, VERMONT					
*SNL02030193001.009	MECHANICAL PROPERTIES DATA (TENSILE STRENGTH, AVERAGE GRAIN DENSITY, & POROSITY) FOR DRILLHOLE UE25 NRG-5 SAMPLES FROM DEPTH 781.0 FT. TO 991.9 FT.	08/13/93-11/04/93	ASTM STM D3967-92: "SPLITTING TENSILE STRENGTH OF INTACT ROCK CORE SPECIMENS.", AND ASTM STM D854-92: "TEST METHOD FOR SPECIFIC GRAVITY OF SOILS."	A	Y	P
	ACQN/DEVL LOCATION : NER, INC., WHITE RIVER JUNCTION, VERMONT					
*SNL02030193001.010	MECHANICAL PROPERTIES DATA (AVERAGE GRAIN DENSITY) FOR DRILLHOLE UE25 NRG-2B SAMPLES FROM DEPTH 2.7 FT. TO 87.6 FT.	09/23/93-11/02/93	ASTM STM D854-92: "TEST METHOD FOR SPECIFIC GRAVITY OF SOILS."	A	Y	P
	ACQN/DEVL LOCATION : NER, INC., WHITE RIVER JUNCTION, VERMONT					
*SNL02030193001.011	MECHANICAL PROPERTIES DATA (POROSITY) FOR DRILLHOLE UE25 NRG-2A SAMPLES FROM DEPTH 135.3 FT. TO 166.5 FT.	08/13/93-11/02/93	ASTM STM D854-92: "TEST METHOD FOR SPECIFIC GRAVITY OF SOILS."	A	Y	P
	ACQN/DEVL LOCATION : NER, INC., WHITE RIVER JUNCTION, VERMONT					

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
*SNL02030193001.012	MECHANICAL PROPERTIES DATA (ULTRASONIC VELOCITIES, STATIC ELASTIC PROPERTIES, & UNCONFINED STRENGTH) FOR DRILLHOLE UE25 NRG-5 SAMPLES FROM DEPTH 847.2 FT. TO 896.5 FT.	08/13/93-11/30/93	STANDARD LABORATORY ROCK MECHANICS PROCEDURES AS PER TP-219: "UNCONFINED COMPRESSION EXPERIMENTS AT 22 DEGREES C AND A STRAIN RATE OF 10E-5 S-1.", ASTM STM D2845-90: "LABORATORY DETERMINATION OF PULSE VELOCITIES AND ULTRASONIC CONSTANTS OF ROCK."	A	Y	P
	ACQN/DEVL LOCATION : NER, INC., WHITE RIVER JUNCTION, VERMONT					
*SNL02030193001.013	MECHANICAL PROPERTIES DATA (ULTRASONIC VELOCITIES, STATIC ELASTIC PROPERTIES, UNCONFINED STRENGTH, TENSILE STRENGTH, & POROSITY) FOR DRILLHOLE UE25 NRG-2B SAMPLES FROM DEPTH 2.7 FT. TO 87.6 FT.	09/23/93-11/30/93	STANDARD LABORATORY ROCK MECHANICS PROCEDURES AS PER TP-219: "UNCONFINED COMPRESSION EXPERIMENTS AT 22 DEGREES C AND A STRAIN RATE OF 10E-5 S-1.", ASTM STM D3967-92: "SPLITTING TENSILE STRENGTH OF INTACT ROCK CORE SPECIMENS.", ASTM STM D2845-90: "LABORATORY DETERMINATION OF PULSE VELOCITIES AND ULTRASONIC ELASTIC CONSTANTS OF ROCK.", & ASTM STM D854-92: "TEST METHOD FOR SPECIFIC GRAVITY OF SOILS."	A	Y	P
	ACQN/DEVL LOCATION : NER, INC., WHITE RIVER JUNCTION, VERMONT					

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
Activity - 8.3.1.14.2.3						
*SNF29041993002.002	YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT GEOLOGY AND ROCK STRUCTURE LOG FOR DRILLHOLE RF #8.	06/01/93-06/30/93	SCIENTIFIC NOTEBOOK FOR GEOTECHNICAL LOGGING OF CORE BY EXAMINATION OF CORE AND VIDEO RECORDS FROM NRG HOLES AND INSTRUCTIONS FOR ESTABLISHING QA RECORDS BASED UPON T&MSS ROCK STRUCTURE LOGS.	A	N	P
	ACQN/DEVL LOCATION : YMP SAMPLE MANAGEMENT FACILITY					
*SNF29041993002.003	YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT GEOLOGY AND ROCK STRUCTURE LOG FOR DRILLHOLE UE25 NRG-1.	05/01/93-05/30/93	GEOTECHNICAL CORE LOGGING OF UE25 NRG-1. SCIENTIFIC NOTEBOOK FOR GEOTECHNICAL LOGGING OF CORE BY EXAMINATION OF CORE AND VIDEO RECORDS FROM NRG HOLES AND INSTRUCTIONS FOR ESTABLISHING QA RECORDS BASED UPON T&MSS ROCK STRUCTURAL LOGS.	A	Y	P
	ACQN/DEVL LOCATION : YMP SAMPLE MANAGEMENT FACILITY					
*SNF29041993002.004	YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT GEOLOGY AND ROCK STRUCTURE LOG FOR DRILLHOLE UE25 NRG-2A.	08/01/93-08/31/93	GEOTECHNICAL CORE LOGGING OF UE25 NRG-2A. SCIENTIFIC NOTEBOOK FOR GEOTECHNICAL CORE LOGGING BY EXAMINATION OF CORE AND VIDEO RECORDS FROM NRG HOLES AND INSTRUCTIONS FOR ESTABLISHING QA RECORDS BASED UPON T&MSS ROCK STRUCTURAL LOGS.	A	Y	P
	ACQN/DEVL LOCATION : YMP SAMPLE MANAGEMENT FACILITY					
*SNF29041993002.005	YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT GEOLOGY AND ROCK STRUCTURE LOG FOR DRILLHOLE UE25 NRG-3.	06/01/93-06/30/93	GEOTECHNICAL CORE LOGGING OF UE25 NRG-3. SCIENTIFIC NOTEBOOK FOR GEOTECHNICAL LOGGING OF CORE BY EXAMINATION OF CORE AND VIDEO RECORDS FROM NRG HOLES AND INSTRUCTIONS FOR ESTABLISHING QA RECORDS BASED UPON T&MSS ROCK STRUCTURAL LOGS.	A	Y	P
	ACQN/DEVL LOCATION : YMP SAMPLE MANAGEMENT FACILITY					

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
*SNF29041993002.006	YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT GEOLOGY AND ROCK STRUCTURE LOG FOR DRILLHOLE USW NRG-6.	05/01/93-05/30/93	GEOTECHNICAL CORE LOGGING OF USW NRG-6. SCIENTIFIC NOTEBOOK FOR GEOTECHNICAL LOGGING OF CORE BY EXAMINATION OF CORE AND VIDEO RECORDS FROM NRG HOLES AND INSTRUCTIONS FOR ESTABLISHING QA RECORDS BASED UPON T&MSS ROCK STRUCTURAL LOGS.	A	Y	P
	ACQN/DEVL LOCATION : YMP SAMPLE MANAGEMENT FACILITY					
*SNF29041993002.007	YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT GEOLOGY AND ROCK STRUCTURE LOG FOR DRILLHOLE UE25 NRG-5.	08/01/93-08/30/93	GEOTECHNICAL CORE LOGGING OF UE25 NRG-5. PREPARED IN ACCORDANCE WITH SCIENTIFIC NOTEBOOK FOR GEOTECHNICAL LOGGING OF CORE BY EXAMINATION OF CORE AND VIDEO REOORDS FROM NRG HOLES AND INSTRUCTIONS FOR ESTABLISHING QA RECORDS BASED UPON T&MSS ROCK STRUCTURE LOGS.	A	Y	P
	ACQN/DEVL LOCATION : YMP SAMPLE MANAGEMENT FACILITY AND JFT AGAPITO					
*SNF29041993002.008	YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT GEOLOGY AND ROCK STRUCTURE LOG FOR DRILLHOLE UE25 NRG-4.	10/01/93-10/29/93	GEOTECHNICAL CORE LOGGING OF UE25 NRG-4. PREPARED IN ACCORDANCE WITH SCIENTIFIC NOTEBOOK FOR GEOTECHNICAL LOGGING OF CORE BY EXAMINATION OF CORE AND VIDEO RECORDS FROM NRG HOLES AND INSTRUCTIONS FOR ESTABLISHING QA RECORDS BASED UPON T&MSS ROCK STRUCTURE LOGS.	A	Y	P
	ACQN/DEVL LOCATION : YMP SAMPLE MANAGEMENT FACILITY AND JFT AGAPITO					

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
*SNF29041993002.009	YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT CORE HOLE ROCK STRUCTURAL DATA SUMMARY FOR HOLE UE25 NRG-1, UE25 NRG-2, UE25 NRG-2A, UE25 NRG-3, UE25 NRG-4, UE25 NRG-5, USW NRG-6, & RF #8.	11/01/93-11/30/93	GEOTECHNICAL CORE LOGGING OF NRG-1, NRG-2, NRG-2A, NRG-3, NRG-4, NRG-5 & NRG-6. PREPARED IN ACCORDANCE WITH SCIENTIFIC NOTEBOOK FOR GEOTECHNICAL LOGGING OF CORE BY EXAMINATION OF CORE AND VIDEO RECORDS FROM NRG HOLES AND INSTRUCTIONS FOR ESTABLISHING QA RECORDS BASED UPON T&MSS ROCK STRUCTURE LOGS.	D	Y	P
	ACQN/DEVL LOCATION : J. F. T. AGAPITO					
Activity - 8.3.1.15.1.1.3						
*SNL01A05059301.001	THERMAL CONDUCTIVITY DATA FROM USW NRG-6 DRILLHOLE FROM DEPTH OF 28.8 FT. TO 416.0 FT.	05/01/93-11/01/93	GUARDED-HEAT-FLOW-METER METHOD.	A	Y	P
	ACQN/DEVL LOCATION : HOLOMETRIX, BEDFORD, MASS.					
Activity - 8.3.1.15.1.2.1						
*SNL01B05059301.002	THERMAL EXPANSION DATA FROM USW NRG-6 DRILLHOLE FROM DEPTH OF 28.8 FT. TO 416.0 FT.	05/21/93-11/11/93	SINGLE PUSH-ROD DILATOMETER.	A	Y	P
	ACQN/DEVL LOCATION : HOLOMETRIX, BEDFORD, MASS.					

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
Activity - 8.3.1.15.1.3.1						
**SNSAND80145300.000	SAND80-1453: "ROCK MECHANICS PROPERTIES OF VOLCANIC TUFFS FROM THE NEVADA TEST SITE." NNA.870406.0497	11/01/78-07/01/80	UNIAXIAL AND TRIAXIAL COMPRESSION TEST AT CONSTANT STRAIN-RATE WERE RUN ON SAMPLES OF VOLCANIC TUFF FROM HOLE UE25A#1 AND G-TUNNEL, BOTH LOCATED ON THE NEVADA TEST SITE. TESTING IS ACCOMPLISHED IN A 1.8 GN ULTRA-STIFF, ELECTRO-HYDRAULIC, SERVO-CONTROLLED COMPRESSION TESTING MACHINE. RAM DISPLACEMENT IS USED AS THE PROGRAMMED FEEDBACK VARIABLE. (FOR MORE DETAIL SEE SAND80-1453)	D	N	T
	ACQN/DEVL LOCATION : SNL					
Activity - 8.3.1.15.1.4.1						
**SNSAND80145300.000	SAND80-1453: "ROCK MECHANICS PROPERTIES OF VOLCANIC TUFFS FROM THE NEVADA TEST SITE." NNA.870406.0497	11/01/78-07/01/80	UNIAXIAL AND TRIAXIAL COMPRESSION TEST AT CONSTANT STRAIN-RATE WERE RUN ON SAMPLES OF VOLCANIC TUFF FROM HOLE UE25A#1 AND G-TUNNEL, BOTH LOCATED ON THE NEVADA TEST SITE. TESTING IS ACCOMPLISHED IN A 1.8 GN ULTRA-STIFF, ELECTRO-HYDRAULIC, SERVO-CONTROLLED COMPRESSION TESTING MACHINE. RAM DISPLACEMENT IS USED AS THE PROGRAMMED FEEDBACK VARIABLE. (FOR MORE DETAIL SEE SAND80-1453)	D	N	T
	ACQN/DEVL LOCATION : SNL					

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
Activity - 8.3.1.15.1.8.1						
*SNF28021693001.001	SLTR93-7001, ESTIMATION OF ROCK MASS QUALITY OF THE NORTH RAMP STARTER TUNNEL. (ROCK MASS CLASSIFICATION USING THE "Q" SYSTEM).	04/15/93-07/16/93	PRELIMINARY ROCK MASS QUALITY WAS ASSESSED BASED ON EXAMINATION OF THE TUNNEL USING THE "Q" SYSTEM. (SEE SNL WA-0065 FOR A MORE DETAILED DESCRIPTION).	A	Y	C
	ACQN/DEVL LOCATION : TOP HEADING OF THE NORTH RAMP STARTER TUNNEL					
Activity - 8.3.1.16.1.1.1						
*GS931183116111.002	NEVADA TEST SITE FLOOD INUNDATION STUDY - PART OF U.S. GEOLOGICAL SURVEY FLOOD POTENTIAL AND DEBRIS HAZARD STUDY, YUCCA MOUNTAIN SITE, BY JAMES O. BLANTON III.	06/07/91-05/24/92	DEVELOPED USING PROBABLE MAXIMUM FLOOD TECHNIQUE AND METHOD DEFINED IN RECLAMATION TECHNICAL PROCEDURE YMP-USBR HP-03,R0, SPECIAL PROCESS FOR DETERMINING WATER SURFACE PROFILES AND FLOOD INUNDATED SURFACE AREAS.	D	N	P
	ACQN/DEVL LOCATION : USBR, DENVER, CO					
*GS931183116111.003	NEVADA TEST SITE PROBABLE MAXIMUM FLOOD STUDY - PART OF U.S. GEOLOGICAL SURVEY FLOOD POTENTIAL AND DEBRIS HAZARD STUDY, YUCCA MOUNTAIN SITE, BY KENNETH L. BULLARD.	06/07/91-05/24/92	DEVELOPED USING PROBABLE MAXIMUM FLOOD TECHNIQUE WHICH COMPLIES WITH ANSI STANDARD FOR DETERMINING DESIGN BASIS FLOODING AT POWER REACTOR SITES.	D	N	P
	ACQN/DEVL LOCATION : USBR, DENVER, CO					

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
Activity - 8.3.1.17.4.1.2						
*GS931083117412.002	SGB LOCAL EARTHQUAKE ARCHIVE TAPES CONTAINING DATA FROM JUNE 1993 THROUGH SEPTEMBER 1993, TAPES L1247 THROUGH L1256.	06/01/93-09/30/93	SP-11,R3, OPERATION AND CALIBRATION OF REMOTE TELEMETERED SEISMIC ARRAY	A	Y	P
	ACQN/DEVL LOCATION : SOUTHERN GREAT BASIN SEISMIC NETWORK					
*GS931083117412.003	PRELIMINARY SEISMICITY AND FOCAL MECHANISMS FOR THE SOUTHERN GREAT BASIN OF NEVADA AND CALIFORNIA: JANUARY 1992 THROUGH SEPTEMBER 1992, BY S.C. HARMSEN	05/01/93-10/13/93	REDUCTION OF SEISMOGRAMS OBTAINED FROM THE SGBSN USING COMPUTER MODEL HYPO71.	D	Y	P
	ACQN/DEVL LOCATION : USGS BELH, GOLDEN, CO					
Activity - 8.3.1.17.4.2.1						
*GS930883117421.002	MAPPING AND CHARACTERIZING THE SURFICIAL PROPERTIES OF THE QUATERNARY DEPOSITS OF MIDWAY VALLEY USING AIRPHOTOS AND FIELD RECONNAISSANCE. SUBSURFACE SOIL DATA WERE RECORDED FROM SOIL PITS MWV-P1 THROUGH MWV-P10, MWV-P12 THROUGH MWV-P17, MWV-P19 THROUGH MWV-P26, AND MWV-P28 THROUGH MWV-P31 ON THESE DIFFERENT QUATERNARY DEPOSITS.	02/01/90-09/13/93	PROCEDURE GP-17,R1, DESCRIBING AND SAMPLING SOILS IN THE FIELD, WAS FOLLOWED DESCRIBING AND SAMPLING SOIL TEST PITS. PROCEDURE GP-01,R2, GEOLOGIC MAPPING, WAS FOLLOWED FOR MAPPING GEOLOGICAL DEPOSITS IN MIDWAY VALLEY.	A	Y	P
	ACQN/DEVL LOCATION : N754750(N) E579000(N) ;N780250(N) E596000(N)					

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
Activity - 8.3.1.17.4.3.2						
*GS930783117432.012	COMPILATION OF KNOWN AND SUSPECTED QUATERNARY FAULTS WITHIN 100 KM OF YUCCA MOUNTAIN, BY L.A. PIETY.	10/01/92-06/01/93	COMPILATION OF PUBLISHED LITERATURE AND READILY AVAILABLE DATA.	D	N	P
	ACQN/DEVL LOCATION : USBR, DENVER, COLORADO					
*GS931083117432.001	TOPOGRAPHIC PROFILES OF THE BEATTY SCARP	06/17/93-06/19/93	GP-52,R0, TOPOGRAPHIC PROFILING OF GEOMORPHIC FEATURES -- FIELD MEASUREMENT	A	Y	P
	ACQN/DEVL LOCATION : 36 48'00"N 116 45'00"W ;36 52'30"N 116 42'00"W					
Activity - 8.3.1.17.4.5.2						
*GS931283117452.005	GEOLOGIC MAPPING IN CRATER FLAT, IN AND AROUND FOUR 7.5 MINUTE QUADRANGLES: 1) EAST OF BEATTY MOUNTAIN, 2) BEATTY MOUNTAIN, 3) CRATER FLAT, 4) BIG DUNE.	03/14/93-05/15/93	TECHNICAL PROCEDURE GP-01,R2, GEOLOGIC MAPPING.	A	Y	P
	ACQN/DEVL LOCATION : 36 52'30"N 116 37'30"W ;37 00'OO"N 116 30'00"W					
*GS931283117452.006	GEOLOGIC MAP OF THE EAST OF BEATTY MOUNTAIN 7.5 MINUTE QUADRANGLE, NYE COUNTY, NEVADA, BY C.J. FRIDRICH, P.P. ORKILD, M. MURRAY, J.R. PRICE, R.L. CHRISTIANSEN, P.W. LIPMAN, W.J. CARR, W.D. QUINLIVAN, AND R.B. SCOTT.	05/15/93-10/12/93	USGS GP-01,R2, GEOLOGIC MAPPING	D	Y	P
	ACQN/DEVL LOCATION : USGS, DENVER, CO					

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
Activity - 8.3.1.17.4.6.1						
*GS931183117461.003	GEOLOGIC MAPPING AND FIELD OBSERVATIONS PERTAINING TO QUATERNARY FAULTING ACQN/DEVL LOCATION : 36 41'15"N 116 33'45"W 36 56'15"N 116 22'30"W	03/29/91-07/22/93	THE DATA WERE COLLECTED UNDER NWM-USGS GP-01,R1 AND R2, GEOLOGIC MAPPING.	A	Y	P
*GS931183117461.004	PRELIMINARY QUATERNARY FAULT MAP OF THE YUCCA MOUNTAIN REGION, BY F. SIMONDS, J. WHITNEY, K. FOX, A. RAMELLI, J. YOUNT, M. CARR, C. MENGES, R. DICKERSON AND R. SCOTT. ACQN/DEVL LOCATION : USGS, DENVER, CO	07/01/93-08/31/93	MAP WAS PLOTTED FROM THE INFORMATION OBTAINED THROUGH FIELD OBSERVATIONS.	D	Y	P
Activity - 8.3.1.17.4.6.2						
*GS931283117462.006	PRELIMINARY TRENCH LOG, AND ACCOMPANYING DESCRIPTIONS AND DATA SHEETS FOR LITHOLOGIC UNITS, SOILS, AND DEFORMATION, FOR TRENCHES SCR-T1 AND SCR-T3 (PARTS OF BOTH NORTH AND SOUTH WALLS IN EACH TRENCH). LOGS AND DATA PREPARED BY C. MENGES, J. OSWALD AND J. COE. EACH LOG INCLUDES CEILING MAPPED PHOTOGRAMMETRICALLY AND MANUALLY (WITH CONVENTIONAL METHOD). ACQN/DEVL LOCATION : N718620(N) E556680(N) N721790(N) E559700(N)	05/01/93-10/31/93	TECHNICAL PROCEDURE NWM-USGS GP-07,R1, CONVENTIONAL GEOLOGIC MAPPING OF TRENCH WALLS, AND TECHNICAL PROCEDURES NWM-USGS GP-39,R0, GEOPHOTOGRAMMETRIC MAPPING OF TRENCH WALLS: FIELDWORK; AND NWM-USGS GP-40,R0, GEOPHOTOGRAMMETRIC MAPPING OF TRENCH WALLS - LABORATORY METHODS.	A	Y	P

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
*GS931283117462.007	U-TH ISOTOPIC DATA FOR U-SERIES DISEQUILIBRIUM DATING OF PEDOGENIC CARBONATE ASSOCIATED WITH QUATERNARY FAULTING ON THE EAST SIDE OF YUCCA MOUNTAIN. DATA INCLUDE SAMPLE AND SPIKE WEIGHTS, AND CUMULATIVE ALPHA DECAY COUNTS FOR 238U, 236U, 232TH, 230TH, AND 229TH AS WELL AS CALCULATED U AND TH CONCENTRATIONS, ACTIVITY RATIOS AND CORRELATION COEFFICIENTS.	11/01/93-12/15/93	YMP-USGS GCP-03,R2, U-SERIES DATING	A	Y	P
	ACQN/DEVL LOCATION : USGS U-SERIES LABS, DENVER, CO					
*GS931283117462.008	AGE CALCULATED FROM ACQUIRED U-TH ISOTOPIC DATA.	11/01/93-12/15/93	230TH/238U CALCULATIONS DETERMINED BY MIXING LINE REGRESSION USING MAXIMUM LIKELIHOOD ESTIMATION ALGORITHMS (LUDWIG AND TITTERINGTON, MAXIMUM LIKELIHOOD ESTIMATION OF U-TH ERRORS, IN REVIEW FOR PUB. IN GEOCHEMICA ET COSMOCHEMICA ACTA)	D	Y	P
	ACQN/DEVL LOCATION : USGS U-SERIES LABS, DENVER, CO					
Activity - 8.3.1.17.4.7.1						
**GS920283117471.004	COMPARISON OF VIBROSEIS AND EXPLOSIVE SOURCE METHODS FOR DEEP CRUSTAL SEISMIC REFLECTION PROFILING IN THE BASIN AND RANGE PROVINCE, BY T.M. BROCHER AND P.E. HART.	06/06/89-06/21/91	ANALYTICAL AND INTERPRETIVE METHODS BASED ON THE AUTHORS' COMBINED EDUCATION AND WORK EXPERIENCES WERE USED TO DEVELOP THIS ARTICLE	D	N	P
	ACQN/DEVL LOCATION : USGS, MENLO PARK, CA					

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
Activity - 8.3.1.17.4.10.2						
*GS931031174102.001	STRAIN ACCUMULATION NEAR YUCCA MOUNTAIN, NEVADA, 1983 - 1993, BY J.C. SAVAGE, M. LISOWSKI, W.K. GROSS, N.E. KING, AND J.L. SVARC. ACQN/DEVL LOCATION : USGS, MENLO PARK, CA	07/01/93-07/30/93	DATA WERE DEVELOPED ACCORDING TO THE AUTHORS' EDUCATIONAL AND TECHNICAL EXPERIENCE.	D	N	P
*GS931031174102.002	SURVEY OF DEFORMATION OF 50-KM-APERTURE TRILATERATION NETWORK USING A GEODOLITE, CENTERED ON YUCCA MOUNTAIN, 1983-1984. ACQN/DEVL LOCATION : USGS, MENLO PARK, CA	06/01/83-06/30/83 06/01/84-07/31/84	THE PROCEDURES USED AND THE ACCURACY ATTAINED FOR THESE SURVEYS ARE DESCRIBED IN SAVAGE AND PRESCOTT (1973), PRECISION OF GEODOLITE DISTANCE MEASUREMENTS FOR DETERMINING FAULT MOVEMENTS, J. GEOPHYS. RES., 78, 6001-6008.	A	N	P
*GS931031174102.003	SURVEY OF DEFORMATION OF 50-KM-APERTURE TRILATERATION NETWORK USING GPS AND A GEODOLITE, CENTERED ON YUCCA MOUNTAIN, 1993 ACQN/DEVL LOCATION : USGS, MENLO PARK, CA	04/01/93-05/30/93	TECHNICAL PROCEDURE NWM-USGS GP-43,R0, GEODETIC TRILATERATION AND GLOBAL POSITIONING SYSTEM (GPS) SURVEYS.	A	Y	P

