U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

DISCLAIMER

For additional information write to:

Chief, Hydrologic Investigations Program
Yucca Mountain Project Branch
U.S. Geological Survey
Box 25046, MS 421
Denver Federal Center
Denver, CO 80225

Copies of this report can be purchased from:

U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, MS 517
Denver Federal Center
Denver, CO 80225

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 the
NEVADA OPERATIONS OFFICE
U.S. DEPARTMENT OF ENERGY
Interagency Agreement DE-AI08-92NV10874

Denver, Colorado
1994

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

CONTENTS

PLATE

[Plate is in pocket]

FIGURES

TABLES

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

By Patrick A. Glancy

Abstract

Coyote Wash, an approximately 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 radioactive 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 from 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. Floodflows range in character from water-dominated

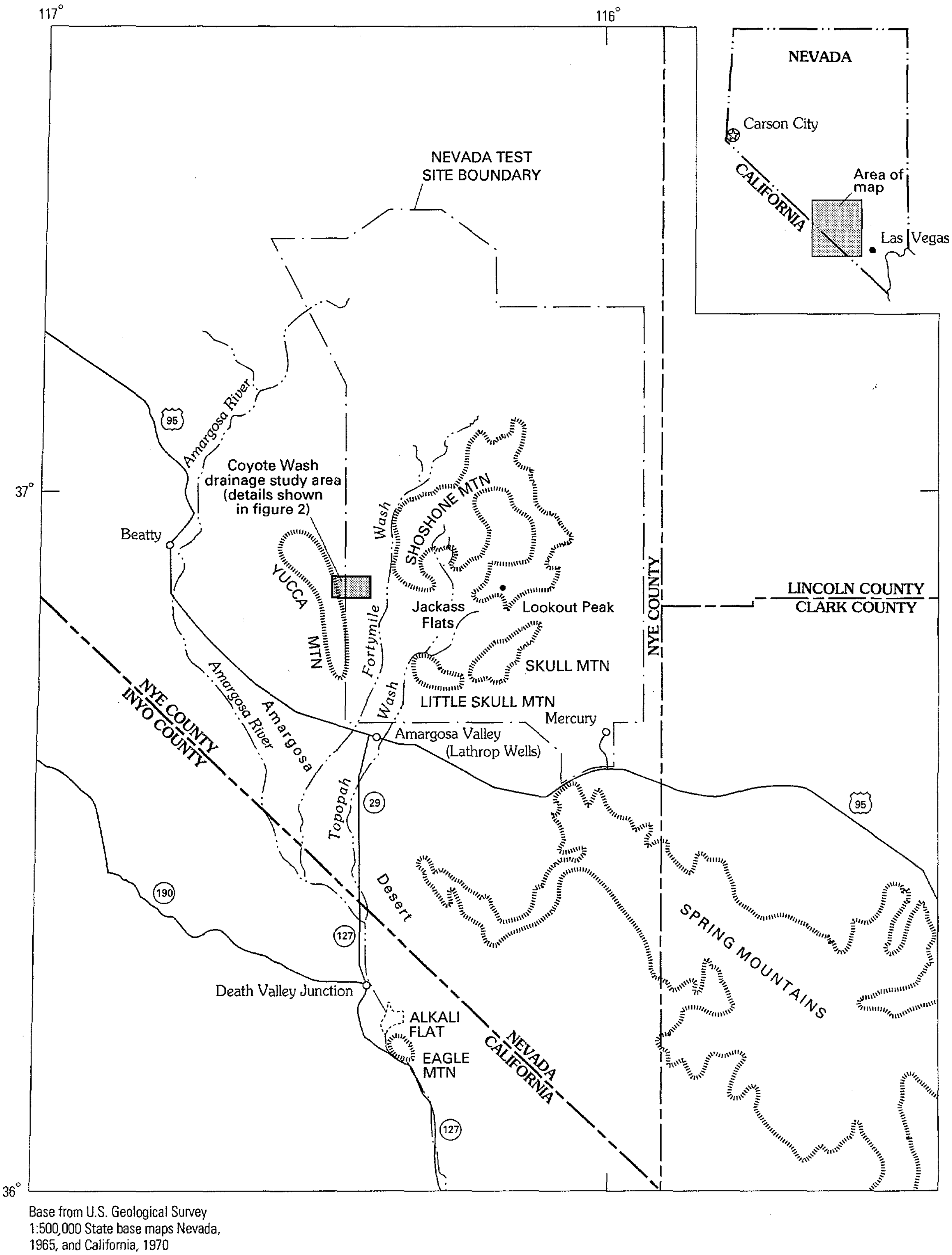


Figure 1. Location of the study area and the Nevada Test Site.

(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 waterfloods, and thus it has flow characteristics different from either of these processes (Johnson, 1970, p. 433–492; Costa, 1984, p. 287–290).

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 floodflows 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.

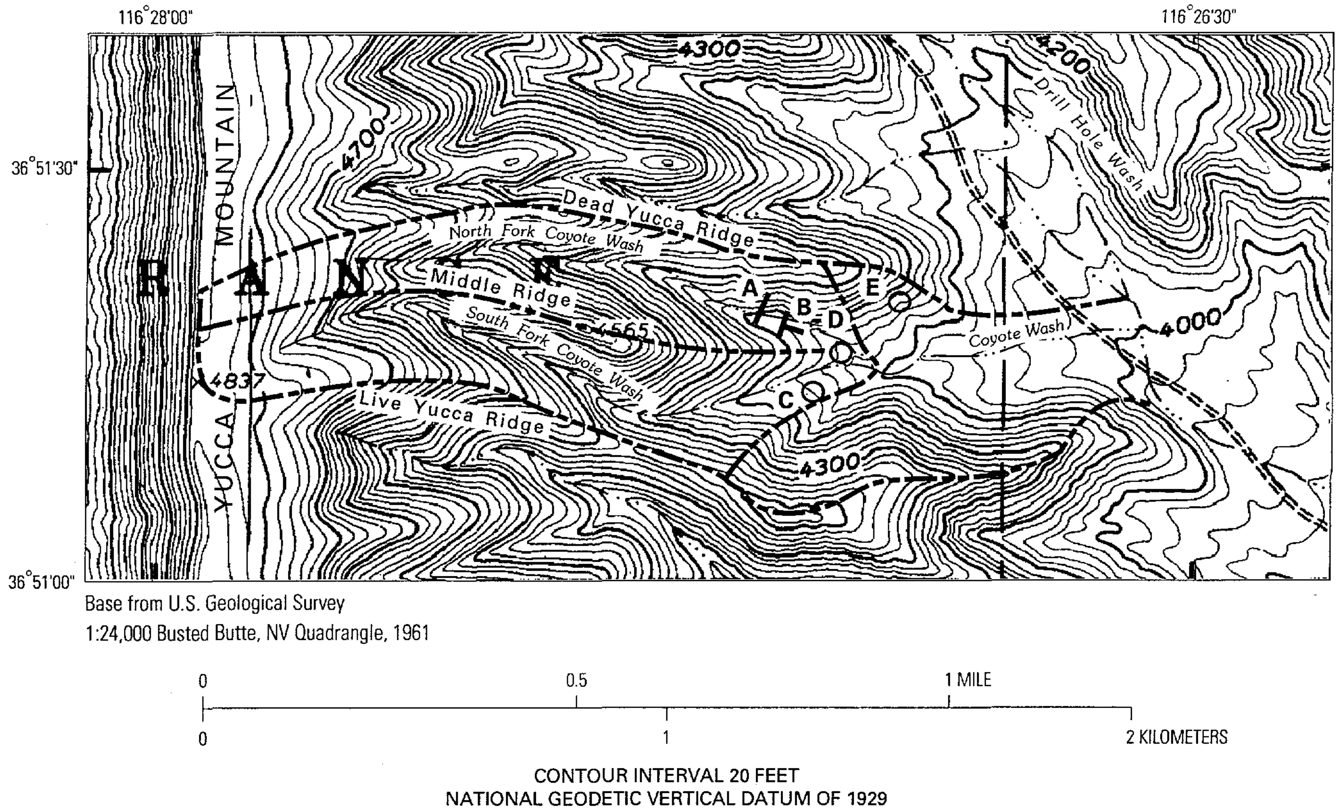
An evaluation of flood and debris hazards requires knowledge about the range of magnitudes and the probable recurrence intervals of storms and floodflows and knowledge about the potential of debris transport. Traditionally, determinations of potential flood magnitudes include quantitative estimates of 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 floodflows. 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 sta-



EXPLANATION

A CROSS-CHANNEL TRENCH

B T-SHAPED TRENCH

C WELL USW G-4

D ORIGINAL PROPOSED-EXPLORATORY-SHAFT LOCATION

E RELOCATED PROPOSED-EXPLORATORY-SHAFT LOCATION

NOTE: MAP LOCATIONS ARE APPROXIMATE

Figure 2. Coyote Wash drainage.

tistical 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.