Activity - 8.3.2.4.1.1

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
*SNSAND92185300.000	SAND92-1853: "EFFECT OF BOUNDARY CONDITIONS ON THE STRENGTH AND DEFORMABILITY OF REPLICAS OF NATURAL FRACTURES IN WELDED TUFF: DATA REPORT"	06/19/92-08/01/93	EP-44, "NORMAL COMPRESSION AND SHEAR TESTS ON ROCK JOINTS." FOUR SERIES OF CYCLIC DIRECT-SHEAR EXPERIMENTS WERE CONDUCTED ON SEVERAL REPLICAS OF THREE NATURAL FRACTURES AND A TENSILE FRACTURE OF WELDED TUFF FROM YUCCA MOUNTAIN. OBJECTIVE WAS TO EXAMINE THE EFFECT OF CYCLIC LOADING ON JOINT SHEAR BEHAVIOR UNDER DIFFERENT BOUNDARY CONDITIONS. SHEAR TESTS WERE PERFORMED UNDER EITHER DIFFERENT LEVELS OF CONSTANT NORMAL LOAD RANGING BETWEEN 0.6 AND 25.6 KIPS OR CONSTANT NORMAL STIFFNESS RANGING BETWEEN 14.8 AND 187.5 KIPS/IN. (FOR MORE DETAIL SEE SAND92-1853)	D	N	C

ACQN/DEVL LOCATION : UNIVERSITY OF COLORADO AT BOULDER

SITE CHARACTERIZATION PLAN BASELINE - PROTOTYPE

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
*SNF30050393001.002	SNL NORTH RAMP STARTER TUNNEL ROCK-MASS MONITORING DATA: PLOTS OF DRIFT CONVERGENCE AND CONVERGENCE RATE FOR ESF STARTER TUNNEL; AND PLOTS OF ROCK BOLT LOAD CELLS. ACQN/DEVL LOCATION : NEVADA TEST SITE-NORTH PORTAL/ESF STARTER TUNNEL	06/01/93-09/30/93	MAKE DISPLACEMENT MEASUREMENTS USING A TAPE EXTENSOMETER; CHECK ROCK BOLT LOAD CELL DATA BY READINGS WITH A VOLTMETER.	A	N	C
*SNL12011393001.003	NICKEL SORPTION ONTO DIFFERENT SUBSTRATE. SUBSTRATES USED WERE WEDRON 510 SAND, SYNTHETIC GOETHITE, AND ACID-WASHED MIN-U-SIL QUARTZ. ACQN/DEVL LOCATION : SNL, ALBUQUERQUE, NM	03/26/93-09/20/93	DATA OBTAINED BY BATCH SORPTION METHODS; NICKEL ANAYLZED BY ATOMIC ABSORPTION; DATA REDUCED USING EXCEL SPREAD SHEET.	A	N	P
*SNL12072193001.001	NOTEBOOK MIT-SAND-AC-6869-1 IN SUPPORT OF "DEVELOPMENT OF METHODS TO EVALUATE URANIUM DISTRIBUTION COEFFICIENTS IN UNSATURATED MEDIA". ACQN/DEVL LOCATION : MIT, CAMBRIDGE, MASS.	12/01/92-10/01/93	UNSATURATED SORPTION MEASUREMENTS USING TURBULA MIXER, ANALYSIS BY ICP.	A	N	P

SOCIOECONOMIC PLAN

DATA TRACKING NO.	TITLE/DESCRIPTION	ACQN/DEVL PERIOD	ACQN/DEVL METHOD	TDIF TYPE	QUALIFIED	LOCATION
*TM00121361T1DB.005	YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT SOCIOECONOMIC MONITORING PROGRAM 1993 EMPLOYEE SURVEY DATA REPORT, STATE & COUNTY DATA, SEPTEMBER 1993 ACQN/DEVL LOCATION : T&MSS	01/01/93-09/30/93	MONITORING OF YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT CHARACTERISTICS AS DESCRIBED IN REVISION 0 OF THE SOCIOECONOMIC PLAN	A	Y	C
*TM00121361T1EB.001	YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT SOCIOECONOMIC MONITORING PROGRAM QUARTERLY EMPLOYMENT DATA REPORT, JULY 1993 THROUGH SEPTEMBER 1993 ACQN/DEVL LOCATION : T&MSS	07/01/93-09/30/93	MONITORING OF YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT CHARACTERISTICS AS DESCRIBED IN REVISION 0 OF THE SOCIOECONOMIC PLAN	A	Y	P

Figure 8.--Schematic diagram showing relationship of subunits Q2c, Q2e, and Q2s in Yucca Mountain area. Dashed lines are inferred.

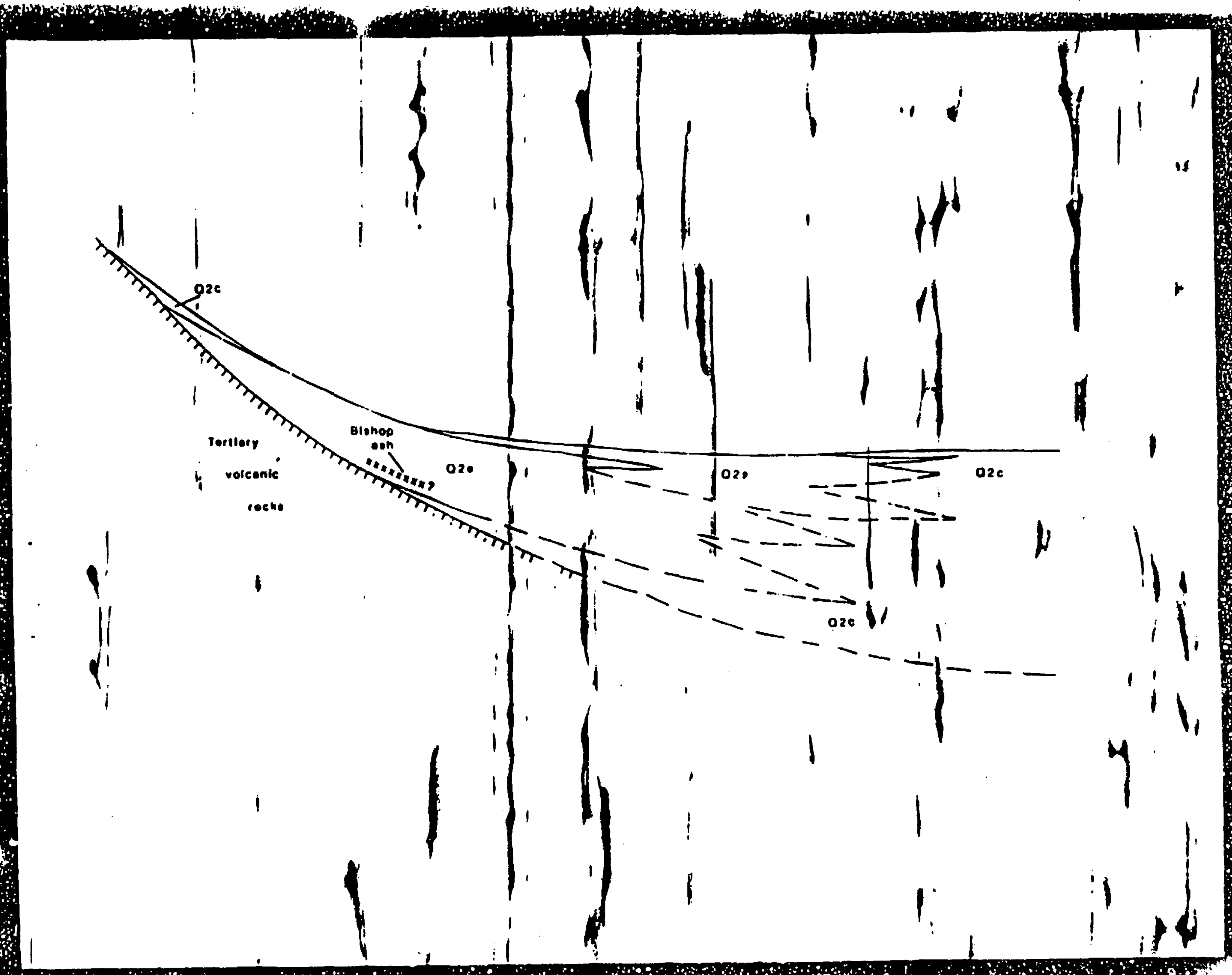

Q2c
Bishop
ash
Tertiary
volcanic
rocks
?
Q2e
Q2e
Q2c
Q2c

Figure 9.--Distribution of Q2e deposits. Based on the Lathrop Wells quadrangle (Swadley, 1983), the Big Dune quadrangle (Swadley and Carr, 1987), the Bare Mountain quadrangle (Swadley and Parrish, in press), author's mapping in the Topopah Spring quadrangle, and reconnaissance mapping elsewhere.

Subunit Q2s is predominantly fine to medium sand. Clasts of volcanic and sedimentary rocks are usually less than 10 mm and are rarely as much as 50 mm in diameter. The larger clasts comprise less than 1 to about 5 percent of less than half the beds. Clay- or silt-size material is rarely present in sandy beds, but beds of clay or silt a few centimeters thick are locally present. Graded beds are locally present and indicate an alluvial origin for subunit Q2s. Color in fresh exposures is very light gray to very pale brownish gray. In outcrop, subunit Q2s is pale brownish gray.

Subunit Q2b.--Subunit Q2b consists of terrace deposits and thin sheets of alluvial fan deposits. The terrace deposits are present on strath terraces in most washes that are incised to depths greater than 3-5 m in the Yucca Mountain area. Alluvial fan deposits of subunit Q2b are present as irregular, thin sheets on piedmont slopes downslope from the mouths of incised washes and on the lower piedmont slopes of the Amargosa Desert. These sheets cannot be distinguished from Q2c except by comparison of soils. Subunit Q2b was included with subunit Q2c as subunit Q2bc on most lower piedmont slopes and the floor of the Amargosa Desert (Swadley, 1983). In major washes such as Fortymile and Topopah Washes, subunit Q2b forms the lowest terrace that has a desert pavement and an Av horizon. Terrace deposits are less than 4 m thick. Alluvial fan deposits on lower slopes probably have a similar thickness. Although much of surface is covered, the best exposures of subunit Q2b are along Fortymile Wash south of the road to Yucca Mountain. Typical terrace surfaces on Q2b deposits can be seen on the west side of Fortymile Wash just north of the road to Yucca Mountain.

Macrotopography is flat; microrelief is less than 0.2 m on lower piedmont slopes and basin floors. Terrace deposits of subunit Q2b in and near bedrock have a low slope toward the washes; on middle to lower piedmont slopes, they are nearly horizontal across the terraces. Drainage patterns on thin sheets on lower piedmont slopes are like those on subunit Q2c.

The soil on subunit Q2b has an Av horizon like that on older deposits. The B horizon is cambic and yellowish to grayish brown below elevations of about 1,200 m and argillic and light brown to pale reddish brown at higher elevations. Calcic horizons range from stage I to II at elevations below about 1,200 m to II and III at higher elevations. Desert pavement is similar to that of subunit Q2c, but is commonly less densely packed and has a duller, less complete varnish than pavements on adjacent Q2c.

Terrace deposits of subunit Q2b are topographically lower than all other Q2 subunits. Thin, alluvial fan deposits of Q2b on lower piedmont slopes and basin floors are at the same level as or overlie older deposits.

Subunit Q2b is mostly coarse alluvial gravel deposited on strath terraces or as thin sheets of alluvium in the distributary part of washes that originate in bedrock hills. Clast sizes and clay content of Q2b are like those of Q2c. In some washes just downslope from bedrock on the south side of the Calico Hills, subunit Q2b consists of scattered clasts from 10 to 50 cm in diameter that lie on strath terraces.

Terraces of Q2b are eroded only along the edges, but on piedmont slopes, Q2b may be eroded by anastamosing channels for a short distance downslope from the end of the wash responsible for deposition of the material. On lower piedmont slopes and on valley floors, Q2b is eroded only by washes that originate in bedrock or unit QTa.

Subunit Q2a.--Subunit Q2a, as originally defined (Hoover and Morrison, 1981), consists of debris flow deposits that have been identified only in the Calico Hills and between Syncline Ridge and the Eleana Range in western Yucca Flat. At these locations, subunit Q2a occurs along the washes as terrace deposits in bedrock and as sheets that overlie subunit Q2c on the uppermost piedmont slopes. Deposits at both locations are similar: (1) below drainage basins of less than 5 km^2 that originate in argillite of unit J of the Eleana Formation, (2) along washes that lack subunit Q2b, and (3) overlying subunit Q2c. The maximum thickness of subunit Q2a is 2 m.

Macrotopography is flat, but microrelief that ranges from less than 0.5 m to 1 m gives the subunit a hummocky appearance. Except for incision along pre-Q2a washes, no drainage has been developed in the subunit. The soil consists of an Av horizon, a weakly developed cambic B horizon, and a stage I calcic horizon. Desert pavement is poorly developed and very loosely packed. Varnish on pavement fragments is a patchy, dull, brown to dark-brown film.

In addition to microrelief, lithology is the major difference between Q2a and older Q2 subunits. Clasts of volcanic rock or quartzite from 0.5 to 1 m in diameter are scattered through a matrix of pebbles, sand, and silt. In the Calico Hills, most of the matrix grains are argillite; in Yucca Flat, the matrix grains are volcanic rock and argillite. Lack of bedding and the large clasts supported by a silt- to pebble-size matrix indicate a debris flow origin of subunit Q2a.

Subunit Q2a(?) occurs as slopewash deposits and local debris flows at the foot of steep slopes on Yucca Mountain and below fault scarps in Rock Valley and Crater Flat. Subunit Q2a(?) overlies subunits Q2b and Q2c at these locations. The subunit has also been recognized where it overlies older Q2 terrace deposits along Yucca and Drill Hole Washes. In mapping, subunit Q2a(?) has been included with underlying units, because of its patchy distribution and thinness.

Deposits of Q2a(?) are similar to Q2a deposits in macrotopography, microrelief, lack of drainage development, and desert pavement. At most locations, the sand-sized matrix has a reddish-brown color that may be inherited partly from B horizons of older deposits from which it was derived. An Av horizon is present on all Q2a(?) deposits. A cambic B horizon may be present, but is not readily apparent. Calcic horizons are stage I. Deposits of subunit Q2a(?) that overlie older terrace deposits contain fewer clasts than the slopewash deposits and have a crude bedding or layering.

Subunit Q2a(?) differs from subunit Q2a in that:

1. Deposits of Q2a(?) are reddish brown, whereas those of Q2a are shades of gray to brown.
2. Deposits of Q2a(?) appear to have originated on steep slopes rather than in a single drainage basin as did deposits of Q2a.
3. Crude bedding is apparent in deposits of Q2a(?) that overlie older Q2 terrace deposits, whereas, the few exposures of Q2a seem to be a single, unbedded layer.
4. Deposits Of Q2a(?) were derived mostly from volcanic rocks, whereas, Q2a was derived mostly from argillite of the Eleana Formation.
5. The volume of clasts larger than 10 mm is greater in Q2a(?) than in Q2a, but maximum sizes are greater in Q2a.

Although Q2a(?) and Q2a differ, the similarity of their stratigraphic position and topographic location, just downslope from bedrock, suggests that they are probably equivalent in age. Deposits of Q2a(?) have been dated radiometrically, but Q2a has not been dated.

Unit Q1

Unit Q1 consists of alluvial deposits, debris flow deposits, and eolian sand that are mapped in five subunits: Q1c and Q1a, predominantly alluvial gravels and sands; Q1b, debris flows and alluvial gravels; Q1s, alluvial sand sheets; and Q1e, eolian dunes and sand sheets. In comparison to units QTa and Q2, unit Q1 has been only slightly modified since it was deposited. Soils are weakly developed, desert pavements are not present, and only the oldest surfaces have been smoothed by creep and sheetwash.

Subunit Q1c.--Subunit Q1c occurs as terrace deposits, as alluvial fans and sheetwash deposits on middle to lower piedmont slopes, and as alluvial fans at the junction of tributaries with larger washes and across a few fault and terrace scarps. Terrace deposits of subunit Q1c occur in all washes that originate in bedrock or unit QTa. Alluvial fans and sheetwash deposits overlie units Q2 and QTa on middle to lower piedmont slopes. Alluvial fans of Q1c occur at the junction of tributaries with major washes and across some terrace scarps and Quaternary fault scarps. Thickness of subunit Q1c is usually less than 5 m. The best exposures of subunit Q1c are along the banks of terrace deposits in major washes, such as Fortymile Wash and Topopah Wash.

Subunit Q1c has a flat to slightly convex macrotopography. Microrelief is usually less than 0.2 m, but dissection of terraces of Q1c in larger washes can result in a greater relief. Drainage development in Q1c occurs along preexisting washes and as short distributory channels below these washes.

In gravelly deposits, the only noticeable soil horizon is a stage I calcic horizon that consists of calcium carbonate coatings on clasts. In sandy deposits, an A horizon can be detected by a slight darkening of the sand and, locally, a slight increase in calcium carbonate at a depth of 2-5 cm. Desert pavement is lacking on subunit Q1c.

Subunit Q1c varies from pebbly sands to gravels that contain boulders as much as 0.5 m in diameter. Individual beds are commonly well sorted, but clasts may vary from sand to cobbles in adjacent beds. Debris flow deposits make up less than 25 percent of the volume of subunit Q1c, but in alluvial fans at the junction of tributaries to larger washes, debris flow deposits may comprise about half of subunit Q1c. In fresh exposures, subunit Q1c is light gray; the surface is light brownish-gray.

Subunit Q1s.--Subunit Q1s occurs as alluvial sands on middle to lower piedmont slopes and on the floor of the Amargosa Desert. The subunit is a lithofacies of subunit Q1c that was produced primarily by erosion of subunits Q2e and Q2s. The subunit overlies all Q2 subunits except Q2a and Q2a(?) and is overlain by subunit Q1b. Subunit Q1s is limited to middle and lower piedmont slopes below Q2e and Q2s and to the floor of the Amargosa Desert. Maximum thickness of subunit Q1s is 5 m. The best exposures of Q1s are on the piedmont slopes between Little Skull Mountain and Fortymile Wash.

Topography, drainage, soils, topographic relationships, and depositional process in Qls duplicate these characteristics in subunit Qlc. In subunit Qls, the deposits range from 90 to 100 percent sand. Clasts larger than sand are commonly less than 10 cm in diameter and a have a maximum diameter of about 20 cm. A deflation pavement is usually present on subunit Qls; pebbles and larger clasts cover 20-50 percent of the surface.

Subunit Qlb.--Subunit Qlb occurs as debris flow deposits and small amounts of alluvial gravels in all washes. The best exposures of Qlb are along Fortymile Wash, north of the road to Yucca Mountain. In small washes that contain remnants of Qlc terraces, Qlb is preserved as long, convex tongues that are 5 to 10 m wide or as long, flat-topped tongues with convex sides that are 10 to 20 m wide. Maximum thickness of subunit Qlb is 3 m, but most deposits are less than 1.5 m thick. In major washes, such as Dune, Sever, Yucca, Fortymile, and Topopah Washes, subunit Qlb occurs as scattered, elongate patches of cobbles and boulders between individual channels of braided sections of these washes. The patches of cobbles and boulders usually range from 1x2 to 10x50 m, but they may be longer at the edge of a braided channel pattern. Small patches are convex across both the long and short dimensions; larger patches are convex to flat topped across the short dimension. Relief on these patches ranges from 0.3 to 1 m.

Soil development in Qlb deposits is usually weak because of the youthfulness of these deposits and because most of the upper 0.5 m is comprised of pebble- to boulder-sized clasts. Spaces between the larger clasts are empty at the surface and are partly to completely filled by sand- to clay-sized material below the surface. In some exposures, a stage I calcic horizon is present. Subunit Qlb overlies Qlc in small washes, in the upper to middle reaches of major washes, and on middle to lower piedmont slopes. In major washes and the Amargosa River, subunit Qlb locally occurs as terrace remnants less than 0.5 m below Qlc terraces.

The debris flow origin of Qlb is indicated by the lack of bedding, the predominance of cobble- to boulder-sized clasts, and by its occurrence as undissected tongues on Qlc terraces. Small tongues have noses and short levees trailing back from the noses that consist of only boulders from 0.3 to 1 m in diameter. Longer and wider tongues of Qlb have levees that trail back from the noses for most of the length of the tongues. Elongated patches 1 to 5 m wide and 5 to 50 m long of boulders occur on the surface within the larger tongues.

Subunit Q1e.--Subunit Q1e occurs as eolian sand that forms dunes and sandsheets in the Big Dune quadrangle and on the basalt cone and flows northwest of Amargosa Valley. Q1e also forms sand sheets in the southern Yucca Mountain area and near bedrock outcrops on the east side of Jackass Flats. Big Dune is the largest outcrop of subunit Q1e; it is about 5 km long, as much as 2 km wide, and approximately 100 m high. Deposits older than Q1e are not exposed on Big Dune, but to the northwest and southeast of Big Dune, outcrops of Paleozoic rocks are partly covered by Q2e and Q1e dunes. Sand sheets around Big Dune are less than 3 m thick. Sand dunes on lava flows of the Lathrop Wells basalt cone are 2 to 5 m high and lie on a sand sheet 2 to 3 m thick. Sand on the south side of the basalt cone has a maximum thickness of about 2 m. In the Ash Meadows quadrangle, layers of peat are interbedded in sand dunes (Mehringer and Warren, 1976) that are probably equivalent to subunit Q1e.

Soil horizons are not apparent in most outcrops of subunit Q1e. In the Ash Meadows area, weakly developed soils of middle Holocene age are present within dunes of subunit Q1e (Mehringer and Warren, 1976). Radiometric ages, archaeological material in Holocene dunes, and soil morphology (Mehringer and Warren, 1976; Haynes, 1967) indicate that subunit Q1e includes three separate periods of Holocene eolian deposition. The volume and areal distribution of Q1e deposits are much smaller than for subunit Q2e. Except for a small dune on the north side of the Skeleton Hills and the sand on the Lathrop Wells basalt cone, most of subunit Q1e was deposited on the basin floor of the Amargosa Desert or in areas of little topographic relief. Along Fortymile and Topopah Washes and at the mouth of the unnamed wash that drains Crater Flat, subunit Q1e is deposited on Q1b and older units as small patches of rippled sand that are less than 0.5 m thick. Near sources of silt- and clay-sized materials, these particles form laminations between sand beds or are mixed into sand beds.

Subunit Qla.--Subunit Qla occurs as alluvial deposits in the bottom of active channels. In braided channels, the subunit was deposited as small elongated patches that are a few centimeters thick. In major washes, subunit Qla was deposited as channel fill, a few centimeters to 1.5 m below Qlc or Qlb terraces. About 1 km south of the road to Yucca Mountain in Fortymile Wash, subunit Qla is less than 1 m thick, and fills a channel approximately 30 m wide. Along single channels, subunit Qla usually has a relatively smooth surface for 100 to 200 m along the wash with ripples 2 to 5 cm high. Across single channels, 10 to 30 m wide, subunit Qla may have 0.5 to 1 m of relief. Subunit Qla lacks soil development. Within the hills and on upper piedmont slopes, Qla consists of well-sorted gravels that are mostly pebbles with small amounts of sand. On middle to lower piedmont slopes and on the basin floors, Qla consists mostly of sand that contains minor amounts of pebbles.

Pliocene and Quaternary Basalts

Remnants of basalt flows form part of the possible dam west of Eagle Mountain. The basalt flows overlie debris flow deposits and alluvial gravels that were derived partly from Eagle Mountain and partly from the Greenwater Range. The basalts are less than 4 km from basalts in the Greenwater Range that are 4.03-7.16 m.y. old (Luedke and Smith, 1981).

Basalts that are 3.75 and 1.1 m.y. old crop out in Crater Flat (Carr, 1982). The older group of basalts in southeastern Crater Flat is highly dissected. Unit QTa overlies the older basalts that in turn overlie older alluvium (Carr, 1982). The younger group of basalts consists of flows and cones from four eruptive centers that form a gently curved line extending north-northeast across central Crater Flat. The cones and lava flows of the younger group of basalts are dissected, but dissection is limited to ejecta layers on the cones, the brecciated tops of flows, and flow edges.

Basalt flows and a cinder cone occur about 10 km northwest of Amargosa Valley. The flows and the cone are undissected. Basalt ash is interbedded with subunit Q2c less than 1 km north of the cone. Stalactitic calcite on welded tuff cobbles that immediately underlie the basalt flow has been dated at 345 ka (Szabo and others, 1981).

Pliocene and Quaternary Spring Deposits

Spring deposits that consist of tufas and calcite veins and spring vents occur in deposits that range in age from pre-QTa to the present. The spring deposits occur in the Amargosa Desert and near outcrops of Paleozoic carbonate rocks east of Nevada State Highway 373.

Spring deposits occurred between deposition of the waterlaid sediments and deposition of unit QTa, during deposition of unit QTa, and between deposition of unit QTa and post-QTa pedimentation. Some outcrops of tufa that overlie the waterlaid sediments of Amargosa marsh in the headwaters of Carson Slough differ from tufas in the upper unit of the sediments. The tufas occur as single outcrops or a few scattered outcrops that are a few meters to 50 m in their maximum dimension and are not related to channels. Calcite veins and vents cut across the tufas. At one location, tufa that lies on the waterlaid sediments is overlain by unit QTa. At several locations, from Devils Hole to the north side of the Amargosa Desert (Winograd and Doty, 1980), calcite veins and vents in unit QTa are truncated by the pediment cut on unit QTa. At Devils Hole (Cave) No. 2, a sinkhole approximately 300 m north of Devils Hole, a small spring mound that contains tufa is enclosed within unit QTa.

Spring deposits have not been found in units Q2 and Q1, but probably occur locally in these units near modern springs. At Point of Rock Springs in the Ash Meadows area, tufas form a spring mound that covers an area of at least 10,000 m^2. Rounded ridges that are characteristic of unit QTa extend from the tufas upslope into unit QTa. The relationship of the spring deposits to Q1 and Q2 deposits in the wash below the springs is not clear.

Spring deposits are not recognizable in the lower unit of the waterlaid sediments, but the large volume of chalk and magnesium silicates in the lower unit required a large volume of spring discharge during deposition (R.L. Hay, Univ. of Southern Illinois, oral commun., 1980). Evidence of springs was probably not preserved because the waterlaid sediments were not indurated. Induration of the lower unit probably formed an aquitard above the Paleozoic aquifer that underlies most of the Amargosa Desert (Winograd and Thordarson, 1975). This aquitard would restrict the location of most of the upper unit and younger spring deposits to outcrops of Paleozoic carbonate rocks at the edge of the aquitard.

Age of Late Pliocene and Quaternary Deposits

Ages of the waterlaid sediments of Amargosa Marsh and younger surficial deposits have been determined mostly by radiometric dating methods. Most of these methods, such as ^{14}C, $^{40}K/^{40}A$, and fission-track dating, are standard methods, but the uranium-trend method used extensively on middle to late Pleistocene deposits, is relatively new. The uranium-trend method is an empirical method. This method assumes vertical migration of isotopes in a continuously open system, has a variable accuracy that is dependent on the isotopic quantities originally in the sediments, and may require calibration by other dating methods at new locations (Rosholt, 1980, 1985). The consistent determinations of similar ages for deposits and soils considered to be stratigraphically equivalent have clearly demonstrated the usefulness of this method for determining the age of surficial deposits in the Yucca Mountain area.

In this report, the Pliocene-Pleistocene boundary is considered to be 1.7 Ma (Obradovich and others, 1982). The boundary between early and middle Pleistocene is considered to be at the Brunhes-Matuyama magnetic boundary at 788 ka (Johnson, 1982). The boundary between the middle and late Pleistocene is considered to be the boundary between oceanic ^{18}O isotope stages 5 and 6 at 132 ka (Johnson, 1982). The Pleistocene-Holocene boundary is considered to be at the boundary between ^{18}O stages 1 and 2 at 11 ka (Kominz and others, 1979).

Basalt flows at the possible dam near Eagle Mountain have not been dated, but basalts in the Greenwater Range, less than 4 km to the west, have K-Ar ages between 4.03±0.12 and 7.16±0.22 Ma (Luedke and Smith, 1981). Both the basalt at the possible dam and in Greenwater Range are faulted. The proximity of the faulted basalts at the two locations suggests that the basalts are probably the same age, and that impoundment of a lake probably began less than 4-7 Ma ago.

Deposition of the lower unit of the waterlaid sediments of Amargosa marsh began prior to deposition of an included ash bed dated at 3.22±0.12 Ma by the K-Ar method (R.F. Marvin and others, U.S. Geological Survey, written commun., 19[illegible]) and 2.95±0.42 Ma by the fission-track method (C.W. Naeser, U.S. Geological Survey, written commun., 1980). An ash bed in the lower unit, where it is unconformably overlain by the river gravels of ancestral Rock Valley Wash in SE1/4 NE1/4 sec. 19, T. 16 S., R. 50 E., has been dated at 2.1±0.4 Ma by the fission-track method (C.W. Naeser, U.S. Geological Survey, written commun., 1982). The ash bed underlies recrystallized chalk at the edge of the river gravels and is probably just below the top of the lower unit.

Fossils in the upper unit of the waterlaid sediments indicate that Amargosa marsh may have persisted into the Quaternary period. In secs. 22 and 23, T. 14 S, R. 49 E., just north of U.S. Highway 95, a small outcrop of the upper unit consists of tuffaceous sands and clays overlain by diatomaceous marl, which in turn is overlain by tufa. Richard M. Forester (U.S. Geological Survey, written commun., 1979) identified several species of ostracodes from the diatomaceous marl. *Cypridopsis vidua* (Muller), also identified by Forester from a sag-pond deposit in unit QTa in Yucca Flat, is known from the Pliocene and Quaternary, but is much more common in the Quaternary. Charles A. Repenning (U.S. Geological Survey, written commun., 1982) identified vertebrate fragments from the tufa and the underlying diatomaceous marls as being less than 2 m.y. old. Tooth fragments of *Mammuthus* sp. cf. *M. columbi* (Falconer), *Equus* sp., and a large camelid were identified. Poorly preserved fragments of a tusk and limb bones occur in the diatomaceous marl. Repenning states that *Mammuthus* is not known to be older than 2 Ma in North America. He states that the thickness of the enamel plates from the *Mammuthus* teeth suggest an age considerably less than 2 Ma. Thus, deposition of the waterlaid sediments of Amargosa marsh probably ended in early Pleistocene time.

The fossils in the upper unit verify the stratigraphic position of the 2.1 Ma-old ash bed in the lower unit. Although the recrystallized chalk above the ash bed is known only in the lower unit, the topographic position of the chalk, when compared to that of the tufas of the upper unit, which are exposed 2 km to the east, suggest that the chalk might be in the upper unit. If the ash is in the upper unit, then either a long hiatus occurred shortly after deposition of the ash and before deposition of the fossils in the upper unit, or the chronologic range of Mammuthus is incorrect. Because neither alternative seems reasonable, the 2.1 Ma-old ash is assumed to be in the lower unit of the waterlaid sediments of Amargosa marsh.

Unit QTa overlies the upper unit of the waterlaid sediments of Amargosa marsh on the west side of the Paleozoic ridge that contains Devil Hole. It also overlies the river gravels of ancestral Rock Valley Wash. Unit QTa is, therefore, younger than the 2.1 Ma-old ash in the lower unit of the waterlaid sediments and the Mammuthus remains in the upper unit, and is probably Quaternary in age.

Delicate leaves are preserved on plant casts in the tufa of the upper unit [illegible] of Devils Hole. The preservation of the leaves occurs only near the eroded edge of overlying deposits of unit QTa. Further from the edge of QTa deposits, exposed plant casts are partially dissolved and leaves are not discernible. The preservation near the edge of unit QTa and dissolution further away suggests that unit QTa was deposited shortly after the deposition of the tufa and thus preserved the leaves of the plant casts that otherwise would not have been preserved.

Unit QTa is designated as both Pliocene(?) and Pleistocene, but the faunal evidence indicates that it is probably only Pleistocene in age. In addition to the probable Pleistocene age of the upper unit of the waterlaid sediments of Amargosa marsh at the *Mammuthus* locality, fossils in sag-pond deposits within unit QTa in Yucca Flat also indicate a Quaternary age. Richard M. Forester (U.S. Geological Survey, written commun., 1979) reports that *Cypridopsis vidua* (Muller) in the sag-pond deposits in western Yucca Flat has not been found in sediments believed to be Miocene or older, but is far more common in the Quaternary than in the Pliocene. *Scottia* n. sp. (sensu stricto), also found in the sag-pond deposits is known only from Pleistocene sediments in North America, and therefore, the sag-pond deposits and the overlying part of unit QTa are probably Quaternary.

The Bishop ash, 738 ka (Izett, 1982), has been found at several locations in the Yucca Mountain area at or within 5 m of the base of subunit Q2e and less than 3 m above the base of subunit Q2c in the Calico Hills just west of Fortymile Wash. The pedimentation, development of a soil, and dissection of unit QTa prior to deposition of unit Q2 and the presence of an alluvial unit between units QTa and Q2 strongly suggest that deposition of unit QTa took place significantly before 738 ka.

Although the Bishop ash (738 ka) occurs at or near the base of subunits Q2e and Q2c at all locations where the ash has been found, deposition of subunit Q2c could have begun significantly before the ash was deposited. All locations of the ash are topographically high and on or just above bedrock. These locations suggest that older deposits of subunit Q2c may be concealed at lower elevations.

Radiometric ages determined for units Q2 and Q1 are shown in table 1 (Rosholt and others, 1985; Szabo and others, 1981). The uranium-trend method determines when deposition or erosion ended, and thus, when soil formation began. Uranium-trend plots of data are linear for samples of unit Q2 that include both the B and calcic horizons. Disturbance of the vertical, open system, on which the empirical uranium-trend method is based, by biotic or tectonic processes can affect the system and may result in ages younger than the actual age (J.N. Rosholt, U.S. Geological Survey, oral commun., 1981). At the ETS trench in Jackass Flats, the soil that was sampled appears to be undisturbed, but the age of 160 k.y. is much younger than the stratigraphic position of Q2s warrants. About 20 m south of the sample site the beds from which the sample was taken are eroded at a topographic scarp. The sample age, therefore, probably indicates the end of erosion, rather than the end of deposition.

The repetition of ages determined for multiple samples of subunits Q2a(?), Q2b, and Q2c for both buried and surface deposits at different locations demonstrates the precision of the uranium-trend method. Coincidental agreement of ages at two or three locations for a single stratigraphic unit may be possible, but coincidental agreement of five or six ages in widely separated locations that vary in geomorphic position, soil development, and soil parent material seems unlikely. Similarly, the hypothesis that numerous ages of four stratigraphic units could be displaced equally by some unknown mechanism also seems unlikely.

Table 1.--Radiometric ages of Quaternary stratigraphic units in the Yucca Mountain area

Stratigraphic unit	Material	Age (ka)[1]	Method	Sample locality
Subunit Q1c	Charcoal in fluvial sand	8.3±0.075	^{14}C [2]	Amargosa River bank 6 m below surface 2 km SE of Beatty
Av horizon	Eolian silt and sand	30±30	U-trend[4]	SW Frenchman Flat trench
Av horizon[3]	Carbonate in eolian silt and sand	25±10	U-series[5]	Basalt cone 11 km WNW of Amargosa Valley
Subunit Q2a(?)	Slopewash gravel	31±10	U-trend[4]	RV-1 trench, Rock Valley
Do-----	B horizon	36±20	U-trend[4]	RV-2 trench, Rock Valley
Do-----	B horizon in slopewash gravel	37±24	U-trend[4]	RV-1 trench, Rock Valley
Do-----	B horizon in slopewash gravel	38±10	U-trend[4]	RV-2 trench, Rock Valley
Do-----	B horizon in slopewash gravel	38±10	U-trend[4]	Trench 14, Yucca Mountain
Do-----	Alluvial gravel	40±10	U-trend[4]	CF-3 trench, east-central Crater Flat
Do-----	Slopewash gravel	41±10	U-trend[4]	Trench 13, Yucca Mountain
Do-----	Alluvial gravel	47±18	U-trend[4]	Trench 2, Yucca Mountain
Do-----	B horizon in slopewash sand	55±20	U-trend[4]	Trench 14, Yucca Mountain

Table 1.--Radiometric ages of Quaternary stratigraphic units in the Yucca Mountain area--Continued

Stratigraphic unit	Material	Age (ka)[1]	Method	Sample locality
Subunit Q2b	Alluvial gravel	145±25	U-trend[4]	Trench 2, Yucca Mountain
Do-----	Alluvial gravel	160±25	U-trend[4]	Charlie Brown gravel pit, Shoshone, California
Do-----	Calcareous B horizon	180±40	U-trend[4]	RV-1 trench, Rock Valley
Do-----	Alluvial gravel	190±50	U-trend[4]	CF-3 trench, east-central Crater Flat
Do-----	Alluvial gravel	190±0	U-trend[4]	SW Frenchman Flat trench
Do-----	Alluvial gravel	200±80	U-trend[4]	SW Frenchman Flat trench
Subunit Q2s	B and calcic horizons	160±90	U-trend[4]	ETS trench, Jackass Flats
Subunit Q2c (younger soil and underlying deposits)	Alluvial gravel	240±50	U-trend[4]	Trench 13, Yucca Mountain
Do-----	K horizon	270±30	U-trend[4]	RV-1 trench, Rock Valley
Do-----	Alluvial gravel	270±30	U-trend[4]	CF-3 trench, east-central Crater Flat
Do-----	Alluvial gravel	270±35	U-trend[4]	Jackass Divide trench
Do-----	K horizon	270±90	U-trend[4]	Trench 14, Yucca Mountain
Do-----	Alluvial gravel	310±40	U-trend[4]	RV-1 trench, Rock Valley

Table 1.--Radiometric ages of Quaternary stratigraphic units in the Yucca Mountain area--Continued

Stratigraphic unit	Material	Age (ka)[1]	Method	Sample locality
Subunit Q2c (older soil and underlying deposits)	Alluvial gravel	390±100	U-trend[4]	RV-1 trench, Rock Valley
Do-----	Alluvial sand	400±50	U-trend[4]	Western SCF trench southern Crater Flat
Do-----	Slopewash sand	420±50	U-trend[4]	Trench 14, Yucca Mountain
Do-----	Alluvial gravel	430±40	U-trend[4]	Jackass Divide trench
Do-----	Alluvial gravel	480±60	U-trend[4]	Western SCF trench southern Crater Flat
Do-----	K horizon in gravel	480±90	U-trend[4]	Trench 14, Yucca Mountain

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[1] ± one standard deviation.
[2] Analyzed by S.W. Robinson, U.S. Geological Survey, Menlo Park, California.
[3] Correlated to Av horizon by appearance.
[4] Rosholt and others, 1985.
[5] Szabo and others, 1981.

The age of subunit Qle in the Yucca Mountain area has not been determined, but numerous ^{14}C dates for charcoal and fossil seeds from sand dunes in two nearby areas indicate the probable times of accumulation. In the Ash Meadows area, three dates for charcoal in dunes and 10 dates for fossil seeds in peat interbedded with sand that is probably equivalent to Qle range from 2,940±100 to 5,320±70 yr B.P. (Mehringer and Warren, 1976). In the Corn Creek Springs area, about 35 km northwest of Las Vegas, seven charcoal samples at and near the base of dunes ranged from 4,030±100 to 5,200±100 yr B.P. (Haynes, 1967). A weakly developed soil occurs above this older material in both areas (Mehringer and Warren, 1976; Haynes, 1967). Three charcoal samples in eolian sand above the soil in the Ash Meadows area were dated between 1,950±100 and 440±280 yr B.P. These intermediate-age deposits are overlain by a very weakly developed soil, which in turn, is locally overlain by Paiute pottery shards. Virgin Branch pottery shards that occur locally below the soil provides a maximum age of about 1,000 yr B.P. for the soil. Charcoal associated with the shards above the soil was dated at 220±100 yr B.P. (Mehringer and Warren, 1976).

On the basis of the stratigraphy in several trenches in the dunes at Ash Meadows, archaeological artifacts, and similar age dates in both the Ash Meadows and Corn Creek Springs areas, Mehringer and Warren (1976) concluded that there were three periods of eolian sand deposition during Holocene time: 5,300 to 3,000, 2,000 to 1,000 or less, and 200 yr B.P. to the present. The periods of sand deposition were separated by intervals of nondeposition and soil development from 3,000 to 2,000 and about 1,000 to 400 yr or less B.P. Similar periods of deposition and soil development in subunit Qle in the Yucca Mountain area are likely, because of the proximity of the Ash Meadows and Corn Creek Springs areas to Yucca Mountain.

At the numerous locations where subunits Qlc or Qls and Qle occur together, Qle always overlies Qlc or Qls. The minimum age of Qlc and Qls is, therefore, probably greater than 5,300 yr B.P. Where subunits Qle and Qlb occur together, sand sheets of Qle less than 0.5 m thick overlie Qlb. The stratigraphic position of Qlb above Qlc and Qls and the thinness of Qle overlying Qlb suggest that Qlb may be younger than the oldest period of Qle deposition, 5,300 to 3,000 yr B.P., and older than the youngest period of Qle deposition, or older than 1,000 yr B.P.

Subunit Qla probably corresponds to a period of arroyo erosion that began about 1840 throughout the southwestern United States (Antevs, 1955). In the Syncline Ridge area, a juniper tree, dated by dendrochronology, began growing in 1858 on a Qlc terrace. Erosion of the terrace by a Qla wash to a depth of 0.7 m exposed and killed a large root of the juniper tree in 1928.

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RAW DATA

NNA.900917.0062

July 20, 1990

To: Mildred Murray, Central Records
From: D.L. Hoover, Central Regional Geology Branch D. Hoover
Subject: Records for OFR-89-359

This memo is notify you that there are no notes or analyses for OFR-89-359, Preliminary description of Quaternary and Late Pliocene surficial deposits at Yucca Mountain and vicinity, Nye County. The report was compiled from the reports cited in the references.

WBS. 1.2.5.1.1
QA. N/A
Page ___ of 1

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Columns 1 through 3 must by completed for each document or package submitted.
This transmittal must be signed (authenticated) by the Authorized Project Personnel

Transmittal Number

1. Document/Package Type	2. Number	3. Title and Author or Originator	For LRC Use Only 4. Number
Manuscript package segment Note: All documents in this package segment represent best copies available	OFR 89-359	Preliminary description of Quaternary and Late Pliocene Surficial Deposits at Yucca Mountain and Vicinity, Nye County, Nevada by D.L. Hoover	

Authenticated By: Virginia M. Glanzman Signature*: Virginia M. Glanzman Organization USGS Date 10/27/89

Received By: LRC Staff Member Mary Morales Signature Mary Morales Organization LRC Date 10/27/89

* This signature affirms that all of the backup data pertaining to the [illegible] report(s) are provided [illegible] this transmittal, that there is an explanation for any missing data, and [illegible] are ready [illegible] processing [illegible] Local Records Center

YMP-USGS-QMP-17.01, R3
Attachment 6
Page 1 of 1

GS930208316111.02

Enclosure 1

10/27/89 JAC JAC 10/27/89

Observations from ~~8~~ 7/84 debris flows (modern hillslope erosion) at Jake Ridge ~ 5 km east of Yucca Mountain

Objective: Initial reconnaissance to determine if pre- and post-flow aerial photographs would be a viable medium to measure the volume of material eroded.

Technical Procedure NWM-USGS-GP-01 used as guide for notetaking

Observations:

1.) Main areas of deposition at base of hillslope appear to be ~ 1.0 - 1.5 m thick.

2.) Erosion has widened what appear to be previously existing channels and stripped the upper slope to bedrock. All channels observed were cut to bedrock. Narrow channels on lower hillslope appear to be relatively fresh based on ~~vegetation~~ lack of

JAC 10/27/89

Timing of debris flows determined to be 7/84 by Pat Glancy based on his visits to the site in the summer of 1984.

Others present on 10/27/89:
John Whitney - USGS, Denver
Dave Meyer - USGS, Carson City

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5.) Large inter-chan
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from ~~by~~ the debris
JE 10/27/89

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6.) Bedrock underlying
hillslopes seems rel
to surface water infiltrati

Conclusion: Based o
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aerial photograph
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measurement accuracy of instrument →
(0.000015m X 10,00

would be possible
analytical plotter.

Jeffrey G. Coe

3/21/92 JAC

Field check of elevation difference map created from pre- and post-flow DEMs at Jake Ridge. DEMs were measured in the USGS Digital mapping Facility, Denver, CO, from pre-flow (1:8000) and post-flow (1:3000) ~~of~~ aerial photographs. Work done as scoping study for SCP activity 8.3.1.6.1.1.1.

Pre-flow photos - Frames 250 + 249 dated 5/24/82

Post-flow photos - Frames 326 + 327 dated 9/20/91

Objectives: Check accuracy of general patterns + depths of deposition and erosion shown on elevation difference map.

Others on trip: John Whitney
Pat Glancy

All thickness measurements made using a tape measure from previous ground surface. See elevation difference map dated 3/21/92 for Check Point locations.

Observations:

There are two
areas within the study
poorly sorted deposit
the road at the
the main hillslope ch
an elongated ~~area~~ JAE
the southern-most e
trending hillslope ch

Depositional lobes along
channel range from
JAE 3/21/92 ~~deep~~ thick. At
check points along
the map accuracy

Check Point	Map Value
CP 1	>1.2 m
CP 2	0.9-1.2 m
CP3	0.9- 1.2m

At check point 4
graded road:

CP4	>1.2 m

The very large "hole" (-1.2 → -1.5m on map) at mid-upper slope level is real. It appears that large chunks of bedrock have been "plucked" off here. The ~~very~~ JAE 8/21/92 upper most part of the hillslope also exibits "fresh" nonvarnished bedrock faces where large chunks of bedrock have been removed.

There is evidence of stripping of colluvium and bedrock all the way up to the base (and slightly further up) of the cliffface (caprock).

The flat top of Jake Ridge, which slopes slightly (~ 4°) to the southeast, shows no evidence ~~for~~ JAE 8/21/92 of water flow. The top surface is flat and is mantled by a thin layer of sand and cobbles.

When looking at the hillslope from the top of the ~~red~~ JAE 3/21/92 hill, it appears that the amount of material eroded exceeds the amount that was deposited in the ~~main~~ JAE 3/21/92 ~~end~~ study area. To offset this notion, one should keep in mind that some of the channels existed prior to the 1984 debris flows.

JAE 3/21/92

The hillslope is ~~f~~ mantled by ~ 0-2 m of colluvium. Boulders in the colluvium @ mid-slope have desert varnish on their exposed surfaces. This may indicate that debris flows are rare events. Otherwise, these boulders would not have remained stable long enough to accumulate varnish.

John Whitney - Varnish probably been accumulating for 100,000 years.

Back at the main deposit by the road: there appear to have been boulders > 1.0 m in diameter that were moved downslope by the debris flows.

Poorly sorted channel levees ~~exist~~ on the mid and lower slopes — also visible on elevation difference map.

In tributary below main terrace level — another depositional lobe where the tributary widens — a "fan" deposit. JAE 3/21/92 This deposit, however, ~~is mixed with~~ contains terrace gravels from other channels (ie, it is not all a result of the Jake Ridge debris flows). This deposit is also poorly sorted with boulders up to about 0.5 m in diameter.

At the intersection of Forty mile Wash and the tributary — thin cobble sized deposits (ie, no large (coarse) clasts from the debris flows made it into Forty mile Wash.) It is impossible to tell how much fine sediment was transported from Jake Ridge into Forty Mile Wash. This area is not covered by photogrammetric measurements.

Conclusion- The elevatio
map provides the be
possible as to the
of erosion and dep
that occurred on the
and at the base of
map Accuracy ranges from
although there appear
areas in the interchann
that are worse (up

Results summarized in
"Photogrammetric analysis of
erosion at Yucca Mountain
at 1992 annual meeting,
JAC 11/2/92

Jeffry A. Coe 3/21

Preliminary Draft

EVIDENCE OF PREHISTORIC FLOODING AND THE POTENTIAL FOR FUTURE EXTREME FLOODING AT COYOTE WASH, YUCCA MOUNTAIN, NYE COUNTY, NEVADA

U.S. GEOLOGICAL SURVEY

Open-File Report 92-458

Prepared in cooperation with the
NEVADA FIELD OFFICE
U.S. DEPARTMENT OF ENERGY under
Interagency Agreement DE-AI08-92NV10874

Dept. Seal

Encl. 3

(WRSIC Information)

GEOLOGICAL SURVEY, WATER RESOURCES DIVISION
ABSTRACT-INDEX SHEET

TITLE: EVIDENCE OF PREHISTORIC FLOODING AND THE POTENTIAL FOR FUTURE EXTREME FLOODING AT COYOTE WASH, YUCCA MOUNTAIN, NYE COUNTY, NEVADA	DATE SENT TO CR: NO. PAGES: 37 NO. ILLUSTRATIONS: 13 NO. TABLES: 3 NO. REFERENCES: 31

AUTHOR: Patrick A. Glancy

DESCRIPTORS: *Alluvial deposits, *Debris flow, *Flood hazards, *Floods, *Flow rates, *Fluvial debris hazards, *Geohydrologic hazards, *Probable maximum floods, *Nuclear wastes, *Sediment transport, *Waste disposal, Arid-zone hydrology, Erosion, Flash floods, Geomorphology, Gravel, Holocene, Non-Newtonian flow, Particle size, Pedogenesis, Pleistocene, Rainfall intensity, Rainstorms, Small watershed, Soil profiles, Stratigraphy, Trenches, Yucca Mountain, Coyote Wash, Nevada Test Site

TYPE OF PUBLICATION: Open-File Report 92-458

ABSTRACT (250 WORDS OR LESS, DOUBLE SPACED):

Coyote Wash, east of Yucca Mountain and southwest of the Nevada Test Site, is the potential location for an exploratory shaft to investigate the feasibility of underground storage of radioactive waste. The potential for flooding and related fluvial-debris hazards was investigated with respect to the potential shaft location. Trenches excavated through fluvial sediment deposits revealed interstratified rock detritus emplaced by floods and debris flows. Most of the deposits are believed to be of late Quaternary age. Debris-flow deposits contain boulders as large as 3 feet in diameter. This evidence of intense prehistoric flooding and debris movement indicates the possibility of similar continuing activity.