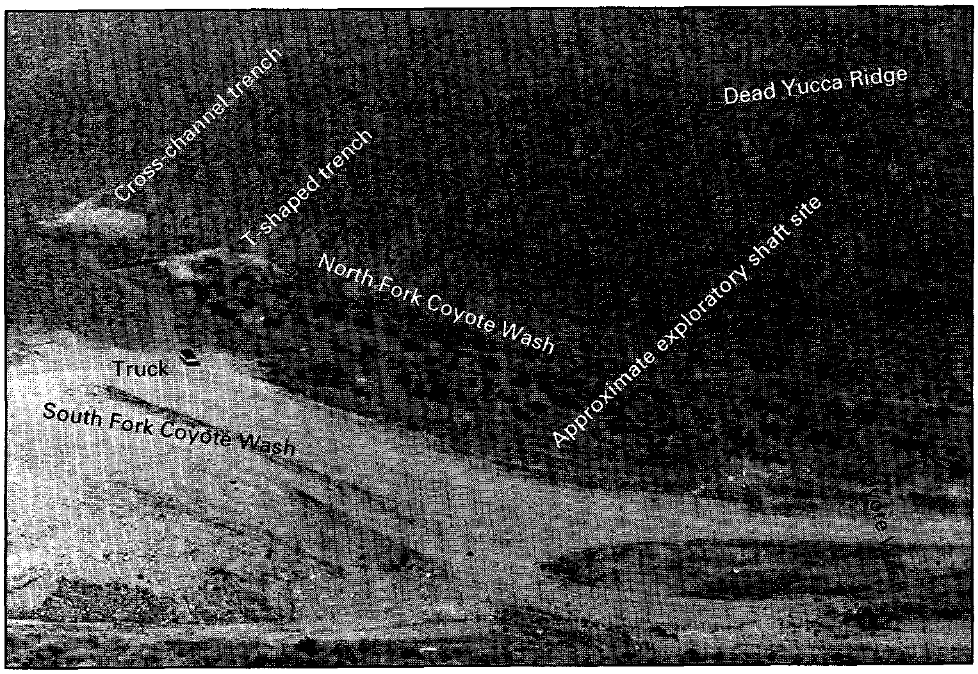


Figure 3. Northwestward view of the site of the original proposed exploratory shaft for the nuclear-waste storage facility (photographed from Live Yucca Ridge on March 17, 1984). Truck shows scale.

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 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 boulders 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).

Acknowledgments

The author thanks J.W. Bell of the Nevada Bureau of Mines and Geology and R.R. Squires and T.L. Katzer, former U.S. Geological Survey employees, for sharing their time and expertise. Many U.S. Geological Survey colleagues also assisted in this investigation, including: W.J. Carr, D.L. Hoover, J.W. Whitney, D.R. Muhs, J.E. Costa, R.R. Shroba, E.M. Taylor, E.J. Helley, and J.C. Yount.

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 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 Plane 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

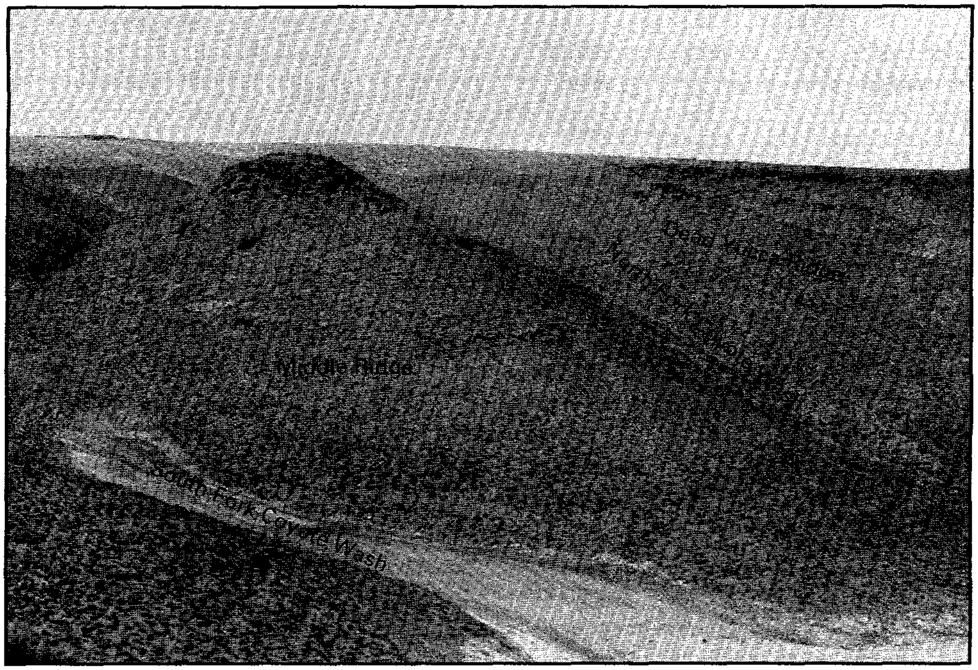


Figure 4. West-northwestward view up Coyote Wash drainage just upstream from the potential shaft sites (photographed on March 17, 1984).

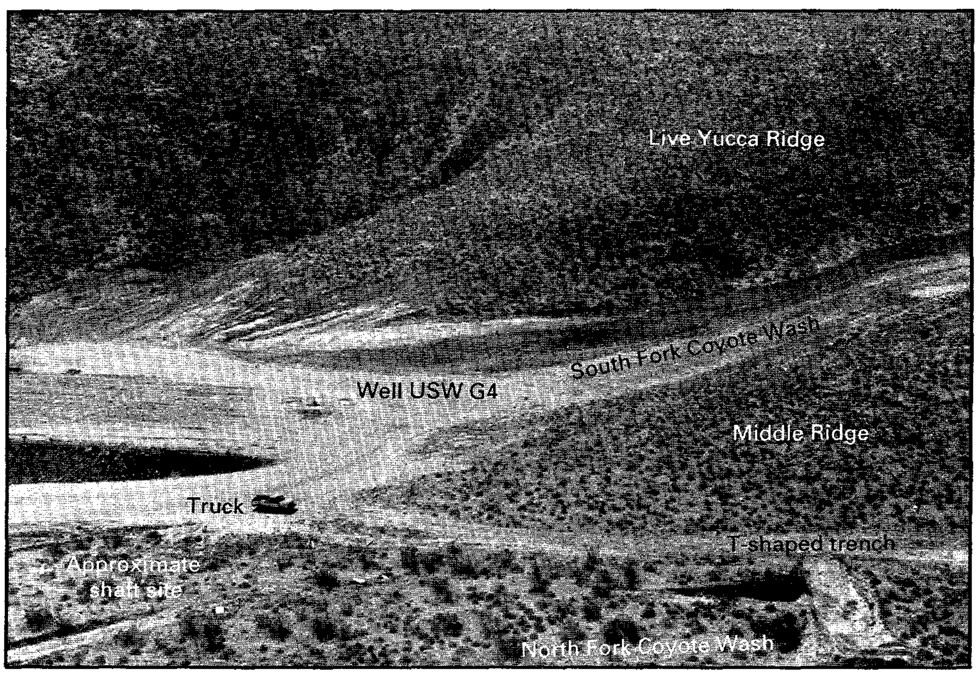


Figure 5. South-southwestward view of original potential shaft site from the south-facing slope of Dead Yucca Ridge (Coyote Wash tributaries flow from right to left; photographed on March 17, 1984). Truck shows scale.

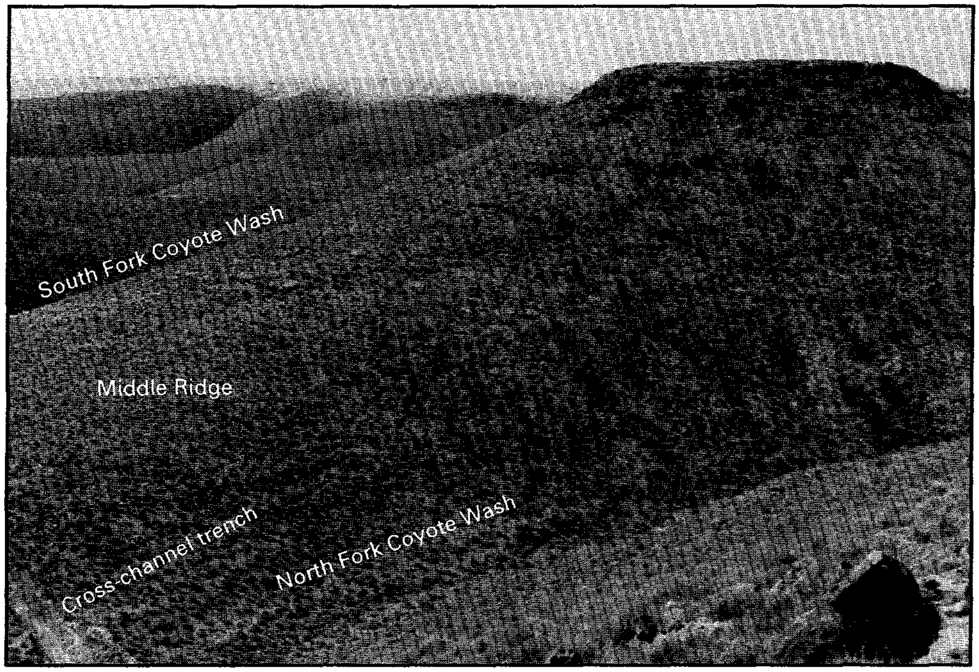


Figure 6. Southwestward view of Middle Ridge from south-facing slope of Dead Yucca Ridge (potential shaft sites are a short distance to left and below photo scene; North and South Forks Coyote Wash flow from right to left; photographed on March 17, 1984).

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

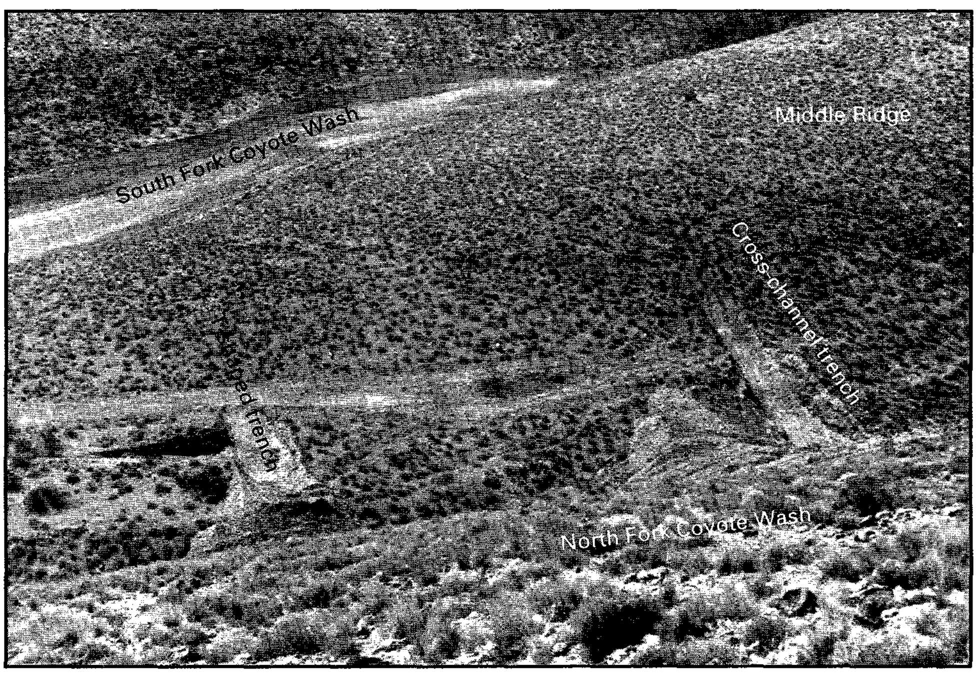


Figure 7. Southwestward view of trenches excavated in North Fork Coyote Wash (downstream is down and to the left in photo; photographed on March 17, 1984). Distance between trenches is about 180 ft.

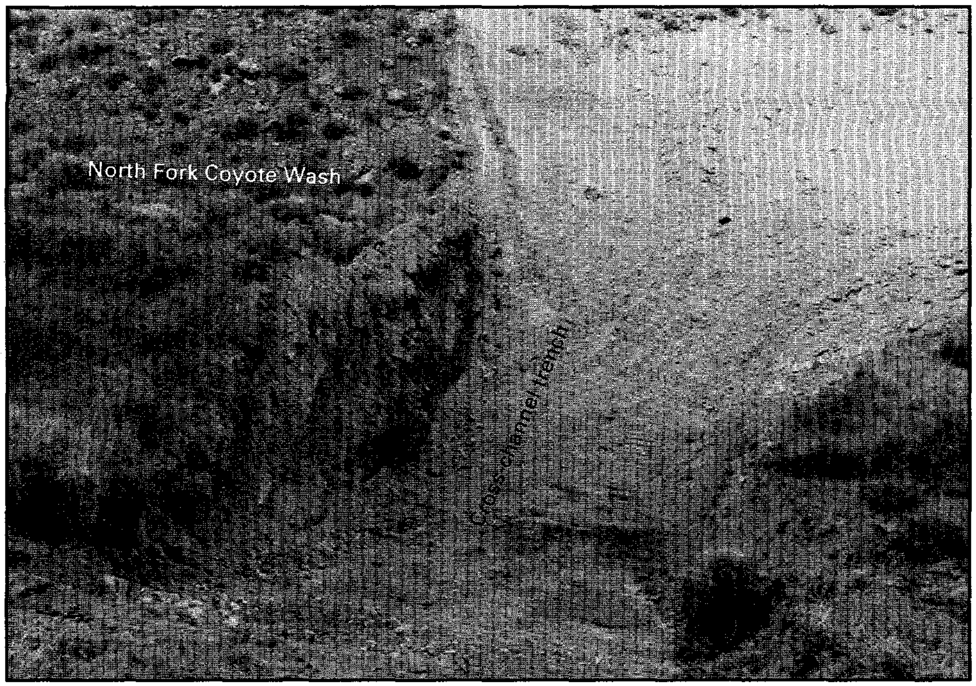


Figure 8. Northward view of cross-channel trench excavated in North Fork Coyote Wash (bottom of trench is at contact of alluvium with bedrock; photographed on August 17, 1983). Trench width is about 35 ft.

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 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 stratgraphic 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

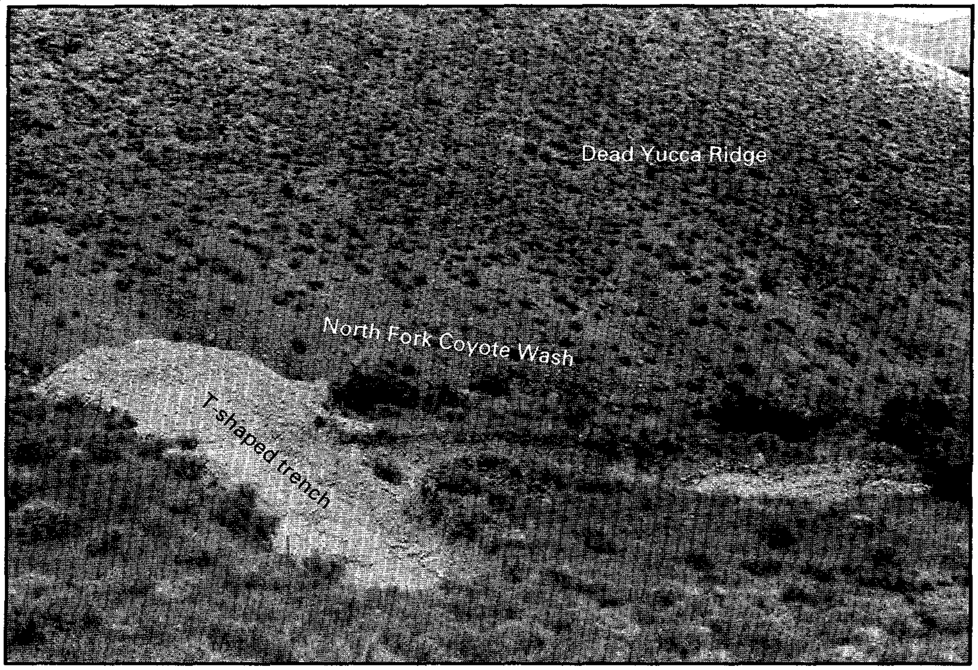


Figure 9. Northward view of T-shaped trench excavated in North Fork Coyote Wash (wash flows from left to right; photographed on August 17, 1983). Approximate length of T-leg is 37 ft.

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.