Empirical estimates of extreme flood flows in North Fork Coyote Wash, a 0.094-square-mile drainage to the shaft site, range from 900 to 2,600 cubic feet per second. Current (1992) knowledge indicates that flows of water and debris of as much as 2,500 cubic feet per second can occur in the vicinity of the shaft from this drainage. Similar size flows from adjacent South Fork Coyote Wash could arrive simultaneously in the vicinity of the shaft. Thus, cumulative water and debris from both tributaries could subject the alluvial flood plain near the shaft site to flows of as much as 5,000 cubic feet per second.

Water Resources Division

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PALEOFLOOD DEPOSITS PROVIDE FLOOD-PREDICTION TOOLS IN SOUTHERN NEVADA

Hydrologists of the U.S. Geological Survey, U.S. Department of the Interior, are evaluating the potential for floods in southern Nevada by examining ancient flood deposits, according to a report published in cooperation with the U.S. Department of Energy. Trenches dug through unconsolidated stream deposits in the bottom of a small drainage channel at Coyote Wash, Yucca Mountain, Nye County, near the Nevada Test Site, provided substantial evidence of prehistoric flooding. This evidence indicates that recurrent flooding has occurred on the eastern flank of Yucca Mountain during the past 10,000 years, and that at least one fluvial debris flow, may have surged down the mountain face earlier than 10,000 years ago. The evidence further indicates that flooding may have been less severe during the past few thousands of years than in earlier times.

Debris deposits left behind by these ancient floods provide evidence of the characteristics of water floods and viscous fluvial debris flows. Modern streamflow deposits similar to these ancient deposits usually are the product of flash flooding in this desert area. On the basis of the geologic principle that evidence of past geologic events can be used to predict present and future events, the characteristics of these paleoflood deposits probably are indicators of the types of flooding that could occur in the future.

MORE

The report "Evidence of prehistoric flooding and the potential for future extreme flooding at Coyote Wash, Yucca Mountain, Nye County, Nevada" by Patrick A. Glancy, published as U.S. Geological Survey Open-File Report 92-458, may be examined at the following U.S. Geological Survey offices and libraries and the U.S. Department of the Interior Natural Resources Library:

1. Nevada District, Water Resources Division, Room 203, 333 West Nye Lane, Carson City, NV 89706.
2. Hydrologic Investigations Program, Yucca Mountain Project Branch, Water Resources Division, Central Region, Room H-2726, Building 53, Denver Federal Center, Denver, Colo. (mailing address: Box 25046, Mail Stop 421, Denver Federal Center, Denver, CO 80225-0046);
3. Colorado Water Resources Library, Water Resources Division, Room H-2313, 2d Floor, Building 53, Denver Federal Center, Denver, Colo. (mailing address: Box 25046, Mail Stop 415, Denver Federal Center, Denver, CO 80225-0046);
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* * * USGS * * *

Evidence of Prehistoric Flooding and the Potential for Future Extreme Flooding at Coyote Wash, Yucca Mountain, Nye County, Nevada

By Patrick A. Glancy

U.S. GEOLOGICAL SURVEY

Open-File Report 92-458

Prepared in cooperation with
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Denver, Colorado
1993

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	0.4047	square hectometer
acre-foot (acre-ft)	0.001233	cubic hectometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per second (ft/s)	0.3048	meter per second
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
millimeter (mm)	0.03937	inch
square foot (ft^2)	0.0929	square meter
square mile (mi^2)	2.590	square kilometer

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

EVIDENCE OF PREHISTORIC FLOODING AND THE POTENTIAL FOR FUTURE EXTREME FLOODING AT COYOTE WASH, YUCCA MOUNTAIN, NYE COUNTY, NEVADA

Abstract

Coyote Wash, an aproximately 0.3-square-mile drainage on the eastern flank of Yucca Mountain, adjacent to the southwestern part of the Nevada Test Site, is the potential location for an exploratory shaft to evaluate the suitability of Yucca Mountain for construction of an underground repository for the storage of high-level radio-active wastes. An ongoing investigation is addressing the potential for hazards to the site and surrounding areas from flooding and related fluvial-debris movement. Unconsolidated sediments in and adjacent to the channel of North Fork Coyote Wash were examined for evidence of past floods. Trenches excavated across and along the valley bottom exposed multiple flood deposits, including debris-flow deposits containing boulders as large as 2 to 3 feet in diameter. Most of the alluvial deposition probably occurred during the late Quaternary. Deposits at the base of the deepest trench overlie bedrock and underlie stream terraces adjacent to the channel; these sediments are moderately indurated and probably were deposited during the late Pleistocene (over 10,000 years ago). Overlying nonindurated deposits clearly are younger and may be of Holocene age (less than 10,000 years old). This evidence of intense flooding during the past indicates that severe flooding and debris movement are possible in the future. Boulders presently exposed in the active channel probably were deposited by water-dominated (Newtonian) fluids; their size indicates they were deposited at a flow rate of about 2,400 cubic feet per second.

Empirical estimates of large floods of the past range from 900 to 2,600 cubic feet per second from the 0.094-square-mile drainage area of North Fork Coyote Wash drainage at two proposed shaft sites. Current knowledge indicates that mixtures of water and debris are likely to flow from North Fork Coyote Wash at rates up to 2,500 cubic feet per second. South Fork Coyote Wash, which has similar basin area and hydraulic characteristics, probably will have concurrent floods of similar magnitudes. The peak flows of the two tributaries probably would combine near the potential sites for the exploratory shaft to produce future flows of water and accompanying debris potentially as large as 5,000 cubic feet per second.

INTRODUCTION

The Nevada Test Site (NTS), an area about 1,350 mi^2 in Nye County, southern Nevada, is in the southern part of the Basin and Range physiographic province (fig. 1). Since 1951, NTS has been the principal site in the United States for the testing of nuclear weapons. Research is currently (1992) being conducted at and adjacent to NTS as part of site-characterization activities for a potential high-level radioactive-waste repository at Yucca Mountain, which abuts the southwest part of NTS (fig. 1). The potential for geohydrologic hazards at Yucca Mountain and in and near NTS is one of the subjects of research; flood potential is the particular focus of this report. Flood-hazard potential is being investigated through a combination of streamflow and paleoflood studies. Flood hazards include those caused by the transport of debris by streamflow and flooding. This effort is part of the Yucca Mountain Project (YMP) site-characterization process to determine the suitability of the area for storage of high-level nuclear wastes.

The current major flood hazard at and near NTS probably is flash flooding. Flash floods are the result of intense rainfalls and runoffs from localized convective storms or fromhe high-intensity precipitation cells within regional storm systems. Flash floods and associated debris movement commonly result in degradation of mountainous terrain, development of alluvial fans, and evolution of drainage-channel morphology. Flood flows range in character from water-dominated (Newtonian) fluids, which have widely varying concentrations of entrained sediments, to sediment-dominated debris flows (non-Newtonian or Bingham fluids), which contain interstitial water. A debris flow is the mass movement of loose, granular rock material mixed with water and air; its hydraulic characteristics are intermediary between those of landslides and water floods, and thus it has flow characteristics different from either of these processes (Johnson, 1970, p. 433-492; Costa, 1984, p. 287-290).

Figure 1. Location of the study area and the Nevada Test Site.

Flood hazards are caused by the flow of water and rock debris. Flowing water is destructive because of its capacity to erode and inundate, and because of its momentum. The associated process of debris transport can cause wide-scale damage during the erosion, movement, and deposition of the debris. Currently, data and knowledge of the water component of floods are more advanced than data and knowledge of the debris-transport component. However, in the semiarid southwest, the damage potential of debris transport commonly is greater than the damage potential of the water carrying the debris. Therefore, effective flood-hazard mitigation at Yucca Mountain depends on understanding flowing water and debris but, particularly, on increased knowledge of debris transport.

A typical flash flood can move massive quantities of entrained debris in a few hours or less; particle-size distribution of the entrained debris can range from clay-size particles to boulders that are several feet in diameter. The quantity and character of the transported debris depend on the available debris along the flood path and on the hydraulic characteristics of the transporting fluid. Transported debris generally causes damage by: (1) Erosion of the stream channel along the flow path, (2) impact with obstacles, (3) abrasion of material swept into the flow, and (4) burial of objects and ground surfaces; resulting landscape modifications commonly are vivid. Erosion and deposition of sediment within and along the channel system also affect the hydraulic characteristics of future flood flows by changing the geometry of stream channels.

The nature and severity of hazards caused by flooding and associated debris transport depend on several factors: (1) Storm characteristics, (2) antecedent soil-moisture conditions, (3) vegetation, (4) drainage basin and channel characteristics, (5) quantity and character of debris available for transport, (6) types and extent of erosion caused by the flooding, and (7) land use.

An evaluation of flood and debris hazards requires knowledge about the range of magnitudes and the probable recurrence intervals of storms and flood flows and knowledge about the potential of debris transport. Traditionally, determinations of potential flood magnitudes include quantitative estimates of flow rates, associated velocities, depths, and the extent of inundated areas. In areas where debris movement is important, these determinations also can include sediment concentrations, particle-size distributions, and volumes of sediment incorporated in the flood flows. Recurrence intervals are the average time between similar magnitudes of the above listed flow characteristics.

Background Regarding the Flood Investigation

The U.S. Geological Survey initiated flood investigations near Yucca Mountain in cooperation with the U.S. Department of Energy in 1980 (Christensen and Spahr, 1980). These investigations were initially part of the Nevada Nuclear-Waste Storage Investigations, later renamed the Yucca Mountain Project, under Interagency Agreement DE-AI08-78ET44802. Yucca Mountain was designated by the U.S. Congress as a national candidate, repository site for the potential storage of high-level nuclear wastes. The investigations were refocused and intensified in 1982 (Squires and Young, 1984). A high priority was assigned during 1983 to a specific phase of the flood studies by directing specific attention to the small (approximately 0.3 mi^2) ephemeral drainage basin of Coyote Wash, located on the east-facing slopes of Yucca Mountain (figs. 1 and 2). This site-intensive phase of the flood investigations developed because the downstream part of the Coyote Wash basin was selected as the proposed site of an exploratory shaft. The shaft was planned to allow study of the subsurface geohydrological environment as a part of the Site Characterization Plan of the Yucca Mountain Project.

The exploratory shaft was originally sited near the active channel of Coyote Wash, on unconsolidated sedimentary deposits that seemed to have been emplaced by flooding processes. The proposed shaft location was also near the confluence of the Coyote Wash basin's two major tributaries--North and South Forks of Coyote Wash (figs. 2 and 3).

The urgent need for an assessment of flood-hazard potential at and near the proposed site for the exploratory shaft precluded a standard, long-term program of hydrologic-data collection. An appropriate streamflow-data collection effort would involve many years of streamgaging; the resultant long-term records would be essential to the development of an adequate set of streamflow data that would allow a standard statistical analysis of floodflow characteristics, at a level of confidence necessary to properly characterize flood-hazard potential at the proposed shaft site. Also, long-term records of streamflows in the numerous small drainage basins of the region that could be used to geographically transfer or simulate an acceptable streamflow record for Coyote Wash were nonexistent. This lack of both site-specific and regional long-term data precluded any standard estimation of floodflows (flood magnitudes and their recurrence intervals) for the Coyote Wash basin at an acceptable level of confidence. The pressing need to make immediate decisions regarding the existence and nature of potential flood hazards, and in turn the possible urgency to formulate strategies to mitigate any potential hazards for the proposed shaft, dictated that decisions on shaft-location acceptability had to be made without the benefit of the badly needed long-term data. These requirements spawned the investigative strategy described in this report. However, long-term data on precipitation and runoff are still important for a variety of other site-characterization activities in the Yucca Mountain area and region.

Purpose and Scope

This report describes the results of an investigation designed to hurriedly collect readily available, site-specific data that could improve knowledge of the flood-hazard potential of Coyote Wash. It was also planned to make this information, and any other pertinent flood-hazard knowledge, available to evaluate the siting of an exploratory shaft on, or near, the flood plain of Coyote Wash in the vicinity of the confluence of its two major tributaries. Detailed descriptions of the investigation activities, results of the findings, and interpretation of the results constitute the bulk of this report.

Approach

A dual strategy was formulated to meet the study objectives listed above, as follows:

1. Examine available evidence of previous flooding in Coyote Wash, and from an analysis of this evidence, develop a history of prehistoric flooding in the Wash. Attempt to translate the flood history into a realistic awareness of potential flood hazards, both present and future, at the general site of the proposed exploratory shaft.

2. Compile, evaluate, and select several empirical techniques that allow "rule-of-thumb" estimates of the potentially largest flood discharges that would logically be expected in the vicinity of the proposed exploratory shaft, and compare the results of the most pertinent techniques.

Investigative results would (1) identify and characterize the potential for flood hazards, and (2) attempt to quantify the limit of severity of the potential hazards.

This dual strategy gives rise to different technical approaches; the first is site specific and field oriented; the second is regional in scope and office oriented. Neither strategy, or their combination, was expected to allow the preparation of a detailed flood-hazard map of the vicinity of the proposed shaft location (such a map would include a range of flood magnitudes and associated recurrence intervals, as well as the accompanying areal zones and depths of inundation associated with the varying flood discharges). Instead, because of the lack of long-term streamflow data that would allow confident predictions of probable flood magnitudes, their probable recurrence intervals, and their probable areas and degrees of influence, the results of this study would promote a preliminary awareness of the general flood-hazard potential of Coyote Wash; this awareness would include a sense of the magnitude of potential-maximum flood discharges to be expected and a range of hydraulic characteristics of the flows related to the entrainment and transport of debris. Findings of the study could be used to preliminarily evaluate the absence, presence, and degree of flood hazards to which the exploratory shaft might be subjected on the basis of its proposed locations.

The field phase of this flood investigation of Coyote Wash began with a hiking reconnaissance of the drainage basin. This reconnaissance disclosed an abundance of stream-channel and flood-plain deposits just upstream from the proposed site of the exploratory shaft, which had originally been near the confluence of North and South Forks of Coyote Wash (fig. 2). The land-surface configuration of the channel and flood-plain deposits of North Fork Coyote Wash, just upstream from the tributary confluence, exhibited characteristics of debris-flow deposition. That made these stream deposits especially interesting candidates for more detailed study regarding a flood-hazard potential to the originally proposed shaft site. Comparable sediment deposits near the mouth of South Fork Coyote Wash, also upstream from the proposed shaft site, had earlier been badly disturbed and largely removed by clearing and leveling operations related to the drilling of test hole USW G-4 (figs. 2 and 5), and were thus unavailable for study.

The field work thus focused on North Fork Coyote Wash to investigate available evidence of prehistoric flooding and thereby to develop a preliminary understanding of the flood history of Coyote Wash. The detailed field phase of the investigation of prehistoric flooding was mainly accomplished by trenching and exposing the stratigraphy of the channel and flood-plain deposits of North Fork Coyote Wash just upstream from the originally proposed site of the exploratory shaft (figs. 2 and 5). The trench exposures allowed examinations, documentation, and interpretations of the deposits. The stratigraphic disclosures

Figure 2. Coyote Wash drainage.

helped in the assessment of the number of floods represented, allowed a formulation of some sense of the ages of various floods, and allowed a characterization of specific floods according to their hydraulic behavior. Other pertinent data were assembled by surveying cross-sectional and longitudinal profiles of the land surface of the sediment deposits.

The resultant flood history, although only fragmentary, was translated downstream to the nearby site originally selected for the proposed exploratory shaft. Application of knowledge of the chronology and characteristics of past floods indicated that on the basis of this drainage-basin history, the proposed shaft could probably experience numerous floods during the next few thousand years, and that some of the floods could be debris flows capable of moving hazardous debris loads.

The fragmentary flood history was supplemented by a quantitative estimate of the peak discharge of a large flood that had previously occurred. This quantitative determination of flood magnitude was based on hydraulic factors related to the size of the largest boul-

Figure 3. Northwestward view of the site of the original proposed exploratory shaft for the nuclear-waste storage facility (photographed from Live Yucca Ridge on March 17, 1984).

ders remaining in the stream channel that assumedly had moved during a single flood event.

Results of the field studies of prehistoric flooding were supplemented with office exercises to estimate the potential maximum-size floods that could be expected to impact the flood-plain area where the shaft site had been tentatively sited. These potential maximum discharges were derived by two techniques:

1. The U.S. Bureau of Reclamation calculated the Probable Maximum Flood discharge (Bullard, 1986) which was modified by the author of this report to include a reasonable sediment-discharge component, and the modified discharge was included in this report for comparison with other estimates of potential-maximum flood discharges.

2. Several potential-peak flood discharges were derived from different data-based regional and national envelope curves. The envelope curves relate maximum streamflow discharges that have been measured throughout given geographic areas to their specific drainage-basin areas; these sets of measured discharges and their specific drainage areas define graphical curves that can then serve as guides for making "rule-of-thumb" estimates of the magnitudes of the potentially largest flood discharges that could be expected at a given site on the basis of the size of the upstream drainage area.

Preliminary results of the prehistoric flood history, estimates of peak discharges of the potentially largest floods possible, and modified results of the U.S. Bureau of Reclamation's Probable Maximum Flood calculations formed a basis for rejection of the originally proposed site for the exploratory shaft. A different site was then proposed that was higher than, and a short distance northeast of, the original site (fig. 2). The relocated site is on a bedrock slope that is above and beyond any readily discernible flood-plain deposits of Coyote Wash.

Previous Work

Geology of the study area was mapped in the early 1960's by Lipman and McKay (1965) and more recently by Scott and Bonk (1984). Interest in geomorphology and geomorphic processes at NTS has increased during recent years. The first results of a surficial-geology mapping project at NTS have been published by Hoover and others (1981) and Swadley (1983); these results classify the relative ages of different alluvial deposits near Yucca Mountain. Results of a paleoclimatic study of the past 45,000 years in the region also are available (Spaulding, 1983). Possibilities of floods and flood hazards at NTS are discussed by Christensen and Spahr (1980) and Squires and Young (1984) and major floods in nearby areas have been documented by Glancy and Harmsen (1975) and Katzer and others (1976). Precipitation at and near NTS, the prime impetus for flooding, is the subject of reports by Quiring (1965, 1983) and French (1983).

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PHYSIOGRAPHY OF THE STUDY SITE

Yucca Mountain is a generally north-trending ridge along the western boundary of the Nevada Test Site (fig. 1). Topographic prominence of Yucca Mountain mainly results from a series of bounding, north-south normal faults. Coyote Wash basin is a small (approximately 0.3 mi^2) ephemeral drainage on the eastern flank of Yucca Mountain (figs. 1 and 2); it is tributary to Drill Hole Wash, which is tributary to Fortymile Wash. Fortymile Wash basin is a major drainage basin of over 300 mi^2. Fortymile Wash and its numerous tributaries, including Coyote Wash, flow only during infrequent periods of intense precipitation or snowmelt. Fluvial erosion and deposition of sediment in this drainage system thus occur infrequently during the short term (years or tens of years); however, during the long term (hundreds or thousands of years), numerous floods and associated erosion have occurred.

The North and South Forks subbasins of Coyote Wash basin are separated by Middle Ridge. The ridges bounding Coyote Wash basin are known as Dead Yucca Ridge, which lies to the north, and Live Yucca Ridge, which lies to the south. The physiographic setting of the proposed shaft sites are shown photographically (figs. 4-6).

The 1:24,000-scale topographic map of the area [U.S. Geological Survey, (Busted Butte, formerly Topopah Springs SW quadrangle), 1961] indicates that the total length of the oblong-shaped Coyote Wash basin is about 1.25 mi and its average width is about 0.25 mi. Combined drainage area of the two tributary subbasins upstream from the potential shaft sites is about 0.199 mi^2, or about two-thirds of the total Coyote Wash drainage of 0.294 mi^2. The North Fork subbasin is 0.094 mi^2, and the South Fork subbasin is 0.105 mi^2. Thus, 0.095 mi^2 of drainage area contributes to Coyote Wash downstream from the proposed shaft site. Total basin relief is about 860 ft (between 3,980 and

Figure 4. West-northwestward view up Coyote Wash drainage just upstream from the potential shaft sites (photographed on March 17, 1984).

Figure 5. South-southwestward view of original potential shaft site from the south-facing slope of Dead Yucca Ridge (Coyote Wash tributaries flow from right to left; photographed on March 17, 1984).

Figure 6. Southwestward view of Middle Ridge from south-facing slope of Dead Yucca Ridge (potential shaft sites are a short distance to left and below photo scene; North and South Forks Coyote Wash flow from right to left; photographed on March 17, 1984).

4,840 ft); the average basin slope is about 0.130, or 7.5°. Bedrock exposed at the surface or underlying a relatively thin alluvial cover on ridge slopes is the Tiva Canyon Member of the Paintbrush Tuff, an ash-flow tuff of Miocene age (Lipman and McKay, 1965; Scott and Bonk, 1984). Most of the alluvium that partly mantles the drainage was derived from the Tiva Canyon Member; an undetermined part of the fine-grained fraction of the unconsolidated deposits probably is of eolian origin, derived largely from sources outside of the drainage.

Average annual precipitation at Yucca Mountain during 1964 to 1981 was about 6 in. (Quiring, 1983, p. 15-16); of that average, about 70 percent probably fell during the cool (October-April) season and about 30 percent fell during the warm (May-September) season (Quiring, 1983, p. 17-18). Vegetation is moderately sparse, mainly consisting of a scattered cover of desert shrubs, grasses, and a few cacti that do not inhibit erosion or runoff effectively during episodes of intense rainfall, especially on the drier south-facing slopes.

The original proposed location of the exploratory shaft was in the main channel of Coyote Wash (Nevada State Coordinates N766, 081 and E563, 266), a short distance downstream from the confluence of the North and South Forks (figs. 2, 3, and 5). The proposed site of the shaft was relocated about 400 ft northeast to decrease its susceptibility to flooding hazards (Nevada State Plane Coordinates N766,255 and E563,630). The new site is underlain by volcanic bedrock, whereas the land surface at the originally proposed shaft site is underlain by stream-channel sediments. Both proposed shaft sites are located about four-fifths of the distance from the basin crest to its terminus, which is at the confluence with Drill Hole Wash. Upstream from the junction of the North and South Forks, Coyote Wash basin is about 0.9 mi in length and averages about 0.25 mi wide. The channel is underlain by alluvium and colluvium of variable thickness upstream from the confluence with Drill Hole Wash (the mouth of Coyote Wash) to about 0.1 or 0.2 mi upstream from the junction of the North and South Forks. The thickness of these unconsolidated sediment deposits downstream from the trenches generally is unknown, but probably is less than 50 ft at the originally proposed shaft site. In places upstream from this contiguous zone of sediment deposits, the tributary channels are incised within a generally thin cover of alluvium and colluvium; the channel bottom is on bedrock in some places. Near the head of the drainage, for about the upper 0.15 mi of drainage length, the topography flattens and an alluvial and colluvial cover of unknown thickness again dominates the landscape. Steeper hillslopes below the drainage crest, downstream to the North and South Fork confluence, consist of bedrock (consolidated tuff) or are thinly mantled with colluvium, alluvium, and regolith (figs. 4 and 6).

Results of a reconnaissance of the Coyote Wash basin, including the North and South Fork subbasins, indicated that fluvial erosion, fluvial-sediment transport, and fluvial-sediment deposition currently are the dominant land-sculpturing processes in the drainage basin. This reconnaissance also disclosed abundant evidence of intensive erosion and land-slope failures (rills and stripped slopes) and sediment deposition associated with mass movement and fluvial processes.

The ages of the major movements of water and sediment, indicated by erosion scars and sediment deposits, are critical to an adequate understanding of paleoflooding. No evidence enabling age determinations was discovered on the surfaces of hillslopes or stream channels. Stream terraces are present in places, but no evidence was found to establish their absolute ages. The unconsolidated detritus in and along the major drainage thalwegs was the most obvious source of possible evidence noted. Stone stripes on the hillslopes indicate the possibility of rapid movement of large detritus down the slopes; however, the formational processes and ages of stone stripes in this region are not well understood. Also, the ages of stone stripes are not easily determined.