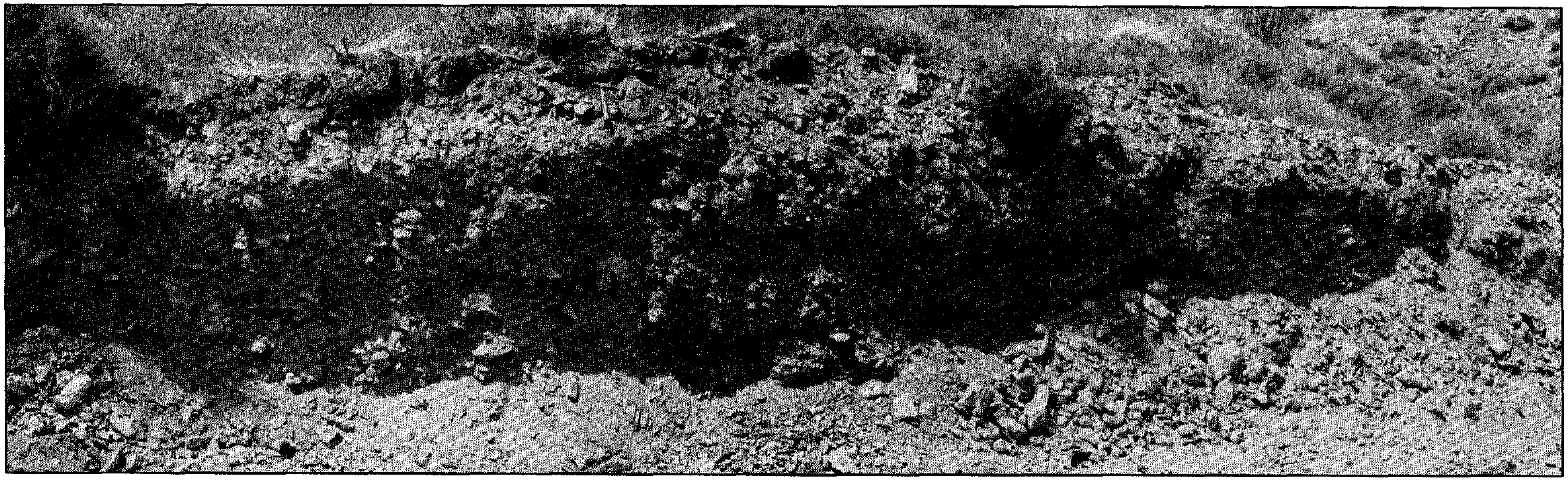


Figure 10. Upstream (west) wall of T-bar part of T-shaped trench excavated in North Fork Coyote Wash (note rock hammer for scale; stratigraphy delineated and described on pl. 1; photographed on August 17, 1983).

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).

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.

Table 2. Particle-size distribution of matrix material from selected trench deposits[1]

Sample number (pl. 1)	Stratigraphic unit (pl. 1)	Particle size (millimeters) 0.001	0.005	0.074	2.0	4.0	63.5	Trask sorting coefficient[2]
		(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

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 mudflows 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 waterflow not concentrated in channels. The stratigraphic evidence that supports a dual genesis for unit A deposits, as shown on plate 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 plate 1 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; and (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 and 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 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 ft apart vertically, and at the downstream end right-bank terrace No. 1 and the thalweg are only 3 ft 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 epi-

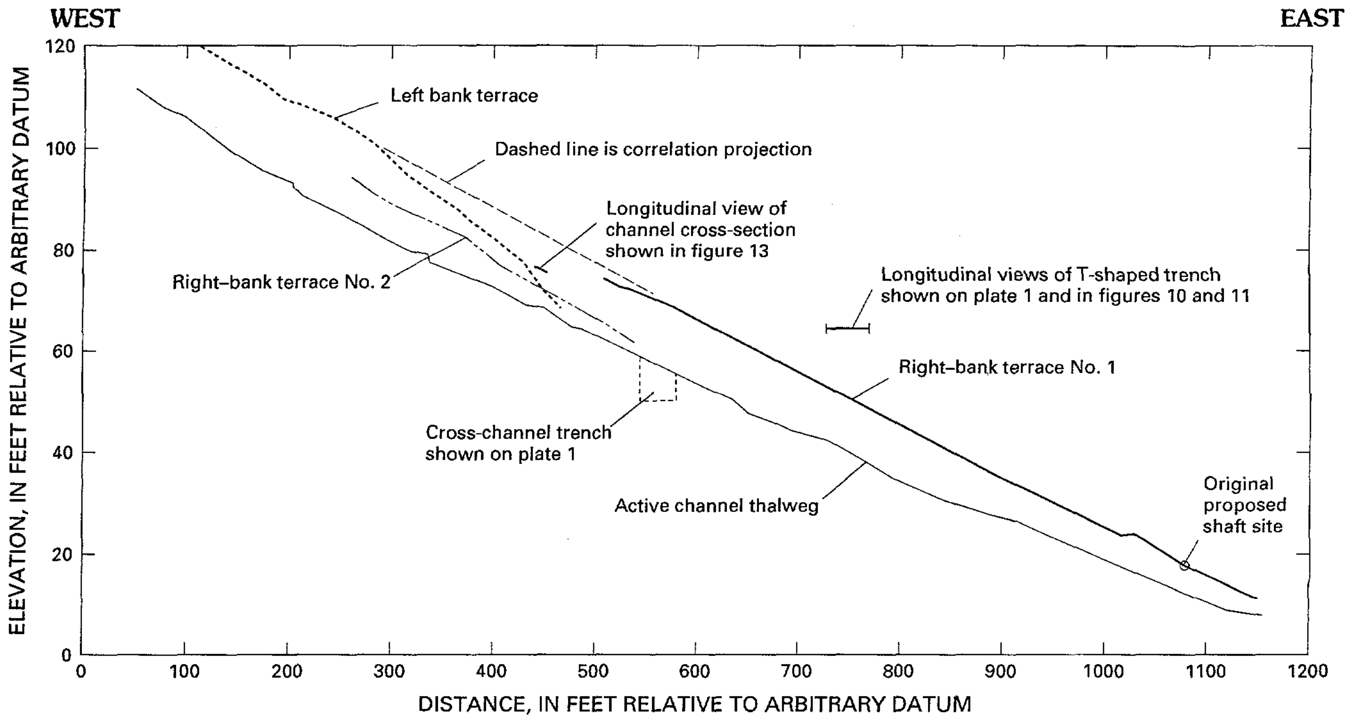


Figure 12. Longitudinal profiles of land-surface features on and along North Fork Coyote Wash.

sodes of channel downcutting during late Quaternary time.

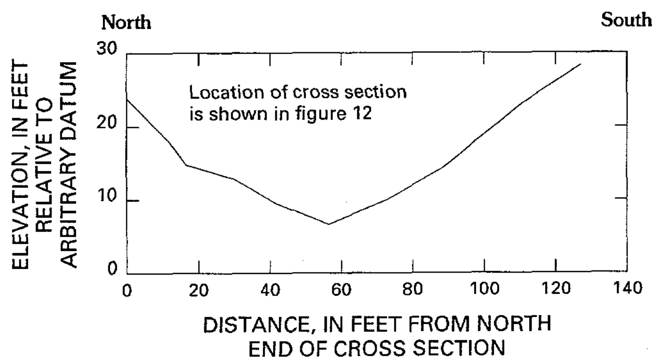


Figure 13. Land-surface profile of channel cross section on North Fork Coyote Wash.

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 floodflows 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:

$$Q = 11{,}000\,A^{0.61}$$

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 data 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.

REFERENCES CITED

American Nuclear Society Standards Committee, 1981, American National Standard for determining design basis flooding at power reactor sites: American Nuclear Society, ANSI/ANS–2.8–1981, 51 p. (NNA.890407.0399)

Bentley, C.B., 1984, Geohydrologic data for well USW G–4, Yucca Mountain area, Nye County, Nevada: U.S. Geological Survey Open-File Report 84–63, 48 p. (NNA.870517.0100)

Bullard, K.L., 1986, Probable maximum flood study for Nevada Nuclear Waste Storage Investigation Project: U.S. Bureau of Reclamation, 11 p., 61 pls. (NNA.870731.0043)

Chow, V.T., 1964, Handbook of applied hydrology: New York, McGraw-Hill, 1,453 p. (NNA.900727.0300)

Christensen, R.C., and Spahr, N.E., 1980, Flood potential of Topopah Wash and tributaries, eastern part of Jackass Flats, Nevada Test Site, southern Nevada: U.S. Geological Survey Open-File Report 80–963, 26 p. (HQS.880517.1739)

Costa, J.E., 1983, Paleohydraulic reconstruction of flash-flood peaks from boulder deposits in the Colorado Front Range: Geological Society of America Bulletin, v. 94, no. 8, p. 986–1004. (HQS.880517.2646)

____1984, Physical geomorphology of debris flows, *in* Costa, J.E., and Fleisher, P.J., eds., Development and applications of geomorphology: New York, Springer-Verlag, p. 268–317. (NNA.900710.0168)

____1987, A comparison of the largest rainfall-runoff floods in the United States with those of the People's Republic of China and the World: Journal of Hydrology, v. 96, no. 1–4, p. 101–115. (NNA.940602.0453)

Costa, J.E., and Jarrett, R.D., 1981, Debris flows in small mountain stream channels of Colorado and their hydrologic implications: Bulletin of the Association of Engineering Geologists, v. XVIII, no. 3, p. 309–322. (NNA.900710.0169)

Crippen, J.R., 1982, Envelope curves for extreme flood events: American Society of Civil Engineers, Journal of the Hydraulics Division, v. 108, HY 10, p. 1208–1212. (NNA.940602.0454)

Crippen, J.R., and Bue, C.D., 1977, Maximum floodflows in the conterminous United States: U.S. Geological Survey Water-Supply Paper 1887, 52 p. (NNA.940520.0055)

French, R.H., 1983, A preliminary analysis of precipitation in southern Nevada: Desert Research Institute, University of Nevada System Report DOE/NV/10162–10, 39 p. (NNA.900710.0170)

Gile, L.H., 1975, Holocene soils and soil-geomorphic relations in an arid region of southern New Mexico: Quaternary Research, v. 5, no. 3, p. 321–360. (NNA.900710.0171)

Glancy, P.A., and Harmsen, Lynn, 1975, A hydrologic assessment of the September 14, 1974, flood in Eldorado Canyon, Nevada: U.S. Geological Survey Professional Paper 930, 28 p. (HQS.880517.1766)

Hansen, M.E., Schwartz, F.K., and Riedel, J.T., 1977, Probable maximum precipitation estimates, Colorado River and Great Basin drainages: U.S. Department of Commerce and U.S. Department of the Army Hydrometeorological Report no. 49, 161 p. (NNA.890714.0070)

Hoover, D.L., Swadley, W.C., and Gordon, A.J., 1981, Correlation characteristics of surficial deposits with a description of surficial stratigraphy in the Nevada Test Site region: U.S. Geological Survey Open-File Report 81–512, 27 p. (NNA.870406.0033)

Johnson, A.M., 1970, Physical processes in geology: San Francisco, Freeman and Cooper, 577 p. (NNA.900710.0172)

Katzer, T.L., Glancy, P.A., and Harmsen, Lynn, 1976, A brief hydrologic appraisal of the July 3–4, 1975, flash flood in Las Vegas Valley, Nevada: Las Vegas, Nevada, Clark County Flood Control Division, Department of Public Works, 40 p. (HQS.880517.1963)

Kirpich, Z.P., 1940, Time of concentration of small agricultural watersheds: Civil Engineering, v. 10, no. 6, p. 362. (NNA.900710.0173)

Lipman, P.W., and McKay, E.J., 1965, Geologic map of the Topopah Spring SW quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ–439, scale 1:24,000, 1 sheet. (NNA.900720.0032)

Machette, M.N., 1985, Calcic soils of the Southwestern United States, *in* Weide, D.L., ed., Soils and Quaternary geology of the Southwestern United States: Geological Society of America Special Paper 203, 21 p. (NNA.900712.0001)

Matthai, H.F., 1969, Floods of June 1965 in South Platte River basin, Colorado: U.S. Geological Survey Water-Supply Paper 1850–B, 64 p. (NNA.900710.0175)

Quiring, R.F., 1965, Annual precipitation amount as a function of elevation in Nevada south of 38 1/2 degrees latitude: U.S. Weather Bureau Research Station Report, 14 p. (NNA.870406.0428)

____1983, Precipitation climatology of the Nevada Test Site: U.S. National Weather Service Report WSNSO 351–88, 34 p. (NNA.870406.0324)

Scott, R.B., and Bonk, Jerry, 1984, Preliminary geologic map of Yucca Mountain, Nevada, with geologic sections: U.S. Geological Survey Open-File Report 84–494, 1 map, scale 1:12,000, 2 data sheets, 9 p. (HQS.880517.1443)

Spaulding, W.G., 1983, Vegetation and climates of the last 45,000 years in the vicinity of the Nevada Test Site, south-central Nevada: U.S. Geological Survey Open-File Report 83–535, 199 p. (NNA.910221.0112)

Squires, R.R., and Young, R.L., 1984, Flood potential of Fortymile Wash and its principal southwestern tributaries, Nevada Test Site, southern Nevada: U.S. Geological Survey Water-Resources Investigations Report 83–4001, 33 p., scale 1:24,000, 1 sheet. (NNA.890511.0110)

Swadley, W.C., 1983, Map showing surficial geology of the Lathrop Wells quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I–1361, scale 1:48,000, 1 sheet. (NNA.890823.0099)

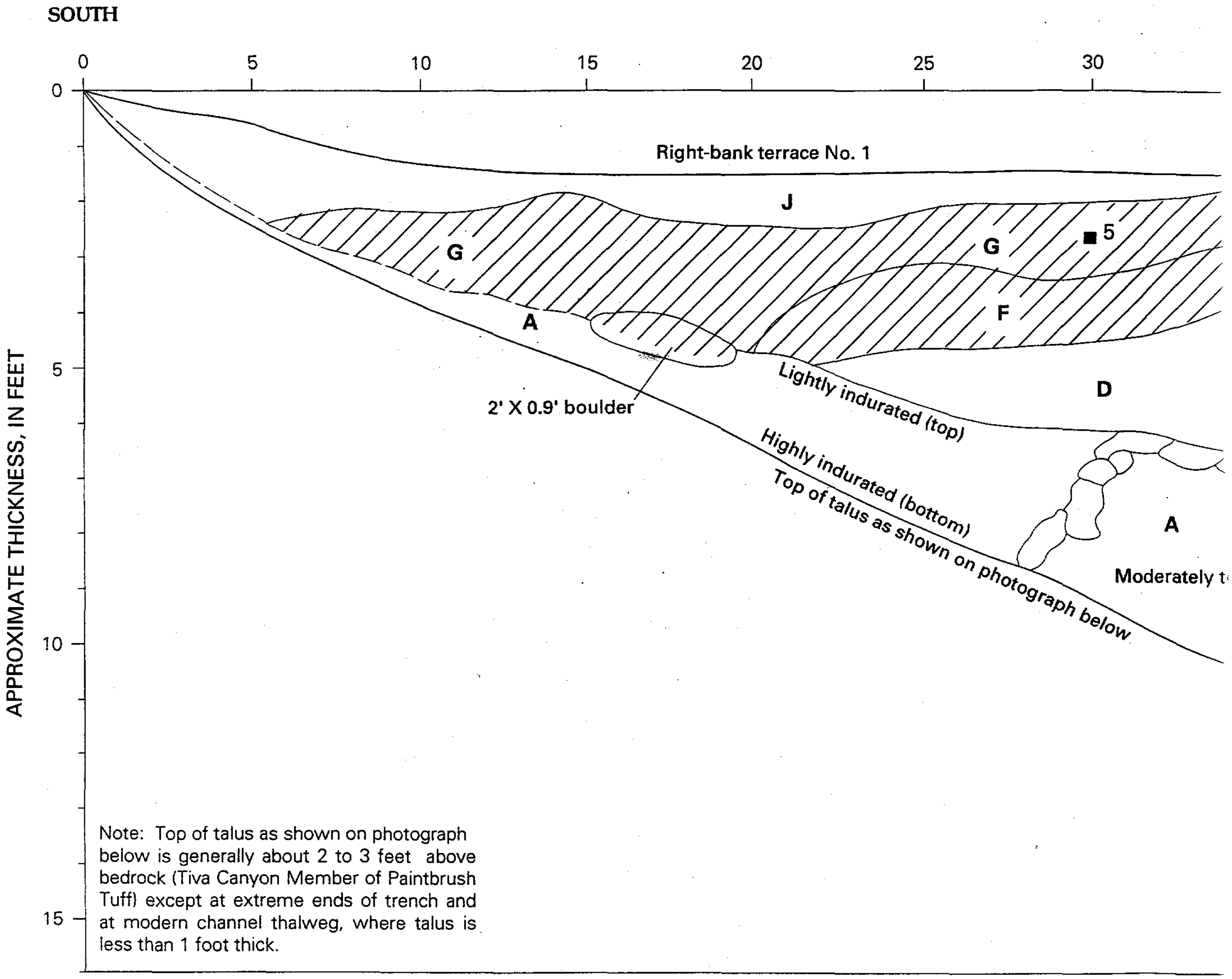
Trask, P.D., 1932, Origin and environment of source sediments of petroleum: Houston, Gulf Publishing Co., 323 p. (NNA.900710.0177)

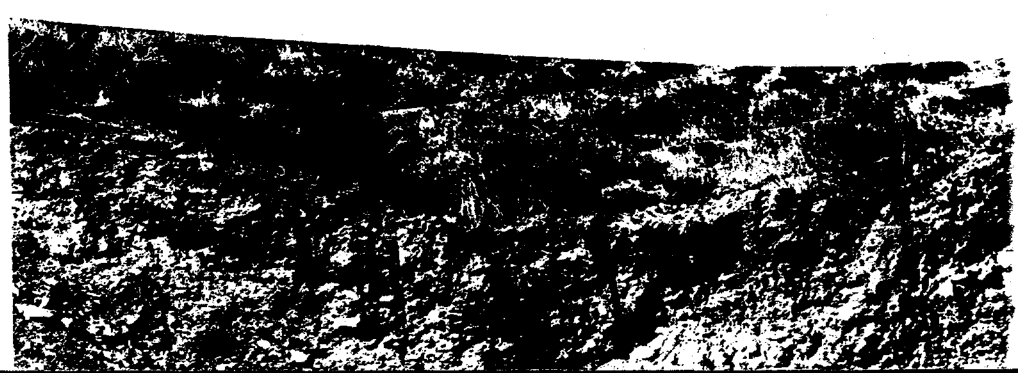
U.S. Bureau of Plant Industry, Soils, and Agricultural Engineering, 1951, Soil survey manual: U.S. Department of Agriculture Handbook 18, 503 p. (NNA.900710.0176)