EVIDENCE OF PREHISTORIC FLOODING

Results of the reconnaissance of Coyote Wash drainage indicated that the best evidence of past flooding in the drainage would be determined by a stratigraphic investigation of stream-channel deposits. The lower reaches of the major tributary channels of Coyote Wash (North and South Forks) contain substantial deposits of fluvial sediment. The originally proposed exploratory-shaft site location is on the surface of unconsolidated Quaternary sediment deposits of unknown thickness. However, test hole USW G-4 (fig. 2), about 100 ft to the south, penetrated about 22 ft of unconsolidated sediments before bedrock was encountered (Bentley, 1984, p. 6); on the basis of that information, thickness of unconsolidated deposits at the original shaft site is estimated to be probably less than 50 ft. The relocated shaft site is on a bedrock drainage-divide shoulder a short distance northeast of and higher than the alluvial flood plain (fig. 2). Unfortunately, sediment deposits near the mouth of South Fork Coyote Wash, just upstream from the shaft site, were badly disturbed and largely removed by clearing and leveling operations related to the earlier drilling of test hole USW G-4 (fig. 2); thus, investigation of sediment deposits of South Fork Coyote Wash was prevented. Channel deposits in the lower reaches of North Fork Coyote Wash, also just upstream from the proposed shaft sites, were almost undisturbed. The surface configuration of some of these deposits is irregular; locally, lobate concentrations of boulders and cobbles are at the surface, indicating that these deposits were probably emplaced by debris flows. Because the age of these deposits was not known, trenches were excavated through the deposits to examine internal stratigraphy, to interpret modes of emplacement, and to possibly determine depositional ages.

Stream-constructed terraces were discovered throughout the general reach of North Fork Coyote Wash where the trenches were excavated. Topographic slopes of the terraces were profiled by using a surveying level, and the resultant topographic profiles were geomorphologically interpreted.

Trenching and Stratigraphic Data Collection

A bulldozer was used to excavate trenches through sediment deposits in the channel of North Fork Coyote Wash at two sites about 0.1 mi upstream from the originally proposed shaft site (figs. 3 and 7). The upstream cross-channel trench was excavated through the channel sediments to the underlying bedrock (fig. 8), about 120 ft in length and to a maximum depth of about 8 ft (pl. 1). It was cut perpendicular to the stream channel to expose a complete, vertical section of the channel deposits. A second trench, T-shaped, about 180 ft downstream from the cross-channel trench, dissected sediments resembling debris-flow deposits. Aligned with the T-leg parallel to the channel, this trench thus exposed the upper few feet of this deposit both longitudinally and laterally (fig. 9). Length of the T leg is about 40 ft; T-bar width is about 70 ft, and maximum depth is about 4.5 ft (pl. 1 and figs. 10 and 11).

Generalized trench sketches, prepared from onsite examinations and measurements, are shown on plate 1. Photographs of the trenches, shown on plate 1 and in figures 10 and 11, also were used to prepare the sketches. These sketches depict the general stratigraphic relations of the various textural units; large-scale, detailed trench logs are beyond the scope of this report.

Fine-grained matrix sediment was sampled for color comparisons from 10 stratigraphic units exposed

Table 1. Matrix-material colors from selected stratigraphic units of North Fork Coyote Wash trenches

Stratigraphic unit (pl. 1)	Munsell color[1] (dry)
A (debris-flow component)	10 YR 6/4; light yellowish-brown
B	10 YR 6/4; light yellowish-brown
C	10 YR 6/3; pale brown
E	10 YR 6/2-6/3; light brownish-gray to pale brown
G	10 YR 6/3-7/3; pale brown to very pale brown
J (cross-channel trench)	10 YR 6/3; pale brown
J (T-bar component of T-shaped trench)	10 YR 6/3-6/4; pale brown to light yellowish-brown
K	10 YR 6/3; pale brown
L	10 YR 6/4-7/4; light yellowish-brown to very pale brown
R	10 YR 6/3-7/3; pale brown to very pale brown
S	10 YR 7/3; very pale brown

[1] Munsell colors are the color standards accepted for soil classification by the U.S. Department of Agriculture (U.S. Bureau of Plant Industry, Soils, and Agricultural Engineering, 1951). The specific color names listed in this table are preceded by the corresponding Munsell notations of color to provide increased precision for characterizing the colors of samples collected. Munsell color notations consist of three variable components that collectively specify all colors in the system according to hue, value, and chroma. For example: 10 YR 6/4 specifies a Munsell color with a hue (relation to red, yellow, green, blue, or purple) of 10 YR (10 specifies the yellow-red range as maximum yellow with minimum red; 5 would indicate a midrange of yellow to red), a value (degree of lightness) of 6, and a chroma (strength) of 4.

Figure 7. Southwestward view of trenches excavated in North Fork Coyote Wash (downstream is down and to the left in photo; photographed on March 17, 1984).

Figure 8. Northward view of cross-channel trench excavated in North Fork Coyote Wash (bottom of trench is at contact of alluvium with bedrock; photographed on August 17, 1983).

Figure 9. Northward view of T-shaped trench excavated in North Fork Coyote Wash (wash flows from left to right; photographed on August 17, 1983).

Figure 10. Upstream (west) wall of T-bar part of T-shaped trench excavated in North Fork Coyote Wash (note rock hammer for scale; stratigraphy delineated and described on pl. 1; photographed on August 17, 1983).

Figure 11. South wall of T-leg part of T-shaped trench excavated in North Fork Coyote Wash (maximum height of trench wall is about 4.5 ft; length of trench wall is between 35 and 40 ft; stratigraphy delineated and described on pl. 1; photographed on August 17, 1983).

in the trench walls. Results are listed in table 1. Color designations were assigned by visual comparisons of the dry sediment with scientifically calibrated standard color references known as Munsell Soil Color Charts. Munsell colors are the color standards accepted for soil classification by the U.S. Department of Agriculture (U.S. Bureau of Plant Industry, Soils, and Agricultural Engineering, 1951).

Samples were collected from the trench walls to determine particle-size distribution in each stratigraphic unit. These data are listed in tables 2 and 3 and discussed in the next section of the report. Because individual stratigraphic units are nonhomogeneous and the samples collected might not be statistically representative of the respective particle populations, any single sample might not portray precisely the particle-size character of the unit; however, the data probably provide a general sense of the particle-size characteristics of most units. Samples from all units did not include cobbles and boulders when present; otherwise, they probably represent adequately the particle-size distribution of the matrix material contained in the deposits.

Trench Stratigraphy

Nineteen stratigraphic units were identified in the trench walls that expose the sediment deposits of North Fork Coyote Wash (pl. 1) on the basis of visual differences in the textural characteristics of the deposits. Sediments exposed in the trenches have several features in common. Rock fragments coarser than sand are virtually monolithologic because all the particles were derived from the Tiva Canyon Member of the Paintbrush Tuff that underlies the entire drainage basin. These fragments were transported a relatively short distance after they were detached from bedrock; most are angular or only slightly rounded. Weathering characteristics of the bedrock produced many platy-shaped lithic fragments that had a low degree of sphericity, particularly among particles smaller than cobbles; higher degrees of sphericity generally seem to be more characteristic of rock fragments that are the size of cobbles and boulders.

A substantial, but undetermined, fraction of the fine-grained sediments (sand size and finer) probably is of eolian origin and was blown into North Fork Coyote Wash drainage from other drainages; the dominant colors of this windblown material are tan to brown. This subtle color variability indicates the fine-grained fraction of the deposits is not as monolithologic as the coarse-grained fraction. Colors of the various stratigraphic units are affected by the relative proportion of: (1) Brown detritus among the fine-grained particles (sand and finer) and (2) gray coarse-sized rock fragments (coarser than sand). A color classification for only the fine-grained fractions of several of the stratigraphic units listed in table 1 indicates that only subtle differences in the overall colors of the fines are perceptible.

The monolithologic character of the rock fragments larger than sand size causes a generally monochromatic grayish appearance to most of the sediment deposits. However, color does vary between the monolithologic tuff fragments. Tonal variations in the gray color of the coarse-grained fragments are affected by: (1) The unweathered color of the Tiva Canyon Member, and (2) the degree of chemical weathering of the individual fragments. The weathering characteristic that most strongly alters color of the tuff fragments is a carbonate precipitate that differentially coats some particles. The degree to which fragments are coated ranges from wholly uncoated clasts, which show the fresh or weathered color of the newly fractured Tiva Canyon Member, to totally coated fragments, which in turn show the off-white color of the carbonate precipitate. Specific shades of gray of the uncoated clasts are variable, depending on the degree of chemical weathering of the bedrock from which they were derived and on the individual weathering and fracture histories of the clasts after they detached from bedrock.

Ten samples were collected from the matrix material of selected stratigraphic units of the trench walls for particle-size analyses; analytical results are listed in tables 2 and 3. The resultant particle-size data of table 2 were transposed graphically into grain-size accumulation curves for each of the 10 samples. Particle diameters for the D_{75} and D_{25} (particle diameters for which 75 and 25 percent, by weight, are finer) fractions were extracted from the grain-size accumulation curves for use in determining the Trask sorting coefficient for each sample. The coefficient is calculated as $\sqrt{D_{75}/D_{25}}$. According to Trask (1932, p. 71 and 72), a coefficient smaller than 2.5 indicates a well-sorted sediment; a coefficient of 3.0 is "normal"; a coefficient larger than 4.5 indicates poorly sorted sediment. The coefficients in table 2 indicate that only one sample is "normally" sorted according to Trask's criteria; coefficients for the remaining nine samples range from 4.6 to 10.3, indicating poorly sorted sediments for those units.

Costa and Jarrett (1981, table 2, p. 315) compiled data on Trask sorting coefficients for sediment deposits emplaced by eight debris flows and three water-dominated floods. From these data, they concluded that average sorting coefficients for debris flows and mud-

Table 2. Particle-size distribution of matrix material from selected trench deposits[1]

Sample number (pl. 1)	Stratigraphic unit (pl. 1)	Particle size (millimeters)						Trask sorting coefficient[2]
		0.001	0.005	0.074	2.0	4.0	63.5	
		(Percent finer by weight)						
1	A	3.1	8.0	20.8	43.2	58	100	10.3
2	B	0.9	2.5	5.9	22.4	26	100	3.2
3	E	0.7	2.0	8.2	29.2	41	100	4.6
4	C	0.5	2.1	8.1	34.8	40	93	6.8
5	G	0.7	2.1	9.4	26.8	28	68	6.3
6	S	0.7	1.9	13.8	30.8	31	67	8.9
7	S	0.9	1.9	9.1	23.7	25	52	5.2
8	R	0.4	1.1	5.9	28.9	36	94	4.8
9	K	0.2	0.6	4.5	13.0	16	95	6.5
10	N	0.4	1.1	9.8	31.3	33	85	4.9

[1] Particle-size distributions determined by Holmes and Narver, Inc., Materials Testing Laboratory at the Nevada Test Site using sieve and hydrometer techniques.

[2] Sorting coefficient (Trask, 1932) for which a coefficient smaller than 2.5 is well-sorted sediment, 3.0 is normal, and larger than 4.5 is poorly sorted.

Table 3. Particle-size distribution of matrix material from selected trench deposits according to size classes

[Particle-size distributions determined by Holmes and Narver, Inc., Materials Testing Laboratory at Nevada Test Site, using sieve and hydrometer techniques; mm, millimeter; <, less than; >, greater than]

Sample number (pl. 1)	Stratigraphic unit (pl. 1)	Size class					
		Colloids (<0.001 mm)	Clay (<0.005 mm >0.001 mm)	Silt (<0.074 mm >0.005 mm)	Sand (<2 mm >0.074 mm)	Pebbles (<63.5 mm >2 mm)	Larger than pebbles (>63.5 mm)
		(Percent, by weight)					
1	A	3.1	4.9	12.8	22.4	56.8	0
2	B	0.9	1.6	3.4	16.5	77.6	0
3	E	0.7	1.3	6.2	21.0	70.8	0
4	C	0.5	1.6	6.0	26.7	58.2	7
5	G	0.7	1.4	7.3	17.4	41.2	32
6	S	0.7	1.2	11.9	17.0	36.2	33
7	S	0.9	1.0	7.2	14.6	28.3	48
8	R	0.4	0.7	4.8	23.0	65.1	6
9	K	0.2	0.4	3.9	8.5	82.0	5
10	N	0.4	0.7	8.7	21.5	53.7	15

flows range from 3.9 to 11.5 and that coefficients for average sorting coefficients for debris flows and mudflows range from 3.9 to 11.5 and that coefficients for sediments deposited by waterfloods in mountainous regions range from 1.8 to 2.7 (Costa and Jarrett, 1981, p. 313). According to these criteria, all 10 samples collected from the trenches of North Fork Coyote Wash (colluvium) generally are poorly sorted, indicating all or most units sampled could be of debris-flow origin. Although other depositional criteria also must be met to distinguish debris-flow deposits from water-dominated flow deposits, principally the chaotic and heterogeneous admixing of all erodible-size particles and the absence of stratification, results of the sorting criterion applied to the North Fork Coyote Wash samples indicates the sediments were deposited rapidly with inherently poor sorting. The ephemeral and flash-flood character of present-day (1992) runoff in the study area would be expected to produce deposits that also would be poorly sorted.

The deposits exposed by the cross-channel and T-shaped trenches do not represent a continuous and uninterrupted history of deposition at the sites where the trenches were dug because some floods probably did not deposit sediment at these sites and some deposits may have been eroded; rather, the deposits represent an unknown fraction of the total geologic record from the time of emplacement of the underlying bedrock of the Tiva Canyon Member of the Paintbrush Tuff. These sediment deposits, of late Quaternary age, overlying late Tertiary bedrock (Tiva Canyon Member), denote a deposition hiatus of several million years. Thus, no record of flooding and debris movement remains from that long period except the presence of the stream channel incised in the bedrock; no evidence of the magnitudes or frequencies of runoff remain. Because runoff evidence clearly is incomplete, competent analyses and interpretations of the deposits exposed by the trenches will at best yield fragmentary records of the history of flooding and debris transport in North Fork Coyote Wash. Although no sites are known in the drainage basin where fluvial deposition was continuous, those selected near the potential locations of exploratory shafts likely are representative choices for trenching to investigate the paleoflood history.

Cross-Channel Trench

The upstream cross-channel trench (figs. 3 and 7) exposes complex erosional and depositional evidence within Quaternary deposits of North Fork Coyote Wash. This trench was cut to Tiva Canyon Member bedrock across the full channel width. The safety requirements, which enabled only one wall of the trench to remain vertical, restricted comparisons between strata exposed in the upstream and downstream (west and east) walls. A diagrammatic cross-sectional sketch of the upstream, vertical west wall of the trench and a composite photograph of the vertical trench wall, taken about 7 months after excavation, are shown on plate 1.

Sediments in the upstream trench wall were separated into two general age groups on the basis of weathering and induration: (1) Two older basal units (units A and B of pl. 1) composed of slightly to moderately indurated sediments, which overlie the Tiva Canyon Member of the Paintbrush Tuff; and (2) eight younger, overlying unconsolidated and nonindurated units (units C-J).

Unit A

Basal unit A (pl. 1) is a heterogeneous mixture of cobbles, gravel, and fine-grained sediments that also contain a few randomly distributed boulders. A particle-size analysis of a sample from this unit (sample 1 in table 2; sampling location shown on pl. 1) consists of about 57 percent pebbles, 22 percent sand, 13 percent silt, and 8 percent clay and colloids. The sample did not contain any boulders or cobbles that are common in the deposit (photo of pl. 1), demonstrating that any single, randomly collected sample of small volume does not portray perfectly the particle-size makeup of this deposit. The sample probably is a reasonable representation of the matrix of the deposit, as are other samples from other deposits. However, one notable characteristic is the proportionately large quantity of silt, clay, and colloids in this sample compared with samples from the other units. Whether all this fine-grained sediment was part of the original deposit, or whether some unknown fraction of the sediment is the result of postdepositional pedogenesis or weathering, is uncertain. The upper surface of unit A, along its contact with overlying units C, D, and E, includes a concentrated layer of coarse cobbles and small boulders typical of the upper surface of many debris-flow deposits. This zone of large clasts is dominated by fragments in the 3- to 10-in. size.

Texturally, most of unit A qualifies as a debris flow. Costa and Jarrett (1981), Costa (1984), and J.E. Costa, (U.S. Geological Survey, written commun., 1985) characterize debris-flow deposits as: (1) Lacking internal bedding, (2) comprising a heterogeneous distribution of different sized detrital particles, and (3) having a combined silt-clay content equal to or exceeding 6 percent. Unit A qualifies on all criteria. The Trask sorting coefficient of 10.3 for sample 1 is the largest coefficient of the 10 samples; it indicates very poor sorting and is well within the range of coefficients for debris flows (Costa and Jarrett, 1981, p. 313). However, debris-flow deposits can appear strikingly similar texturally to slope-wash deposits. The wedge-shaped southern part of unit A, texturally similar to debris-flow deposits (pl. 1), seems to be indurated slope wash (colluvium) because of the lateral persistence of unit A up the slope of Middle Ridge, southward and away from the channel. However, the remaining thicker mass of the deposits, at the north end of unit A near the bedrock channel axis, seems to be a debris-flow deposit because overland runoff that is competent enough to transport larger clasts (1- or 2-ft-diameter boulders) downslope as unsorted slope wash probably would concentrate adequate streamflow in the wash channel to sweep the accumulated slope wash downstream. Therefore, unit A deposits probably are derived from two sources: (1) Mostly debris-flow material that traveled some distance down the channel before coming to rest (massive northern part of the unit); and (2) a lesser volume of material, upslope and away from the flood plain of the wash (southern part), which traveled down the north-facing slope of Middle Ridge through the action of gravity, assisted by water flow not concentrated in channels. The stratigraphic evidence that supports a dual genesis for unit A deposits, as shown on plates 1, includes: (1) A concentrated layer of mixed cobbles and boulders at the top of the northern part of unit A terminates abruptly at its southern limit and forms a vertically stacked concentration of similar coarse fragments at its northern limit, about midway beneath the length of the contact with overlying unit D; the abrupt lateral termination of coarse clasts southward along the surface of unit A probably indicates a lithologic boundary between the thinner slope-wash deposits of unit A to the south and thicker debris-flow deposits of the unit to the north; (2) the accumulation of coarse clasts at the surface of the northern part of the unit is common to deposits emplaced by debris flows; and (3) both the slope-wash and debris-flow components of unit A consist of unbedded, unsorted, mixed-size materials that probably have a combined silt-clay fraction exceeding 6 percent (a sample of the debris-flow component has about 20 percent combined silt, clay, and colloids).

An older age for unit A, relative to other deposits of the cross-channel trench, is indicated by two lines of evidence: (1) A lower stratigraphic position and (2) the indurated character of the deposits. Induration is absent in overlying units. Moderate induration of the northern part of unit A (debris-flow deposits) probably is caused by a weak carbonate cementation; minute stringers of carbonate are visually present throughout the matrix. The southern part (slope-wash deposits) is moderately indurated near the top of the unit and is well cemented near its contact with underlying bedrock. The presence of the incorporated carbonate stringers and the degree of induration of the northern debris-flow deposit indicates it is more mature pedogenically than the overlying mass of nonindurated sediment deposits. D.L. Hoover, (U.S. Geological Survey, oral commun., 1985) considers the deposits of unit A to be equivalent in age (late Pleistocene) to subunit Q2a (Hoover and others, 1981, p. 9). Subunit Q2a comprises mappable geomorphic deposits of a specific stratigraphic character that are present in the vicinity of Yucca Mountain. The nonuniform thickness of the unit and the absence of unit A in the center and northern sections of the channel of North Fork Coyote Wash indicate that some of the unit might have been removed by postdepositional erosion.

Unit B

Debris-flow deposits that comprise unit B, a heterogeneous mixture of particles of various size, mostly overlie bedrock near the center of the cross- channel trench (pl. 1). A few scattered large clasts have average particle diameters ranging from 0.7 to 1.5 ft; most of the coarse-grained fraction consists of cobbles in the 2.5- to 4-in. size range. Unit B seems to resemble other units more than it resembles unit A in particle-size distribution. Particle-size sample 2 from this unit has the smallest Trask sorting coefficient (3.2) of any sample (table 2). That the sorting coefficient is approximately 3 indicates a nearly normal deposit with regard to sorting; however, visually, the deposit appears to be poorly sorted (photo, pl. 1). The sample was composed of matrix material and thus did not contain fragments larger than pebble size; however, particle-size characteristics of the matrix should be comparable to size characteristics of the matrix components of the other units. The deposits of unit B have a matrix predominantly of sand and finer size particles, much of which might be of eolian origin.

The southern end of unit B abuts the northern end of unit A; however, except for some coarse fragments along the upper part of the contact (photo, pl. 1) and an abrupt decrease in induration north of the contact; the boundary between the two units is diffuse and vague. It is difficult to determine whether the two units were deposited contemporaneously, or whether unit B was deposited after earlier deposits of unit A had been eroded to bedrock to form the channel bottom north of the present extent of unit A. In contrast to unit A, unit B is only differentially indurated. Both units are a subtle yellowish to reddish color, visually distinctive from overlying deposits. This yellowish-reddish color indicates that deposits of units A and B are more oxidized than overlying units and that units A and B were deposited appreciably earlier than overlying deposits.

The lower one-half of unit B is moderately indurated, similar to the northern part of unit A; its upper part is weakly indurated. A lenticular pod more intensively indurated than surrounding material exists along the basal and northern part of unit B (pl. 1); this pod may be an erosional remnant of unit A deposits that subsequently was buried by deposits of unit B. Currently (1992), reasons for the marked contrast in induration of this zone are not known.

Deposits of unit B generally are uniform in textural character laterally and vertically. They have only very slight internal bedding and impart no visual sense of particle orientation or fabric; this visual perception of texture indicates that the deposit was rapidly emplaced on the bedrock channel floor, as would occur during debris-flow deposition. Because of the marked differences between units A and B (principally, degree of induration), unit B likely is somewhat younger than unit A--tentatively Late Pleistocene or early Holocene (?).

Carbonate deposits, seemingly equivalent to a pedogenic stage-II precipitate, located at the north end of the unit, near and beneath the present channel thalweg, are discussed under unit C.

Unit C

Deposits of unit C consist of a large-size range of detrital fragments. It contains some cobbles up to 8 in. in size. The fine-grained matrix consists mainly of pebbles and sand; the sand may be mostly reworked eolian material. These deposits appear different from those of unit B, mainly in textural contrast between units, caused by a greater number of large clasts in unit C. The large (6.8) Trask sorting coefficient for particle-size sample 4 (pl. 1 and table 2) indicates a probable debris-flow origin for unit C deposits.

The contact between the northern part of unit B and overlying unit C appears sharp because of the abruptness of the perceived textural change between the two units. An obvious (although subtle) color difference also exists between the two units (table 1), and a discernible hint of fabric (preferred orientation of particles) is associated with the coarse clasts of unit C. The contact between the two units is less obvious toward the north. The deposits of unit C appear to have been emplaced in a channel that was eroded into the upper part of unit B.

There is a zone of carbonate-coated clasts throughout the lower three-quarters of unit C. Although some of the clasts have carbonate precipitates on the sides and tops, almost all clasts are coated on the undersides with a thin (generally less than 0.05 in. thick) carbonate precipitate. The thin coating of carbonate on the undersides of the clasts indicates a pedogenic, stage-I carbonate alteration of deposits of unit C. Carbonate precipitate on the sides and tops of some clasts indicates that those clasts also may have undergone pedogenic alteration in an earlier deposit and had a different particle orientation before they were reworked, transported, and redeposited as part of unit C.

At their northern extent, the clasts of unit C and underlying unit B are coated with carbonate precipitate to a degree equivalent to a pedogenic stage-II carbonate deposit. These carbonate coatings probably are not the result of pedogenesis but probably are mainly the result of repeated wetting and drying of the clasts by infiltration of occasional streamflow from the wash that deposited an accumulative carbonate residue.

Because of its overlying stratigraphic position, unit C is younger than unit B. At its southern extremity, it appears to be overlain by the northern extremity of unit E. Thus, unit C probably is younger than units A and B and probably is older than units D through J.

Units D, E, and F

Deposits of stratigraphic units D, E, and F appear to be internally bedded. Although not well developed, the slight evidence of weak bedding within these units indicates that the sediments of each of the units probably were deposited by Newtonian fluids (water-dominated flows) rather than by debris flows. A particle-size sample was collected only from unit E (sample 3, table 2). The Trask sorting coefficient for this sample (4.6), although large enough to signify a debris-flow origin according to Costa and Jarrett (1981, p. 313), is small compared with that for most other samples of this study. Stratification of unit E generally disqualifies a debris-flow genesis for the deposit. All three units are unconsolidated and nonindurated.

Unit D deposits are a mixture of gravel in a sandy matrix and have a generally characterless appearance compared with deposits of most adjacent units. Unit D seems dominantly composed of fragments in the 3-inch-diameter size but contains some randomly scattered clasts up to a 6-in. size. The deposit has a moderately abundant fine-grained matrix much of which is probably of eolian origin. Unit D overlies unit

A and underlies unit F, indicating that unit D is younger than unit A and older than unit F.