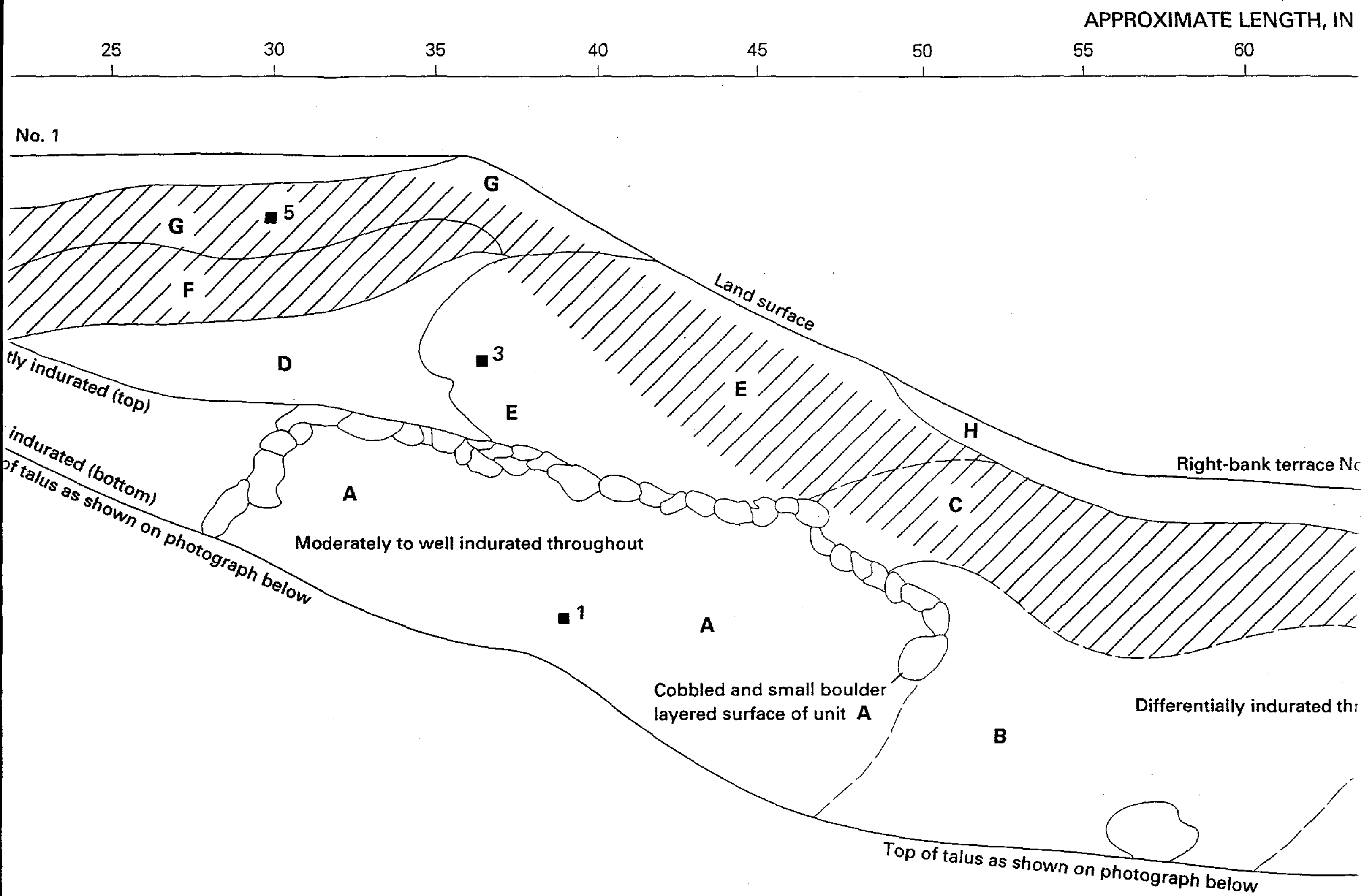
U.S. Geological Survey, 1961, Busted Butte, Nevada (formerly Topopah Spring SW): U.S. Geological Survey Topographic Map, scale 1:24,000, contour interval 20 ft, 1 sheet. (NNA.900713.0183)

The following number is for U.S. Department of Energy Office of Civilian Radioactive Waste Management records management purposes only and should not be used when ordering this publication: Accession number - NNA.940606.0001

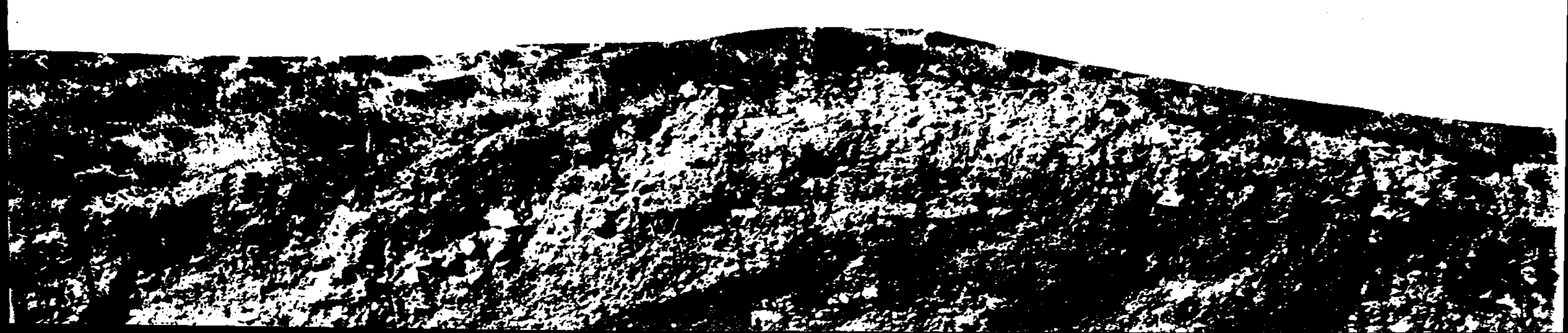
☆ U.S. GOVERNMENT PRINTING OFFICE: 1994 - 573-191 / 80047 REGION NO. 8


SOUTH
0
5
10
15
20
25
30
APPROXIMATE THICKNESS, IN FEET
Right-bank terrace No. 1
J
G
G
5
F
A
D
A
2' X 0.9' boulder
Lightly indurated (top)
Highly indurated (bottom)
Top of talus as shown on photograph below
Moderately t
Note: Top of talus as shown on photograph below is generally about 2 to 3 feet above bedrock (Tiva Canyon Member of Paintbrush Tuff) except at extreme ends of trench and at modern channel thalweg, where talus is less than 1 foot thick.

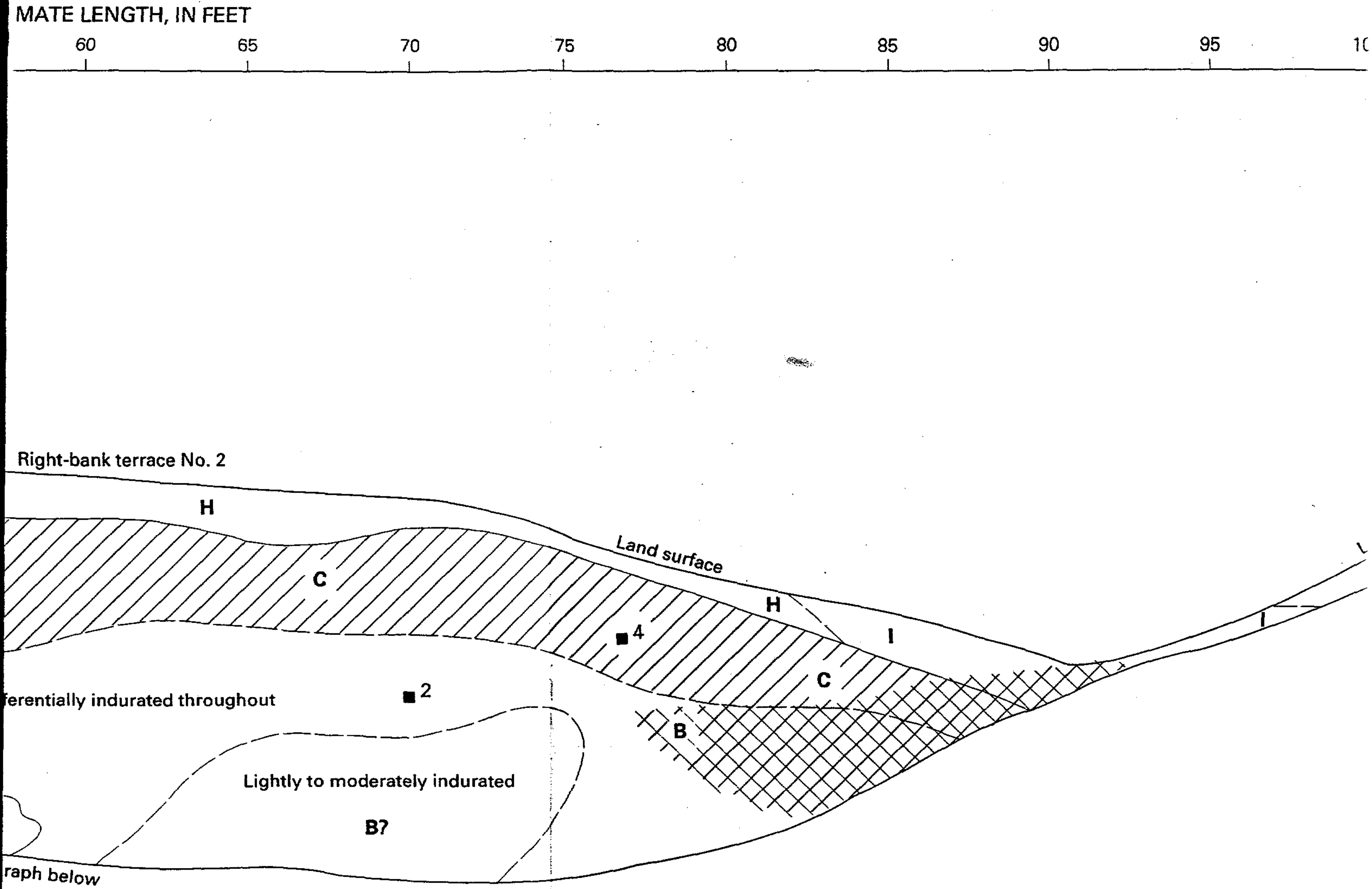




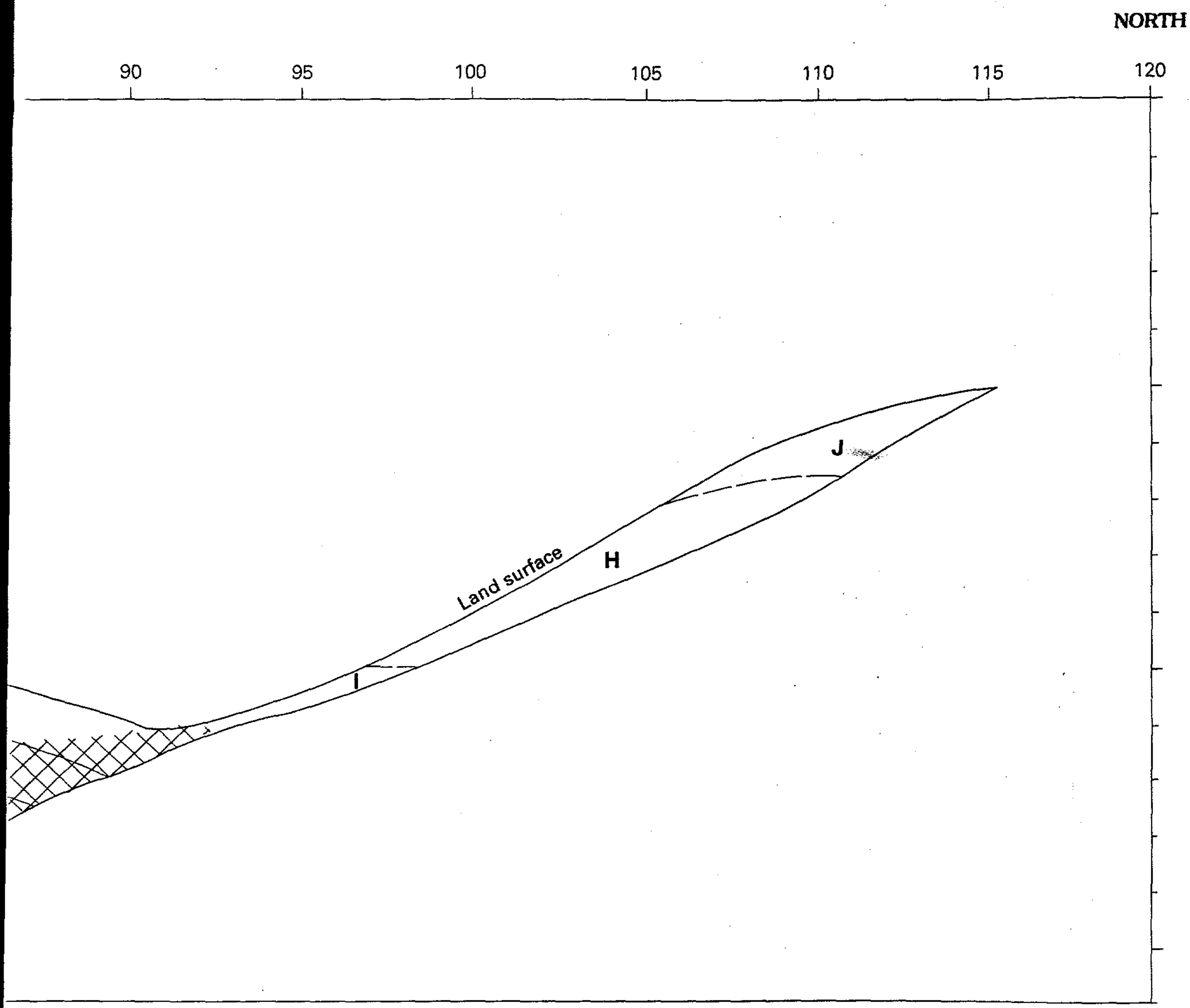
A. CROSS-CHANNEL TRENCH

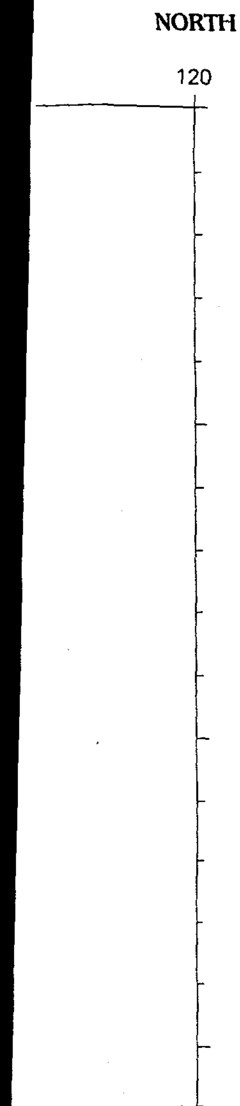


Prepared in cooperation with the
U.S. DEPARTMENT OF ENERGY



NNEL TRENCH (West Wall)


NORTH
90
95
100
105
110
115
120
Land surface
H
I
J



EXPLANATION

S **Debris-flow deposit**—Heterogeneous mass of particles of mixed size dominated by small cobbles ranging in size from 1 to 3 inches in diameter with some randomly scattered small boulders averaging about 1 foot in diameter; sandy matrix; unconsolidated and internally unstratified, 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 1 foot in diameter size (small boulders) mixed with smaller, differing cobble sizes; surface and near-surface clasts not carbonate coated; clasts below about 1 foot in depth have a stage-I coat of carbonate precipitate

R **Water-dominated flow deposit**—Predominantly angular chips averaging about 0.5 inch in diameter with a few coarser clasts of small cobble size (as much as about 5 inches in diameter) randomly scattered throughout; matrix mostly 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 boulders as large as 1 foot in diameter; surface differentially coated with large cobbles and small boulders; abundant matrix of sand and finer size material; unconsolidated and internally unstratified; stage-I carbonate coating on most particles

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 inches 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

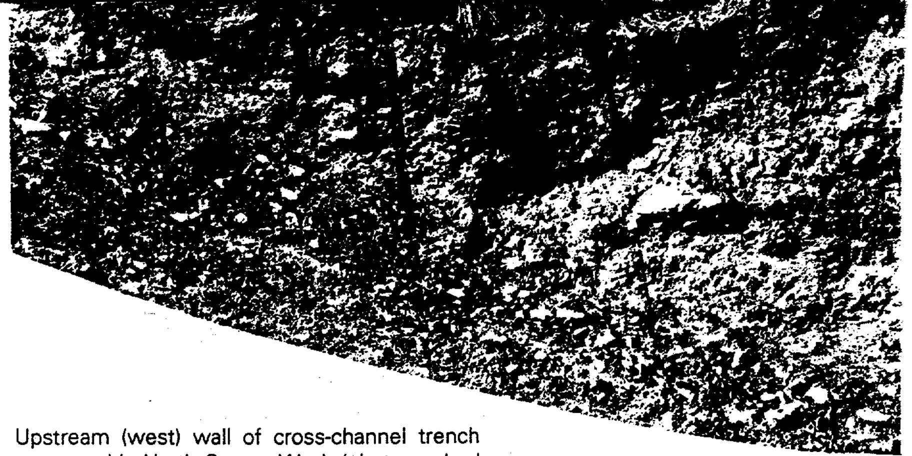
M **Debris-flow deposit(?)**—Lens of heterogeneous mixture of particles of variable size; diameter as much as 4.5 inches; texturally very similar to unit L; coarse particles of small cobble size; abundant fine-grained matrix; no perceptible internal bedding; unconsolidated; stage-I carbonate coating on most clasts