Unit E has a bulbous elliptical shape in cross section (pl. 1); its deposits are composed mainly of pebble-size chips (table 2). The interstices between chips are filled with a dominantly fine-grained sand-size matrix that might be largely of eolian origin. The generally fine-grained particle composition of unit E deposits contrasts visually with those of adjacent stratigraphic units that appear more coarse grained. Deposits of unit E contain a few randomly scattered clasts larger than the dominantly pebble-size particle population; these clasts are as large as about 2 in. in diameter. Few, if any, of these larger clasts were found in sample 3 (table 2). The numerically dominant and smaller pebble-size clasts appear to exhibit a slightly preferred depositional orientation that imparts a visual impression of a weak degree of internal bedding (discussed earlier). The upper part of unit E seems to be mildly altered pedogenically, resulting in clasts coated by stage-I carbonate precipitates. Unit E is younger than unit A. Stratigraphic relations shown on plate 1 indicate unit E was deposited after units C and B, possibly before unit F, and probably before unit G. Its age relation to unit D is uncertain.

In cross section, unit F is lens shaped and appears dominated by pebble-size clasts that have average particle diameters ranging from about 1 to 2 in. Between these larger particles is an abundant matrix of mainly sand and finer size particles that could be reworked eolian material. Clasts throughout the deposit are coated by stage-I carbonate precipitates (pl. 1). Unit F mainly overlies unit D, indicating that its age is younger than D. Unit F also appears slightly to overlap unit E, and it underlies unit G, which indicates a younger age for unit G, the overlying unit. Visually, the boundaries between unit F and adjacent units at its northern and southern ends are indistinct (photo, pl.1), although the overall texture of unit F contrasts markedly with the adjacent units.

Although units D, E, and F seem to have been deposited by water-dominated floods, and in spite of stratigraphic relations that indicate relatively different ages of emplacement, whether these units were deposited by the same or different floods is uncertain. Units D, E, and F clearly were emplaced by a different flood than the flood responsible for the debris flows of units A and B, and the deposits of units D, E, and F probably were emplaced by a different runoff than the one that deposited unit G.

Unit G

Unit G deposits are an unsorted heterogeneous mixture mainly of unconsolidated cobbles, gravel, and sand but contain some scattered boulders that are as large as 1.5 ft in diameter. The finer-grained component might be largely reworked eolian material. The orientations of individual particles indicate only very slight internal bedding. The visually apparent large range in particle sizes, lack of pronounced internal bedding, and absence of particle-size sorting indicate that most of this deposit probably was emplaced as a debris flow. The particle-size data of table 2 (sample 5) confirm the large range of particle sizes present. The Trask sorting coefficient of 6.3 also is well within the range of coefficients for debris-flow deposits described by Costa and Jarrett (1981, p. 313).

Visually prominent coatings of stage-I carbonate precipitate envelop the larger individual clasts throughout unit G. At its southern extremity, unit G overlies the old slope-wash component of unit A. As discussed before, unit G probably was emplaced by a different flood than the flood, or floods, that deposited underlying units D, E, and F.

Units H, I, and J

Deposits of unit H mantle the land surface of the lower stream terraces along the main channel of the wash. They consist of a heterogeneous mixture mainly of cobbles, gravel, and fine-grained sediments but also include a few small boulders ranging up to 1.5 ft in average diameter. The fine-grained fraction of the deposits mainly includes fine- to medium-size sand that probably includes reworked eolian material. Unit H does not appear to be altered pedogenically and it does not exhibit any internal bedding. The unit is believed to consist of fairly young flood deposits.

Deposits of unit I, a mixture of boulders, cobbles, and gravel, mantle the land surface along and near the channel thalweg. Interstices between these coarse clasts are partly filled mainly with fine pebbles and sand; remaining interstices are air-filled voids. These unconsolidated and poorly bedded sediments are modern (young) stream-channel deposits that are recurrently mobilized by streamflow. The clasts lining and underlying the present channel thalweg commonly are coated by stage-II carbonate precipitates. As with units B and C, this carbonate mainly is a precipitate that accumulated from evaporation of infiltrating streamflow rather than as a result of pedogenic processes.

Thicknesses and textures of the deposits of units H and I differ both laterally and longitudinally upstream and downstream from the cross-channel trench; measured thicknesses are as large as about 1.5 ft. The lower contacts of units H and I are always at, or higher than, the pedogenically altered, stage-I carbonate zone. Because thicknesses of units H and I do not exceed 1.5 ft in the trench wall, those units are relatively thin compared with units B and C. The upper surface of units H and I in the photograph on plate1 is at the top of the dark zone that contains organic fragments of grass and shrubs; the lighter colored debris overlying that zone (as thick as about 1.5 ft) is material cast aside by the bulldozer blade during trench excavation and is not included in the sketch on plate 1.

Deposits of unit J mantle the land surface at the northern and southern extremities of the trench wall and are a mixture of mostly gravel and fine-grained materials, but with some large cobbles and boulders ranging in size to as much as about 0.5 ft in maximum diameter. These deposits are unconsolidated and internally unbedded, and they do not appear to be pedogenically altered, except for a possible trace of a cambic-B soil horizon along the southern end of the trench wall, near the contact of unit J with unit G. These are deposits of modern slope wash (colluvium) that were emplaced by unchannelized runoff and soil creep from the hillslopes bordering the channel. The matrix of these sediments contain a substantial amount of eolian-derived material. These deposits are younger than the deposits they overlie (units A-H).

Units I and J continue to accumulate modern sediment deposits. The extensive upper surfaces of units H, I, and J and lesser exposed surfaces of units E and G are the stratigraphic units most subject to future erosion because of their location at the land surface.

Interpretations of Stratigraphic-Age Relations of the Cross-Channel Trench Deposits

The oldest sediments deposited on the Tiva Canyon Member of the Paintbrush Tuff (Miocene) bedrock floor of the North Fork Coyote Wash channel at the site of the cross-channel trench are sediments believed to be of debris-flow origin; this deposit probably is of late Pleistocene age (unit A). At this site, no evidence of flooding and debris movement remains from the late Tertiary or early Pleistocene time, a cumulative time period of several millions of years. Undoubtedly, intensive runoff occurred during that prolonged period because the bedrock channel was eroded during that time. Sediment deposits of unit B likely are younger than those of unit A because they are clearly less indurated; these deposits possibly are of late Pleistocene or early Holocene (?) age. Unit B sediments also appear to consist mainly of debris-flow deposits. Thus, the differing induration of the deposits of units A and B indicates that at least two episodes of debris flows occurred at this site during late Pleistocene or early Holocene time.

The oldest appearing nonindurated deposits, based on stratigraphic position (pl. 1), are those of unit C, also probably debris-flow deposits. By their stratigraphic positions, units D, E, and F are the next youngest deposits; all three of these units seem to have been deposited by Newtonian (water-dominated) flows, but whether each unit represents a separate runoff or whether all, or most, were deposited by the same runoff is not known. Debris-flow deposits of unit G seem to be of younger age than the units they overlie (units A-F); thus, evidence exists within the nonindurated deposits of at least a second episode of late Quaternary debris-flow activity following the episode recorded by indurated deposits of unit A. Deposits of units C through G currently (1992) are believed to be mainly of Holocene age, as is discussed below.

Deposits of units H and I are evidence of relatively recent floods believed to have been Newtonian fluids. Modern slope-wash deposits of unit J likely are products of hillslope-erosion processes and are approximate time equivalents of the channel deposits of units H and I.

Pedogenic alteration (stage-I carbonate deposition), a time-dependent process, of units C through G indicates that those deposits may be relatively old. Also, the zone of carbonate deposition generally conforms to the land-surface topography. In general appearance, the intensity of carbonate coatings on clasts differs laterally and vertically throughout the roughly 3-ft-thick zone of carbonate precipitation (pl. 1). The textural units that evidence the most prominent whitish color as imparted by the particle coatings are those containing the largest fragments or largest concentrations of coarse fragments. The fine-textured units do not display the whitish-color coatings as vividly as do the coarse-textured units. However, on closer examination, although they seem less white in gross appearance, the finer textured zones and units also have stage-I carbonate coatings on individual particles, mainly on the undersides of the clasts. Machette (1985, p. 8) discusses the apparent visual differences in pedogenic carbonate accumulation within deposits of variable texture: "The soil in coarse-grained material appears stronger in outcrop, mainly because coarse sands and gravels have less surface area to coat with carbonate than do silts and clays."

Gile (1975, p. 358), from onsite evidence in the area near Las Cruces in southern New Mexico, believes that carbonate accumulations in soil horizons are the most common and best pedogenic indicators of the ages of soils. He also notes that stage-I carbonate horizons are a major feature of Holocene-age pedogenesis. Gile discovered pebbles that had discontinuous carbonate coatings younger than 1,130 years before present and pebbles that had continuous carbonate coatings younger than 2,120 to 2,850 years before present. Gile's conclusions, assuming they apply to southern Nevada, indicate that the deposits containing the zone of stage-I carbonate deposition could be on the order of one thousand years old or older. Whether soil-forming processes in New Mexico are equivalent or comparable to those at NTS is uncertain. Therefore, an absolute age of the land surface underlain by the pedogenically altered deposits cannot be determined until more is known about local carbonate deposition rates. If local carbonate deposition rates are similar to those described by Gile for New Mexico, the land surface could be as young as a few thousand years.

Only a possible trace of a cambic-B soil horizon is present at the top of the exposed upper surface of unit G. This indicates that units C, E, and G might not be very old. Thus, the age of the upper surface defined by the tops of units C, E, and G could be from one to several thousand years old. The apparent lack of any irrefutable evidence of pedogenic alteration of deposits of units H, I, and J, combined with their stratigraphic positions, indicates that they are quite modern; the deposits of unit I probably are periodically reshuffled during moderate runoffs that can occur approximately once a decade on the average.

In summary, stratigraphic evidence exposed by the cross-channel trench in North Fork Coyote Wash indicates five probable major floods in North Fork Coyote Wash during the late Quaternary: (1) An unknown number (one or more) of intensive runoffs during late Tertiary and Pleistocene times abrasive enough to carve the bedrock channel into the Tiva Canyon Member; (2) at least two severe floods, possibly during late Pleistocene or early Holocene time, which emplaced the debris-flow deposits of stratigraphic units A and B; (3) at least two later severe floods, which emplaced the debris-flow deposits of stratigraphic units C and G. Stratigraphic relations within the cross-channel trench disclose an incomplete record of flooding in North Fork Coyote Wash. The absence of a continuous record of streamflow deposition indicates that some streamflows did not leave a depositional record and some streamflows could have removed evidence of prior deposition. Thus, an unknown number of severe floods could have occurred at unknown times in the past that are not documented by deposits at this site. The water-dominated (Newtonian fluids) late Quaternary flood, or floods, which emplaced the deposits of units D, E, and F, and an unknown number of modern floods that emplaced the deposits of units H and I collectively indicate that severe floods could have occurred frequently in Coyote Wash during late Tertiary and Quaternary times.

T-Shaped Trench

A T-shaped trench was excavated in unconsolidated sediment deposits about 180 ft downstream from the previously described cross-channel trench of North Fork Coyote Wash. The deposits trenched are adjacent to the south side of the active channel of the wash. The approximately 4-ft-deep trench exposed the stratigraphy of deposits that are characterized by a convex lobe-shaped surface. The surface is strewn with large cobbles and small boulders; it resembles the common surficial configuration of the distal end of a debris-flow deposit.

The leg part of the T-shaped trench (T-leg) is aligned approximately parallel to the probable direction of flow that deposited the debris; thus, the crossbar part of the T (T-bar) is roughly perpendicular to the probable flow direction. Sediments exposed by the T-bar part of the trench seem stratigraphically complex; delineations and interpretations of different stratigraphic units therein were uncertain. As in the instance of the cross-channel trench, stratigraphic units or subunits, or both, were differentiated visually on the basis of perceived textural differences within the deposits, as exposed in the trench walls.

Stratigraphic complexity of the T-bar part contrasts with stratigraphic simplicity within the T-leg part. Because of this wide variation in complexity, the stratigraphic units for both parts of the T-shaped trench are first described without interpretation of the origin or ages of the deposits. Following these descriptions, the various units of the T-trench are interpreted tentatively by comparison and likely correlation of units between the T-bar and T-leg parts and by attempts at correlations of stratigraphic units in the T-shaped trench with units in the upstream cross-channel trench. The common features of trench sediments discussed earlier also apply to sediments of the T-shaped trench.

Western Wall of the T-Bar Trench

Stratigraphic units exposed in the trench wall are shown by a sketch on plate 1; a photograph of the trench wall is shown in figure 10. All deposits of the

T-bar part of the T-shaped trench have clasts coated with a stage-I carbonate precipitate.

Units K, L, M, and N

Sediments of unit K dominantly are composed of chip gravel; the majority of fragments have average particle diameters of about 0.5 in.; some scattered particles are as large as 3.5 in. in diameter. The mostly sandy matrix includes a minor part of the deposit (table 2). The Trask sorting coefficient for sample 9 from unit K is 6.5. Sediments of the unit have slight internal bedding.

Sediments of unit L are a heterogeneous mixture of unconsolidated particles of various size, most of which average about 2.5 in. in diameter. Some scattered clasts have major diameters as great as 9 in. The abundant matrix consists of sand- and fine-size particles. The unit has a distorted lens shape (pl. 1), and deposits show no evidence of internal bedding.

Unit M also is a distorted lens-shaped body containing a heterogeneous mixture of fragments of variable size; deposits are texturally similar to those of unit L. Diameters of some particles are as large as about 4.5 in. Interstices between the coarser fragments are filled with an abundance of sand and finer grained particles. No internal bedding is evident within the unit.

Unit N is lens shaped and unconsolidated and its deposits are texturally similar to those of units L and M. The coarsest fragments in the unit average 2.5- to 3.5-in. in diameter, and the coarse-grained fraction is supplemented by an abundant matrix of sand- and fine-size particles (table 2). Sediments of the deposit have no internal bedding. The Trask sorting coefficient of sample 10 from unit N is 4.9.

Unit O

Unit O is a lens-shaped deposit of unconsolidated coarse-grained particles, most of which are 1- to 2.5-in. in diameter; some fragments are as large as 6 in. Voids between the particles are empty (no matrix), and structural strength of the deposit is the result of frictional interlocking between the coarse-grained fragments. No internal bedding is evident in the deposit.

Units P and Q

Unit P is also lens shaped and unconsolidated and its sediments contain a heterogeneous mixture of particles of various size, and some clasts are as large as about 6 in. in average particle diameter. Most of the coarse clasts are in the 1- to 3.5-in. average-diameter range. The deposit is texturally similar to units L, M, and N. It has an abundant matrix of sand and finer size material. No internal bedding of sediments is evident.

Deposits of unit Q are a heterogeneous agglomeration of particles of mixed size, and some boulders average about 1 ft in diameter. The largest of these boulders are about 1.5 ft along the major axis. The boulders and smaller size coarse-grained fragments are interspersed with an abundant matrix of sand and finer size material. The surface of the deposits that comprise this stratigraphic unit contains scattered concentrations of large cobbles and small boulders. The sediments are unconsolidated and unbedded.

Unit J

A small tongue of modern slope-wash deposits (colluvium) is on the surface of the southern extent of the trench wall. Lithologically and texturally, this unit is similar to the slope-wash deposits of unit J in the upstream cross- channel trench; therefore, it also was labeled unit J in this trench, and it is considered to correlate stratigraphically with modern slope-wash deposits upstream and downstream in North Fork Coyote Wash.

Southern Wall of the T-Leg Trench

Stratigraphic units exposed in the trench wall are shown by a sketch on plate 1. They also are pictured in the composite photograph, figure 11.

Unit R

Sediment deposits of unit R mainly are composed of chip gravel having a dominant fragment size of about 0.5-in. average diameter. The deposits include some scattered larger clasts of small cobble size as large as about 5 in. in diameter. The matrix makes up a minor part of the deposits; however, sand-size fragments dominate the matrix (table 3). Sediments of unit R seem to have very slight internal bedding, although specific layers are rather obscure and cannot be traced laterally. This visually slight horizontal layering is shown in figure 11. A zone of carbonate-coated clasts extends through part of the unit (pl. 1). The carbonate coatings appear to be a stage-I carbonate precipitate resulting from pedogenic alteration of the deposits. The Trask sorting coefficient for sample 8 of unit R is 4.8 (table 2); this is small compared with coefficients of most of the other trench samples.

Unit S

Unit S comprises a massive deposit containing a heterogeneous mixture of particles of various sizes. Most of the coarse-grained fraction consists of fragments in the 1- to 3-in. average particle-size range; the deposit includes some randomly scattered boulders as large as about 1 ft in diameter. A sand and finer grained matrix fills the interstices between the coarse-grained fragments of the deposit. Two samples were collected from unit S for particle-size analyses; sample 6 probably is representative of the bulk of the deposit, and sample 7 was collected near the downstream terminus (toe) of the deposit. Both samples verify the large range of particle sizes present. The Trask sorting coefficient of 8.9 for sample 6 is second only to sample 1 of unit A in affirmation of poor sorting.

No evidence of internal bedding was detected within the deposit of unit S, although a sense of particle orientation, or fabric, is portrayed visually by the coarse-grained clasts (fig. 11). The surface of the deposit is mantled by a concentrated layer (1 and 2 particles thick) of coarse fragments; many are the size of small boulders (about 1 ft in average diameter) mixed with some cobbles of medium and large size. The areal density of coarse fragments that cover the land surface of unit S is about 80 percent. Surface and near-surface clasts commonly are not coated by carbonate precipitate; however, clasts within the unit below an average depth of about 1 ft beneath land surface (pl. 1) are coated with a stage-I carbonate precipitate, similar to unit R described previously.

Unit J

A thin, areally restricted deposit of modern slope wash mantles the distal (east) end of the trench wall. This deposit is lithologically and texturally like the modern slope wash of unit J exposed by both the T-bar component of the T-shaped trench and the upstream cross-channel trench; therefore, this deposit is labeled as unit J, and it is considered a downstream extension of unit J described earlier for the cross-channel trench and the T-bar component of the T-shaped trench.

Sedimentological Interpretations of T-Trench Deposits

As stated earlier, sediments exposed in the T-bar component of the T-trench appear stratigraphically complex in contrast to sediments of the T-leg component, which is just a few feet downslope. This interpretation will begin with the simple stratigraphy and progress to the more complex.

Because of their very slight internal bedding, deposits of unit R of the T-leg trench are interpreted to have been deposited by a water-dominated flow (Newtonian fluid). Also, the relatively low Trask sorting coefficient (4.8) indicates better particle sorting than that indicated for most units of the trenches and thereby favors the interpretation of water-dominated deposition. The stratigraphic position of unit R, beneath unit S, indicates that it is older than unit S. The sharp contact between units R and S (fig. 11) indicates that the two units were emplaced by separate flows. The heterogeneity of particle-size distribution, large Trask sorting coefficients (5.2-8.9), lack of internal bedding, marked concentration of coarse clasts at the surface, and the hummocky, convex, and lobelike surface form of unit S are classic characteristics of debris-flow deposits.

The zone of stage-I carbonate coated clasts that transects units R and S attributes some degree of antiquity to the deposits (units R and S), as described for carbonate coated deposits of the cross-channel trench. Lack of induration or consolidation of these deposits (units R and S) is interpreted as indicating that the deposits probably are younger than the deposits of unit A in the cross-channel trench. The deposits of units R and S likely are of late Quaternary age, probably Holocene. Because of the pedogenic indication of antiquity (stage-I carbonate accumulation), sediments are assumed to have been emplaced several thousands of years ago.

Deposits exposed in the western wall of the T-bar component of the T-shaped trench seem more stratigraphically complex than those of the T-leg trench described previously. Units Q and J resemble previously described stratigraphic units and therefore are discussed first: Unit Q has many of the same lithologic and textural characteristics of unit S of the T-leg trench component; therefore, unit Q also is interpreted to be a debris-flow deposit and tentatively is correlated as a stratigraphic equivalent of unit S. The modern slope-wash that comprises unit J also correlates well in all respects with the modern slope-wash units of the T-leg trench component and with those of the cross-channel trench upstream: Therefore, the J-unit designation was assigned to modern slope-wash (colluvial) deposits at all trench sites.

Interpretations for the six units K through P are more tenuous. Deposits of unit K visually resemble in texture and lithologic character those of unit R of the T-leg trench component, indicating that the deposits of unit K probably were emplaced by a Newtonian fluid (a hydraulically water-dominated mixture of water and sediment) rather than by a debris flow. However, the large Trask sorting coefficient (6.5) for the sample from this unit strongly indicates a debris-flow origin. Deposits of unit K are complexly interbedded, or interspersed, with lens-shaped units L through O. Units L, M, N, and P evidence the earlier described textural characteristics that are diagnostic of debris-flow deposits, except that the sample of unit N has a relatively small Trask sorting coefficient (4.9) compared with that of most other trench samples. Unit O is an unusual lens-shaped variant that will be discussed separately. The stratigraphic configuration displayed by this admixture of contrasting textural characteristics (unit K compared with units L through O; pl. 1) indicates that unit K stratigraphically is akin to a matrix that more or less engulfs the lenticular-shaped units L through O. If the textural evidence has been correctly interpreted, and the sediments of unit K were deposited by a Newtonian fluid (whereas units L, M, N, and P are debris-flow deposits), a description of the depositional sequence and processes responsible for the various units is difficult, if not impossible, at present.

Another viable hypothesis, regarding the mass of deposits exposed in the T-bar component of the T-shaped trench, is that they are collectively part of a single debris-flow deposit. The complex stratigraphic relations exposed by the trench can represent complex internal hydraulic processes active within the mass of moving debris before it came to rest.

Unit O is unique among the stratigraphic units exposed in all trenches in Coyote Wash, because the interstices between the particles of the deposit (gravel-size fragments) are air filled, rather than filled by sand and finer grained sediments. In cross section, deposits of the unit-O lens resemble coarse-grained surficial deposits scattered in channels and on slopes around the Yucca Mountain area that similarly are devoid of interstitial filling within about the first foot below land surface. These types of surficial deposits have been noted or examined by several other geomorphic investigators at NTS, including D.L. Hoover, W.J. Carr, and J.W. Whitney (U.S. Geological Survey, oral commun., 1984), but no consensus on origin of these coarse-grained, open-boxwork deposits yet exists. This author believes they are fluvial bedload deposits emplaced by Newtonian (water-dominated) fluids.

Unit O originally might have been a surficial deposit of open-void coarse particles (like those just discussed), which was overrun by the debris flow carrying the sediments that were deposited as unit Q. If the viscosity of the overriding debris flow was too large to allow downward, gravity-induced percolation of the fine-grained, debris-flow matrix into the interstices of unit O deposits, the coarse-grained lens could have been buried and preserved as the open-boxwork deposit, now exposed by the trench. However, this hypothesis is speculative.

In summary, the evidence revealed within deposits exposed by the T-shaped trench indicates that at least major parts of these units resulted from debris-flow activity. Uncertainty exists about the number of debris flows involved in deposition of the total mass and whether major stratigraphic components of the mass were emplaced by Newtonian fluids during floods not associated with those responsible for the debris-flow deposits. The small apparent pedogenic alteration of the mass of deposits exposed by the T-shaped trench indicates the deposits possibly are several thousand years old; however, their nonindurated character indicates they were emplaced during late Quaternary time. In addition to the correlations of unit J (modern slope wash) among all trenches and trench components, and the probably logical correlation of debris-flow deposits of units Q and S within the T-trench, a hypothesis seems reasonable for tentative correlation of debris-flow deposits of unit G in the cross-channel trench with those of units Q and S of the T-shaped trench.

Channel-Surface Features in the Vicinity of the Trenches

Topographic profiles of several stream-channel features of North Fork Coyote Wash, upstream from the proposed shaft site, were constructed (figs. 12-13). The present channel thalweg, two right-bank (south) and one left-bank (north) stream terraces, and one channel cross section about 100 ft upgradient from the upstream cross-channel trench were profiled. Elevations and distances were measured by using a surveying level and stadia rod.

The profile of the active channel thalweg (fig. 12) slopes fairly uniformly at nearly 10-percent grade for about 0.2 mi, from a distance of about 500 ft upstream from the upper cross-channel trench, downstream to the proposed exploratory shaft sites. Several higher terrace segments have been preserved on deposits along the wash.

The following description and interpretation of channel profiles (shown in fig. 12) were suggested by John Bell, Nevada Bureau of Mines and Geology (written commun., 1985).

According to John Bell, if the general slope of the upstream left-bank (north) terrace is projected downstream, it merges with the slope and vertical position of the right-bank (south) terrace No. 1 [see dashed al profiles of land-surface features on and along North Fork Coyote Wash.

Figure 13. Land-surface profile of channel cross section on North Fork Coyote Wash.

line projection in figure 12]. The simple merge of these two terrace segments strongly suggests the segments represent paired terraces and, as such, are evidence for the location and slope of the bed of the wash at some earlier time. The shorter segmented, right-bank terrace No. 2, although of similar slope to the higher terrace pair, clearly represents the position and slope of the bed of the wash at some later time because of its lower position. Still younger (lower) is the present-day channel thalweg. Both the upper paired terraces and right-bank terrace No. 2 appear to be vertically converging downstream with the present-day active channel thalweg of the wash; at the upstream end, the left-bank terrace and the thalweg profiles are about 15 feet apart vertically, and at the downstream end right-bank terrace No. 1 and the thalweg are only 3 feet apart.

The apparent downstream convergence of the slope of the oldest terraces with the slope of the present-day channel thalweg suggests some noteworthy drainage system change between the present time and the time that the oldest terraces were formed. The precise cause of this slope convergence is not known; one possible cause might be tectonic activity in the area. Right-bank terrace No. 2, of intermediate relative age, is not long enough to determine a projected average slope. Thus, its slope cannot be confidently compared with the upper (older) terrace system or with the present channel gradient. The three-tiered vertical separation of the terraces and thalweg profiles suggests at least two notable episodes of channel downcutting during late Quaternary time.

The cross-channel and T-shaped trenches cut through or into the right-bank terraces, which are underlain by unconsolidated sediment deposits. These terraces are younger than, or contemporaneous with, the youngest of the underlying deposits, namely the debris-flow deposit of unit G, which was previously described as possibly not over a few thousand years old. Thus, the formation of the terraces on the deposits indicates that at least two major runoffs (those that sculptured the terrace surfaces) might have occurred during late Quaternary time after the emplacement of the mass of unconsolidated deposits that is exposed by the cross-channel trench. The deposits probably represent several floods, as was previously discussed; evidence of additional floods probably is missing because of erosion or nondeposition during the prolonged evolution of the deposits and terraces. Thus, the deposits, terraces, and general channel morphology are likely products of at least one-half dozen or more major floods during the late Quaternary. As noted earlier, two deposits (units A and B, pl. 1) are likely the result of at least two late Quaternary floods; the number of earlier floods that carved the bedrock channel, prior to emplacement of the earliest preserved deposits, is unknown.

Magnitude of a Large Prehistoric Flood

The immediately foregoing sections of this report describe geologic evidence of past floods and debris flows in North Fork Coyote Wash. The data verify the occurrences but do not disclose the magnitudes of several notable floods. The evidence also tentatively indicates a late Quaternary age for the majority of those floods, thus indirectly indicating a reasonable probability that more floods of similar character can occur during the next several thousand years. The physical characteristics of some of the paleoflood deposits indicate that they were emplaced as non-Newtonian debris flows; other deposits resulted from Newtonian (water-dominated) flows; still others are of an uncertain hydraulic origin.

Surficial channel deposits near the trenches include a number of boulders. A technique to reconstruct peak-flow rates of flash floods that is based on the size of boulders deposited by the peak flows of Newtonian fluids was described by Costa (1983). The technique relates the average size of the five largest boulders, believed to have been transported in a single flood, to the flow velocity required to transport them to the site of deposition. The average boulder size is used in conjunction with measured channel slope to empirically determine the average depth of the flow that transported the boulders. By use of cross-section profiles of the present channel near the boulders (fig. 13), the assessment of average depth enables subsequent determinations of channel width and cross-sectional flow area, as indicated by present channel conditions. The values derived for average velocity (V) and cross-sectional flow area (A) subsequently are inserted into the flow equation, $Q=VA$, to determine a likely magnitude of peak-flow discharge (Q) in the general locale of the boulders.

Costa applied his method using the surficial boulder deposits near the trenches at North Fork Coyote Wash. The boulders were all assumed to have been deposited by the same flood and to be correlative with stratigraphic unit I or possibly unit H of plate 1 (modern channel deposits). Average length of the intermediate (b) axes of the five largest boulders was 3.2 ft, yielding an average velocity of 14.8 ft/s; average depth for the channel slope of 0.093 was determined to be about 3.2 ft; derived upstream cross-sectional area was 161 ft^2, and derived downstream cross-sectional area was 167 ft^2. Peak discharge required for the boulder transport was calculated to be about 2,400 ft^3/s. This estimate of flow was based on the present physical character of the stream channel combined with the evidence of sediment transport by some earlier flow. The proximity of the boulders to the sites of the proposed exploratory shaft indicates that concurrent flows from North Fork Coyote Wash, of the same general magnitude, probably also occurred at the proposed shaft sites.

The estimate of peak discharge (2,400 ft^3/s) can be used to estimate the expected magnitude of future big floods in North Fork Coyote Wash. An assumption critical to the validity of the results is that the boulders were all emplaced by the peak discharge of a Newtonian fluid during one specific flood. This assumption was made for the purpose of applying this technique, even though onsite evidence is inadequate to verify the assumption. The possibility exists that the boulders are exhumed remnants of earlier non-Newtonian debris flows; if that is true, the results reported here are invalid. Regardless of the hydraulic mode of transport, the boulders imply a debris-transport hazard. Assuming the results are valid, however, they indicate that a future flow of at least 2,400 ft^3/s can be anticipated. Also, as Costa suggests (1983, p. 986), application of this technique could result in an underestimate of the peak-flow rate if that rate was competent enough to move boulders larger than those available.

MAGNITUDES OF POTENTIAL FUTURE FLOODS

Empirically derived calculations can also be used to estimate the possible magnitudes of future floods. These empirical techniques mainly are based on data collected from historic floods or storms, or both, that occurred during the last 100 years. Several of the more widely used methods were applied to Coyote Wash drainage; a discussion of these methods follows.

Flood magnitudes are strongly related statistically to drainage-basin areas. Relations between the observed peak discharges of the highest magnitude floods from drainage basins of different sizes, within specific geographical regions, can be depicted graphically. The resultant graphs are commonly known as flood envelope curves. These curves can in turn be used to make reasonable estimates of very large flood-flows to be expected within the specific geographic area of interest. The accuracy of the curves is limited by the length of the flood records and the number of locations at which floods were observed. As flood data accumulate with the passage of time, the relation tends to improve or be redefined. With the passage of time, floods may occur that are larger than those shown for a given size basin on the envelope curve. Those larger floods then lie graphically outside of the envelope curves; as the outliers accumulate, they tend to redefine the envelope curve and better describe the relation between drainage basin size and peak discharges of the potentially largest floods to be expected for varying-size basins.

A quantitative update of the flood envelope curve for drainage areas smaller than 200 mi^2 was presented by Matthai (1969, p. B6), in which he developed the following equation:

$$Q=11{,}000\,A^{0.61} \quad ,$$

where

Q = peak discharge in cubic feet per second; and

A = upstream contributing drainage area, in square miles, for drainages that range from 1 to 200 mi^2.

If the equation is extrapolated to smaller drainages, an estimated peak discharge for North Fork Coyote Wash (drainage area = 0.094 mi^2) is calculated to be about 2,600 ft^3/s.

Extrapolation of regression relations or the equations beyond the range of data used to define the relations is risky, because estimates do not represent real data and are considered speculative. At least two hydrologists advise against extrapolating Matthai's relation for drainage basins smaller than 1 mi^2 (B.N. Aldridge and J.E. Costa, U.S. Geological Survey, oral and written commun., 1984). They believe Matthai's equation generally overestimates the magnitude of peak flows that could be expected from drainage areas of less than 1 mi^2.

B.N. Aldridge (U.S. Geological Survey, written commun., 1984) extended Matthai's envelope curve for drainage basins smaller than 1 mi^2 by using numerous peak-flow data from throughout the United States. According to Aldridge's unpublished extension of Matthai's curve, the maximum discharge to be expected from North Fork Coyote Wash would be on the order of about 1,000 ft^3/s Costa (1987, fig. 2) recently developed a similar envelope curve relating peak discharge to drainage-basin area for the largest rainfall-runoff floods measured by indirect methods on small streams in the conterminous United States. Costa's curve indicates that the largest expected discharge from a drainage area of about 0.094 mi^2 area would be about 900 ft^3/s.

Crippen and Bue (1977) also developed a set of envelope curves that relate peak-streamflow discharges of extreme floods to drainage-basin areas. The curves are based on measurements of peak discharges made prior to October 1974; as such, they define the upper limit of streamflows to be expected from various size drainage basins on the basis of date collected through September 1974. Crippen and Bue divided the 48-conterminous-State area of the United States into 17 geographic regions and developed separate envelope curves for each region. The curve for the region that includes the Yucca Mountain area (Crippen and Bue, 1977, Region 16, fig. 18, p. 15) indicates that the peak discharge of the potential-maximum floodflow for a drainage basin area of 0.1 mi^2 would be about 1,000 ft^3/s. They state (p. 4) that with the continued passage of time, floods more extreme than those used to develop the curves may occur, and that these additional data should be used for the continuing evolution and redefinition of the envelope curves. Crippen (1982) reviews the earlier work of Crippen and Bue (1977) and defines the regional envelope curves by equations. Solving the equation for the region that includes Yucca Mountain (Region 16), the peak discharge of the potential-maximum floodflow for a drainage area of 0.094 mi^2 (approximately 0.1 mi^2) is 926 ft^3/s. This discharge is consistent with the 1,000 ft^3/s discharge extracted from the earlier curve of Crippen and Bue (1977) for a drainage area of 0.1 mi^2. Envelope curves depict the known upper limits of flood discharges for different size drainages; as such, there are no specific recurrence intervals associated with discharges that are extracted from the curves.

A comparison of the results obtained from the runoff-area relations described previously indicates that estimates of potential maximum peak runoff from North Fork Coyote Wash could range from 900 to 2,600 ft^3/s.

Other techniques probably are available to increase the estimative range; however, research and application of all available techniques are beyond the scope of this investigation.

Another empirical method to estimate the potential maximum-peak runoff is the calculation of the Probable Maximum Flood (PMF). The method is based on an estimation of the probable maximum magnitude of rainfall over a drainage basin for a specific time interval; the technique then routes the resultant excess precipitation as streamflow to the site of interest. This method is recommended by the American Nuclear Society for determining design-basis flooding at nuclear reactor sites (American Nuclear Society Standards Committee, 1981). Use of this technique is also a requirement of the U.S. Nuclear Regulatory Commission for Federal licensing of a nuclear facility. The U.S. Bureau of Reclamation determined a clear-water, PMF, peak discharge for North Fork Coyote Wash (Bullard, 1986, table 10) of about 1,600 ft^3/s. This determination was made for the original proposed shaft site, which is just upstream from the confluence of the North and South Fork tributaries of Coyote Wash (fig. 2).

Such an intensive runoff rate would mobilize and transport a substantial quantity of sediment and debris. Hypothetically, a 55-percent volume increase over that of clear-water flow could result (J.E. Costa, U.S. Geological Survey, written commun., 1985). On that basis, the 1,600 ft^3/s peak discharge of the PMF would increase to about 2,500 ft^3/s.

Results of the statistically and graphically derived peak-flow rates described previously, the flow rate derived using the boulder-size paleohydraulic technique of Costa, and results of the PMF calculation as described previously, are:

Methods	Calculated flow rate (ft^3/s
Costa's (1983) boulder technique	2,400, or more
Matthai's (1969) runoff-area envelope curve	2,600
Aldridge's (unpublished)[1] runoff-area envelope curve	1,000
Costa's (1987) runoff-area envelope curve	900
Crippen and Bue's (1977) runoff-area envelope curve	1,000
U.S. Bureau of Reclamation Probable Maximum Flood for North Fork Coyote Wash (Bullard, 1986)[2]	2,500

[1] B.N. Aldridge (U.S. Geological Survey, written commun., 1985).

[2] Bullard's clean-water flow of 1.600 ft^3/s was increased by 55-percent volume to accommodate anticipated entrained sediment load.

These techniques indicate results that differ substantially between the highest and the lowest estimates. Thus, the estimate of flood peaks, with an acceptable degree of confidence, is difficult when assessing small drainage basins that are located in semiarid and arid environments. The critical and unresolved question is which of the techniques, if any, adequately estimates future flood-peak possibilities for Coyote Wash? The answer is unknown at this time (1992). However, because of the serious risks of flood hazards to the transport, handling, and long-term storage of nuclear materials, use of the more conservative estimates is prudent; thus, a potential flood-peak discharge of combined water and sediment as large as 2,500 ft^3/s for North Fork Coyote Wash is indicated. Also, South Fork Coyote Wash, the other major tributary to the shaft site, has a similar drainage area (South Fork = 0.105 mi^2; North Fork = 0.094 mi^2) and similar terrain; thus it would be expected to be capable of yielding similar peak flows. Because of the nearly identical characteristics of both tributary areas and their proximity (fig. 2), a storm capable of causing flooding in one tributary is expected to similarly flood the other tributary, and their peak-flow rates at the mouths, roughly at the sites of the potential shaft, probably would be cumulative. Thus, heavily laden debris flows that have discharges as large as 5,000 ft^3/s can be anticipated in Coyote Wash.

SUMMARY AND CONCLUSIONS

An exploratory shaft, planned as a part of a program to evaluate the suitability of Yucca Mountain for construction of an underground repository for storage of high-level nuclear wastes, was tentatively sited originally in the stream channel of Coyote Wash, Yucca Mountain, Nye County, near the Nevada Test Site. The original shaft site was within the flood plain of the ephemeral channels at the junction of the north and south forks of the wash. Because this site was vulnerable to hazards of intense floods and the precise range of potential flood magnitudes and their potential recurrence frequencies for Coyote Wash are unknown, the shaft site was relocated on a bedrock terrace slightly higher than, and a short distance northeast of, the alluvial flood plain to render it less susceptible to flooding hazards. The drainage terrain is rugged and generally steep; sparse vegetation and thin soil cover cause efficient runoff from intense rainfall. The flooding history of Coyote Wash was investigated by examining channel and flood-plain deposits upstream from the tentative exploratory shaft sites in North Fork Coyote Wash. Trenches were excavated in unconsolidated deposits to permit their examination to characterize and chronicle past flood events. The stratigraphic evidence confirms recurrent prehistoric flooding that was, in most instances, accompanied by episodes of intense debris movement. Although evidence of multiple floods was discovered, the record of sediment deposition and, hence, the flood record, is incomplete. Erosional unconformities exist between some stratigraphic units, indicating a complex history of alternating deposition and erosion in the stream channel and flood plain; the extent to which older flood deposits were removed by these episodes of erosion is unknown.

Some of the deposits exhibit textural features commonly characteristic of sediments that have been emplaced by debris flows—that is, the hydraulic characteristics of the moving fluid mass were dominated by debris rather than by water. Other deposits probably were emplaced by water-dominated flows that had hydraulic characteristics of Newtonian fluids. The upper unconsolidated stratigraphic units, which are the result of multiple flows, are tentatively dated as late Quaternary. Some, and possibly all of the deposits were emplaced during the Holocene (last 10,000 years).

A stage-I pedogenic carbonate zone, about 3 ft thick, conforms to the land-surface profile and mantles most of the nonindurated deposits at a depth slightly below the land surface. The pedogenic carbonate indicates some degree of antiquity for the underlying deposits, but the rate of carbonate accumulation in the vicinity of Yucca Mountain is unknown. The lack of well-defined, B-horizon, soil development above the carbonate zone indicates a young age; thus, a tentative age range of several thousand years is assigned to the uppermost deposits that contain pedogenic carbonate. Deposits on presently active flood plains are younger than 1,000 years.

Nonindurated deposits unconformably overlie semi-indurated deposits of slightly less volume and lateral extent. The semi-indurated deposits are tentatively assigned a late Pleistocene or early Holocene (?) age on the basis of their indurated character and color, which contrast with the nonindurated, overlying deposits.

Stratigraphic analyses of the trenched deposits confirm a history of recurrent flooding during at least the last 10,000 years. It was not possible to evaluate quantitatively the magnitudes of these recurrent floods on the basis of stratigraphic evidence; qualitatively, magnitudes vary from small to large. Stratigraphic and geomorphic evidence indicate that at least one-half dozen and, very likely, many more severe floods occurred during the late Quaternary. Evidence of earlier Quaternary flooding is sparse, but numerous floods probably occurred during that much longer time span. Earlier floods, possibly during late Tertiary time, cut stream channels in the underlying tuffaceous bedrock.

A hydrologic technique that estimates peak-flood discharge on the basis of sizes of larger boulders deposited in the channel was applied to North Fork Coyote Wash. Application of this technique indicates peak discharges of about 2,400 ft^3/s might have occurred sometime during the recent past (probably during the last few thousand years).

Four estimates of potential maximum discharge, based on drainage area, were made using empirical techniques; the estimates range from 900 to 2,600 ft^3/s. A probable maximum flood computation resulted in a clear-water, peak-flow estimate of about 1,600 ft^3/s. Adjusting that rate for a reasonable volume increase caused by entrained sediment indicates that the resulting peak flow might be on the order of 2,500 ft^3/s.

On the basis of sparse present knowledge, considering the large range of the previously described estimates (900 to 2,600 ft^3/s), a possible peak flow of sediment-laden fluid of about 2,500 ft^3/s can be anticipated in North Fork Coyote Wash (drainage area of about 0.094 mi^2). South Fork Coyote Wash (drainage area of about 0.105 mi^2) also can be expected to flow as much as 2,500 ft^3/s. The tributaries join near the proposed shaft site; thus, a possible cumulative peak flow as large as 5,000 ft^3/s can be anticipated at the site. Any flood at the proposed shaft site on the order of several thousand cubic feet per second would move substantial quantities of debris, including boulders up to several feet in diameter. Stratigraphic evidence indicates that very intense runoff also can occur as debris flows.

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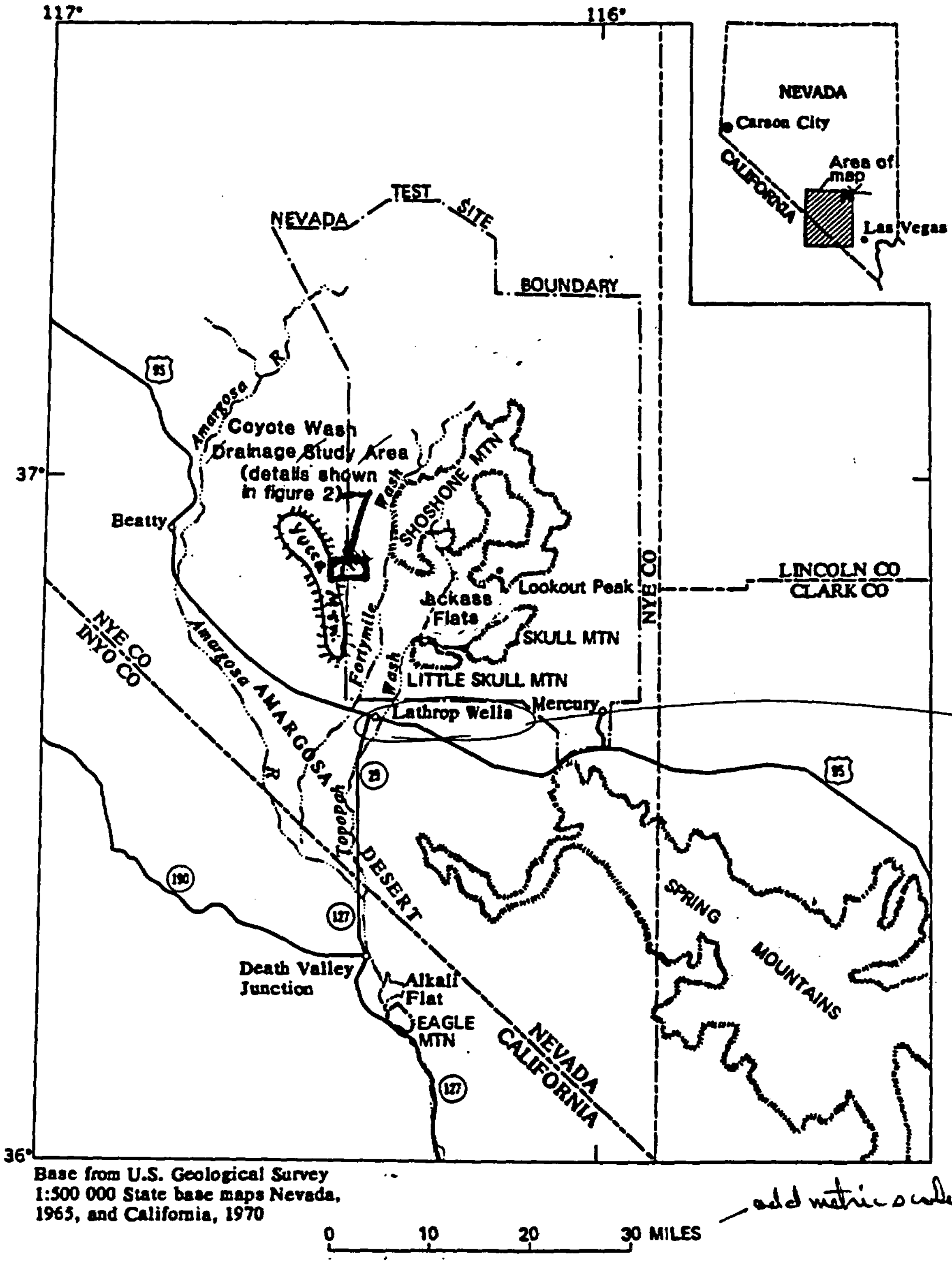


Base from U.S. Geological Survey 1:500 000 State base maps Nevada, 1965, and California, 1970

add metric scale. Also make scale

Now Amargosa Valley (Lathrop wells)

0 MILES
0 KILOMETERS

Figure 1.--Location of the study area and the Nevada Test Site.

base from U.S. Geological Survey
1:24,000 Busted Butte, NV. Quadrangle
1961

Scale

CONTOUR INTERVAL 20 FEET

Datum is sea level

EXPLANATION

A Cross-channel trench

B T-shaped trench

C Well USW G-4

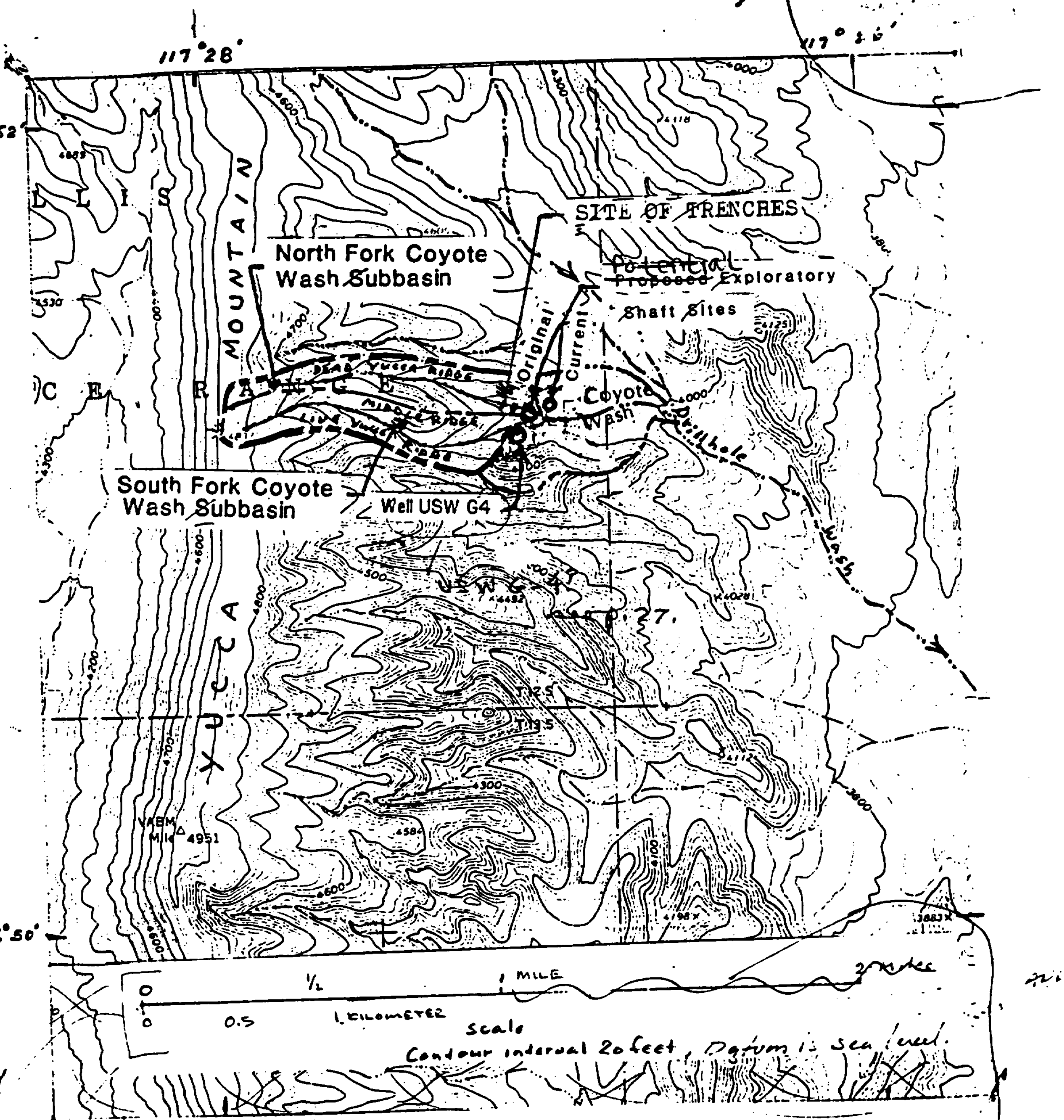
D Original proposed Exploratory Shaft

E Relocated proposed exploratory shaft

Note: Map locations are Approximate

Figure 2.-- Coyote Wash drainage

No arrowheads on leaders



more

Base from U.S. Geological Survey 1:24000 Busted Butte, Nev. Quadrangle, 1961

Figure 2.--Coyote Wash drainage.

Use Yucky scale add metric units

Add neat line around map

Fig. 2

✓

Or just screen base map so
added wording and symbols, lines, etc. are
prominent!

C.J.

yes
JW Grune

Make type larger (possibly 8pt)
and dropout to print white

Type should be caps and lower case:
Cross-channel trench
T-shaped trench
Approximate exploratory shaft site

MAKE THE LABELS
MORE LEGIBLE.

May want to
identify truck
for scale

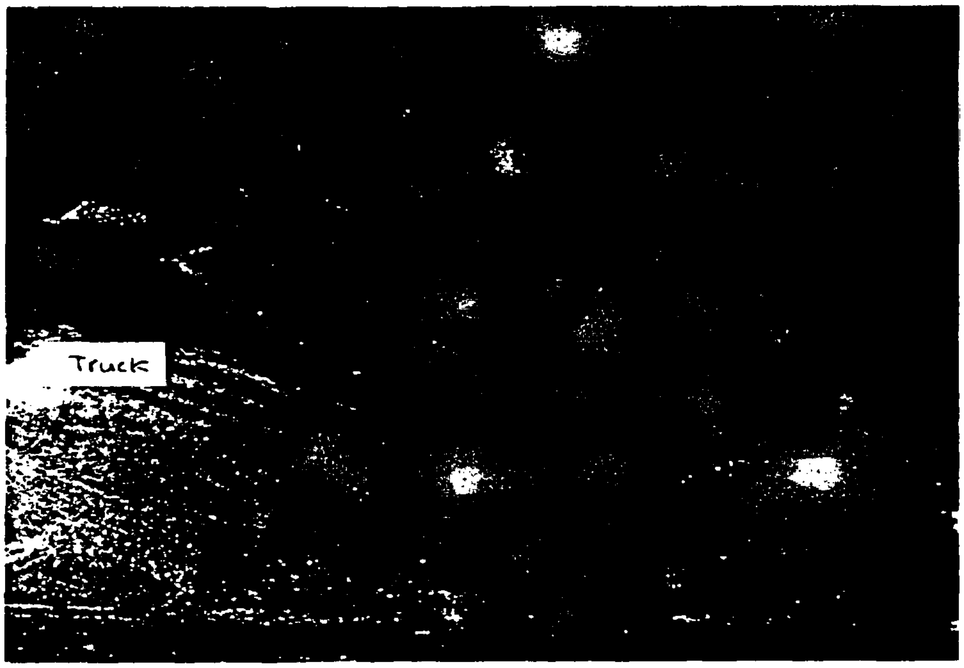


Figure 3.--Northwestward view of the site of the original potential exploratory shaft for the nuclear-waste storage facility (photographed from Live Yucca Ridge on March 17, 1984).

J W Camb

Make type larger
Dropout type to print white
where in midtone area

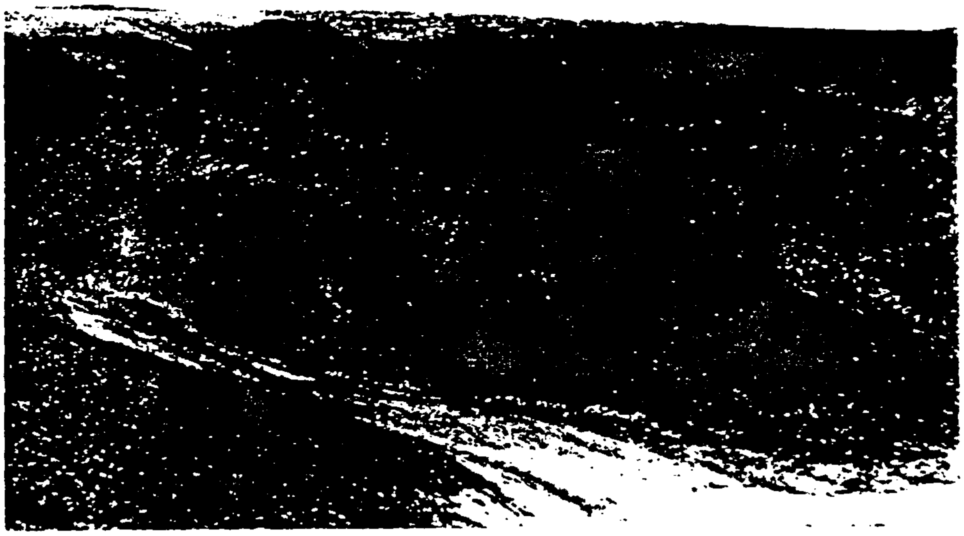


Figure 4.--West-northwestward view up Coyote Wash drainage just upstream from the potential shaft sites (photographed on March 17, 1984).

d w Gme

Make type larger.
Dropout type to print white where in mid tone to dark areas

difficult to read some of the typed overlays.

May want to identify truck for scale

lower case: trench

lower case: Approximate shaft site

Figure 5.--South-southwestward view of original potential shaft site from the south-facing slope of Dead Yucca Ridge (Coyote Wash tributaries flow from right to left; photographed on March 17, 1984).

JW Gume

Make type larger

very difficult to read overlays.

Drop out all type to
print white

Lower case: trench

Figure 6.--Southwestward view of Middle Ridge from south-facing slope of Dead Yucca Ridge (potential shaft sites are a short distance to left and below photo scene; North and South Forks Coyote Wash flow from right to left; photographed on March 17, 1984).

JW [illegible]

Make type larger and
dropout to print white
in midtone and dark
areas

difficult to read typed overlay

scale?

Lower case:
trench (2)

Figure 7.--Southwestward view of trenches excavated in North Fork Coyote Wash (downstream is down and to the left in photo; photographed on March 17, 1984).

J W Gore

Make type larger and
dropout to print white
where in midtown and
dark areas

scale?

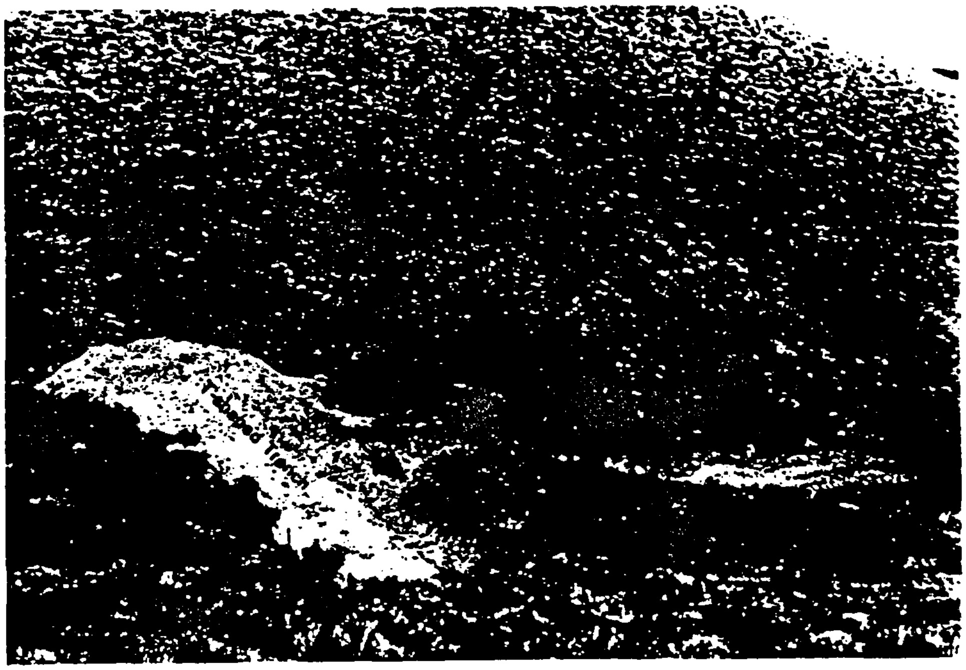
Lower case:
trench

Figure 8.--Northward view of cross-channel trench excavated in North Fork Coyote Wash (bottom of trench is at contact of alluvium with bedrock; photographed on August 17, 1983).

Label point to
the contact?

Make type larger and dropout to print white in midtone to dark areas

scale?



Lower case: trench

Figure 9.--Northward view of T-shaped trench excavated in North Fork Coyote Wash (wash flows from left to right; photographed on August 17, 1983).

JW Gould

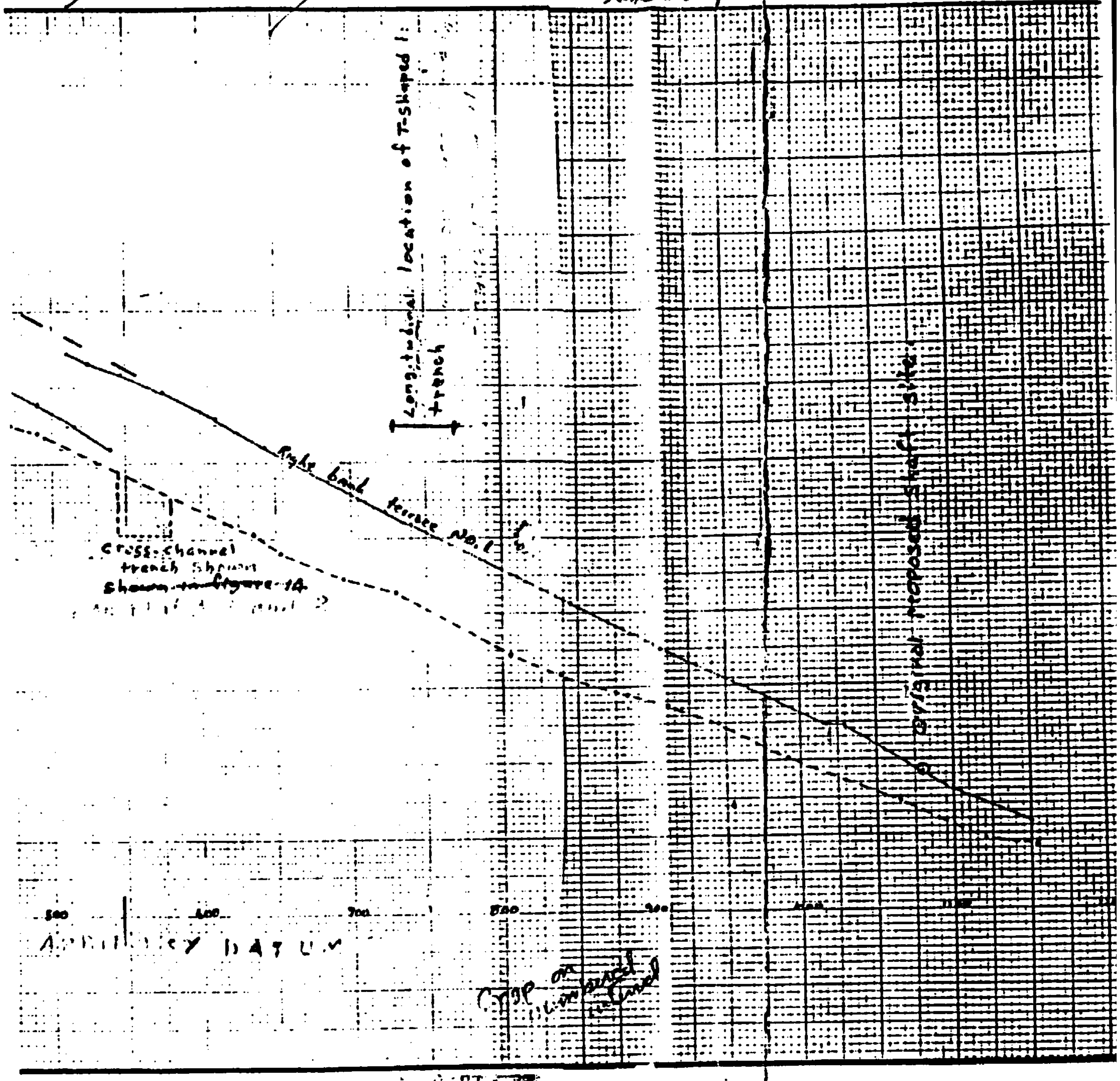
Indicate cropping marks
to make a square finish

Figure 10.--Upstream (west) wall of T-bar part of T-shaped trench excavated in North Fork Coyote Wash (note rock hammer for scale; stratigraphy delineated and described on pl. 1*B*; photographed on August 17, 1983).

Indicate cropping marks
to make square finish

Figure 11.--South wall of T-leg part of T-shaped trench excavated in North Fork Coyote Wash (maximum height of trench wall is about 4.5 ft; length of trench wall is between 35 and 40 ft; stratigraphy delineated and described on pl. 1C; photographed on August 17, 1983).

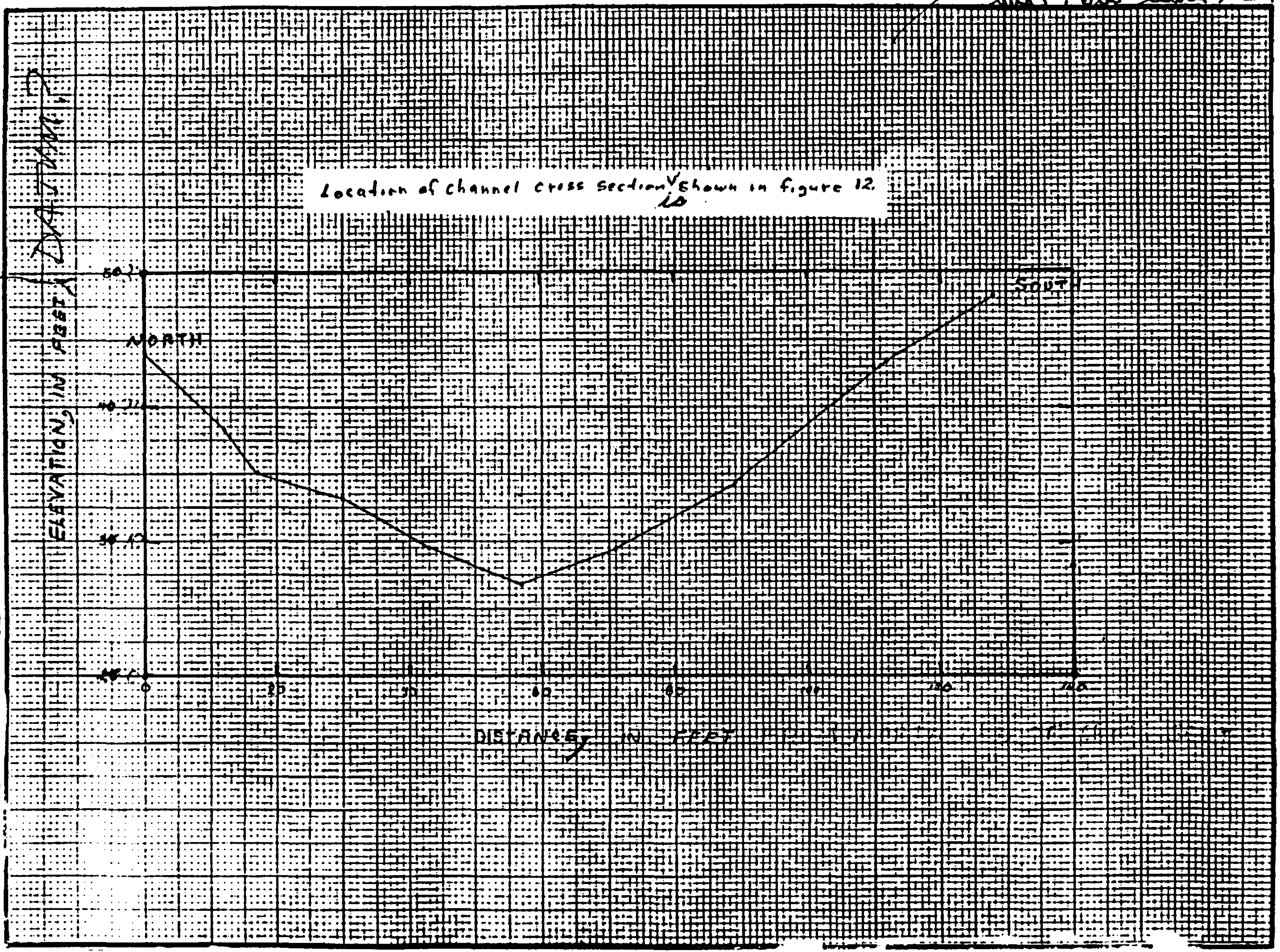
delete internal grid lines but leave tick marks on inside of all 4 neat lines;



Crop on numbered interval

land-surface features on and along

oyote Wash.



suggest deleting the internal grid lines, but leave the tick mark on inside of all 4 neat line

Fig. 13

106

Figure 13.--Land-surface profile of channel cross section on North Fork

✓

EXPLANATION ~~FOR PLATE 1~~

S DEBRIS-FLOW DEPOSIT--Heterogeneous mass of particles of mixed size dominated by small cobbles ranging in size from 1 to 3 ~~in.~~ in diameter with some randomly scattered small boulders averaging about 1 ~~ft~~ in diameter; sandy matrix; unconsolidated and internally ~~unbedded~~ ①, except for surface layer of coarse fragments; fairly densely packed surface layer of coarse clasts (about 80 percent areal density) includes numerous particles averaging about ~~in the~~ 1-foot diameter size (small boulders) mixed with smaller, differing ~~varying~~ cobble sizes; surface and near-surface clasts not carbonate coated; clasts below about 1 ft in depth have a stage-I coat of carbonate precipitate.

R WATER-DOMINATED FLOW DEPOSIT--The dominantly angular chips averaging about 0.5-in. in diameter with a few ~~occasional~~ coarser clasts of small cobble size (as much as ~~up to~~ about 5 in. in diameter) randomly scattered throughout; matrix mostly ~~largely~~ sand; unconsolidated and weakly bedded internally; stage-I carbonate coatings of some clasts in a zone continuous with the carbonate zone of overlying unit.

Q DEBRIS-FLOW DEPOSIT--Heterogeneous mixture of particles of variable size; some ~~small~~ boulders as large as 1 ft in diameter; surface differentially coated with large cobbles and small boulders; abundant matrix of sand and finer size material; unconsolidated and internally ~~unbedded~~ ①; stage-I carbonate coating on most particles.

① Sounds strange... how about "unstratified"?

✓ - suggest spelling out all units in these descriptions

93

~~92~~

JWG

[illegible] 4 INCHES [illegible] SIZE ✓

P DEBRIS-FLOW DEPOSIT (?),--Lens containing heterogeneous mixture of particles of variable size, with most clasts 1- to 3.5-inches in diameter; texturally similar to units L, M, and N; most coarse fragments small cobble size; some large cobbles present; abundant sand and finer grained matrix; no perceptible internal bedding; unconsolidated; stage-I carbonate coating on most clasts.

O WATER-DOMINATED FLOW DEPOSIT (?).--Lens containing mostly pebbles and some cobbles, most 1 to 2.5 ~~in.~~ in diameter; voids empty (no matrix); no perceptible internal bedding; unconsolidated; stage-I carbonate coating on most clasts.

N DEBRIS-FLOW DEPOSIT (?).--Lens of heterogeneous mixture of particles of variable size; texturally similar to units L and M; coarse particles of small cobble size; abundant sand and fine-grained matrix; no perceptible internal bedding; unconsolidated; stage-I carbonate coating on most particles.

M DEBRIS-FLOW DEPOSIT (?),--Lens of heterogeneous mixture of particles of variable size; diameter as much as ~~up to~~ 4.5-in.; texturally very similar to unit L; coarse particles of small cobble size; abundant fine-grained matrix; no perceptible internal bedding; unconsolidated; stage-I carbonate coating on most clasts.

✓

L DEBRIS-FLOW DEPOSIT (?)/--Lens of heterogeneous mixture of particles of variable size, most averaging about 2.5 in. in diameter; plentiful sand- and finer size matrix; contains many small cobbles and occasional large cobbles as large as 9 in./ in diameter; no perceptible internal bedding; unconsolidated; stage-I carbonate coating on most clasts✓

K WATER-DOMINATED FLOW DEPOSIT/--Dominantly chip gravel with medium pebble-size clasts; sand and finer grained matrix make up minor part of deposit; unconsolidated with very slight internal bedding; stage-I carbonate coating on most clasts✓

[illegible] ?

J SLOPEWASH DEPOSIT/--Mixture of mostly gravel and fines with numerous cobbles; occasional large cobbles and small boulders as much as ~~ranging up to about~~ 6 in. in diameter; fine-grained component includes substantial material of eolian origin; unconsolidated and unbedded internally; modern✓

I CHANNEL DEPOSITS/--Mixture of fluvially reworked boulders, cobbles, and gravel with voids part[illegible]ly filled mainly by fine pebbles and sand; unconsolidated and poorly bedded internally; part of deposit adjacent to and underlying current channel thalweg includes stage-II carbonate precipitates; modern✓

H FLOOD DEPOSITS--Heterogeneous mixture mainly of cobbles, gravel, and fines; coarse fragments as large as 1.5 ft in average diameter; fines mainly fine-to-medium sand including probable reworked eolian material; unconsolidated and unbedded internally; fairly young

G DEBRIS-FLOW DEPOSIT--Heterogeneous mixture of mainly cobbles, gravel, and sand; contains some boulders as large as 1.5 ft in average diameter; matrix largely fine sand, ~~much~~ most of which probably is reworked eolian material; unconsolidated with only a very slight internal bedding; visibly prominent stage-I carbonate coating of coarse particles

F WATER-DOMINATED FLOW DEPOSIT--Largely pebbles, 1 to 2 in. in average diameter, with a plentiful sand matrix; abundant much sand that likely is reworked eolian material; unconsolidated and very weakly bedded internally; stage-I carbonate coating of clasts

E WATER-DOMINATED FLOW DEPOSIT--Dominantly pebble-size chips with a fine-grained sandy matrix; matrix ~~may~~ might be largely of eolian origin; a few scattered clasts ~~ranging up to~~ as large as about 2 in. in diameter; unconsolidated and weakly stratified internally; upper and northern part of unit contains clasts coated with a stage-I carbonate precipitate

D WATER-DOMINATED FLOW DEPOSIT--Dominantly gravel averaging about 3 in. in diameter; contains some scattered cobbles ~~up to~~ as large as 6 in. in diameter; sandy matrix; much likely of eolian origin; unconsolidated and very weakly bedded internally

C DEBRIS-FLOW DEPOSIT--Dominantly cobbles averaging 2 to 4 in. in diameter with a matrix of pebbles and sand; contains some cobbles ~~up to~~ as large as 8 in. in diameter; sand ~~could~~ might ~~may~~ be mostly reworked eolian material; unconsolidated and internally unstratified ~~unbedded~~; generally appears to be coarser grained texture than underlying unit B; clasts have stage-I carbonate coating. The northern end of the deposit, near the active channel, contains stage-II carbonate precipitate

B DEBRIS-FLOW DEPOSIT--Heterogeneous mixture of particles of various size; [illegible] occasional large particles averag~~in~~g in the 0.7- to 1.5-foot-diameter range; coarse fraction is dominantly 2.5 to 4 in. in average diameter; dominantly sand and finer-size particles matrix; much [illegible] could ~~may~~ be of eolian origin; slight induration differentially present throughout deposit; lenticular mass at base of northern one-half of deposit, distinctively indurated; deposit shows slight internal bedding; part of deposit adjacent to and comprising present channel thalweg contains stage-II carbonate precipitate; overall color more yellowish or reddish than units C-J

[illegible] time term

A PREDOMINANTLY DEBRIS-FLOW DEPOSIT--Heterogenous mixture of coarse-size fragments and fines; contains some scattered boulders ~~up to~~ as large as 1.5 ft in maximum diameter; matrix contains higher percentage of clay than other units; deposit noticeably indurated and ~~unbedded~~ unstratified internally; induration largely result of carbonate cement; stringers of carbonate, filament-like precipitates throughout deposit; upper part of deposit has large-size cobble layer coating surface, where cobbles (2) vary in average diameter from about 3 to 10 in. Overall color more reddish or yellowish than units C-J; thin part at south is slopewash ①

gray tone screen

☐ Stage-I carbonate developed on coarse (larger than sand-size) particles

ALL CAPS

▨ Stage-II carbonate precipitate on and around most particles of all sizes

Pattern screen

Too wordy?

...upper part of deposit is layer of cobbles that vary in diameter from 3 to 10 inches...

average cannot vary—or, at least, I don't think it can—