L **Debris-flow deposit(?)**—Lens of heterogeneous mixture of particles of variable size, most averaging about 2.5 inches in diameter; plentiful sand- and finer size matrix; contains many small cobbles and occasional large cobbles as large as 9 inches in diameter; no perceptible internal bedding; unconsolidated; stage-I carbonate coating on most clasts

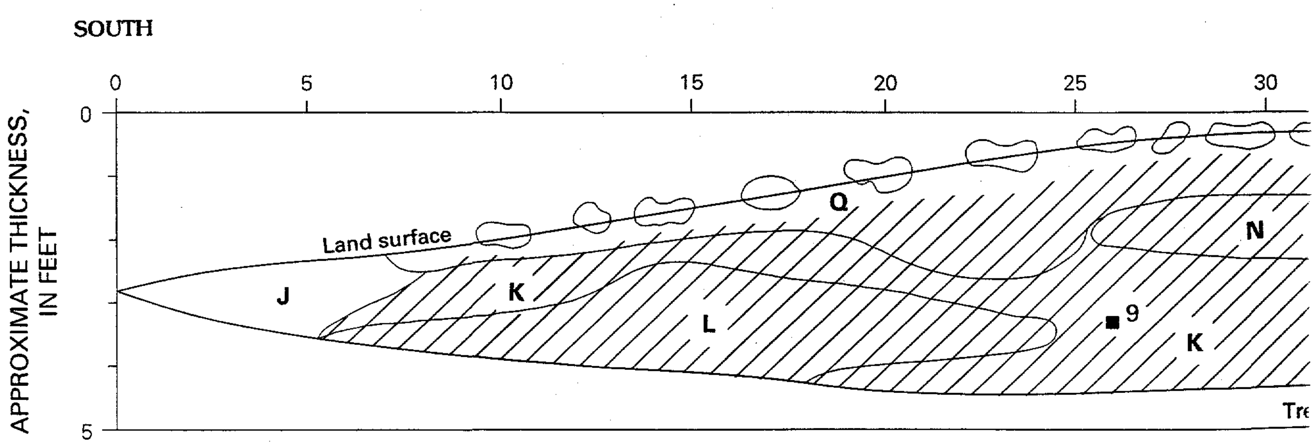
K **Water-dominated flow deposit**—Dominantly chip gravel with medium pebble-size clasts; sand and finer grained matrix make up minor part of deposit; unconsolidated with very slight internal bedding; stage-I carbonate coating on most clasts

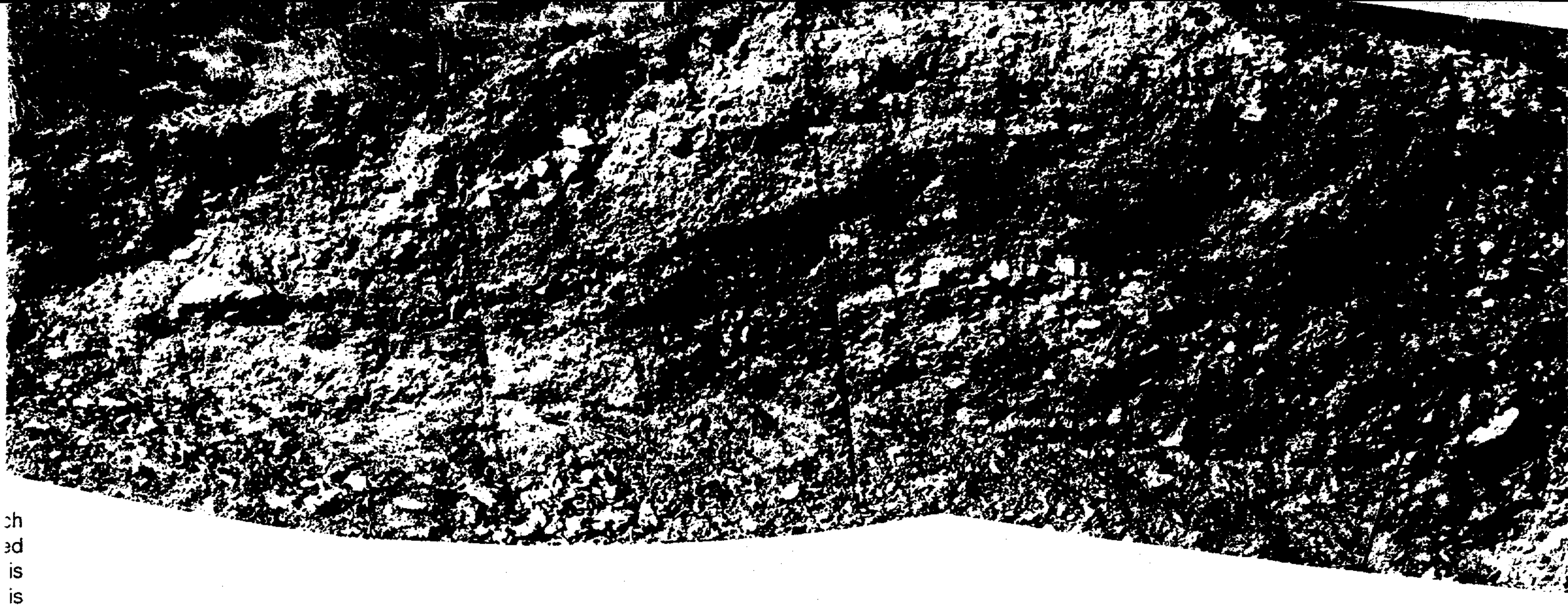
J **Slopewash deposit**—Mixture of mostly gravel and fines with numerous cobbles; occasional large cobbles and small boulders as much as 6 inches in diameter; fine-grained component includes substantial material of eolian origin; unconsolidated and unbedded internally; modern

I **Channel deposits**—Mixture of fluvially reworked boulders, cobbles, and gravel with voids partly 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

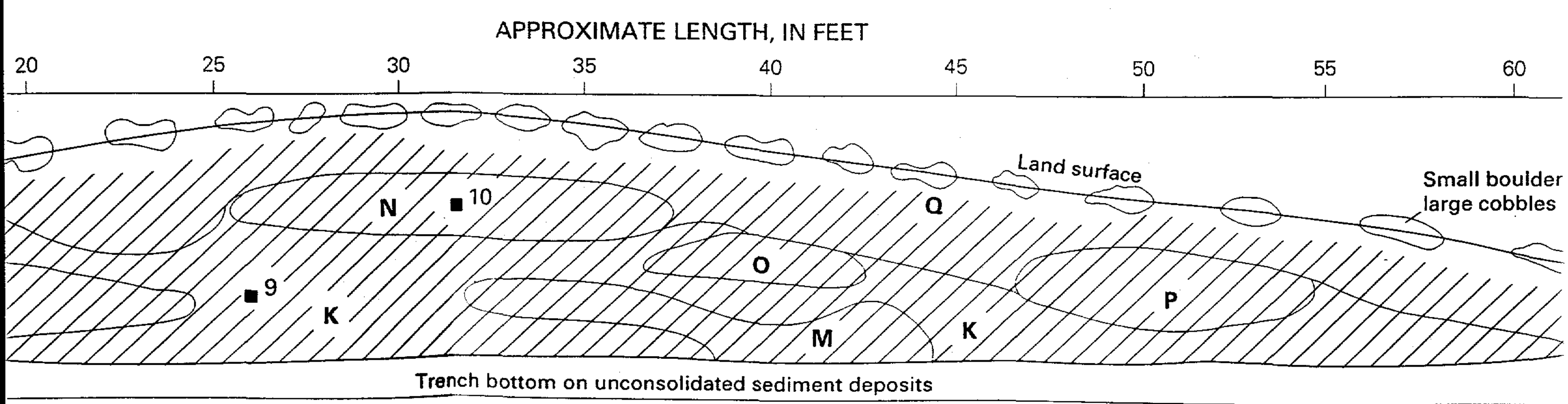


Upstream (west) wall of cross-channel trench excavated in North Coyote Wash (photographed on March 17, 1984). Height of man at right is about 6 feet; maximum trench wall height is about 7.5 feet; length in photograph about 100 feet. Stratigraphy of deposits delineated and described on plate 1A.

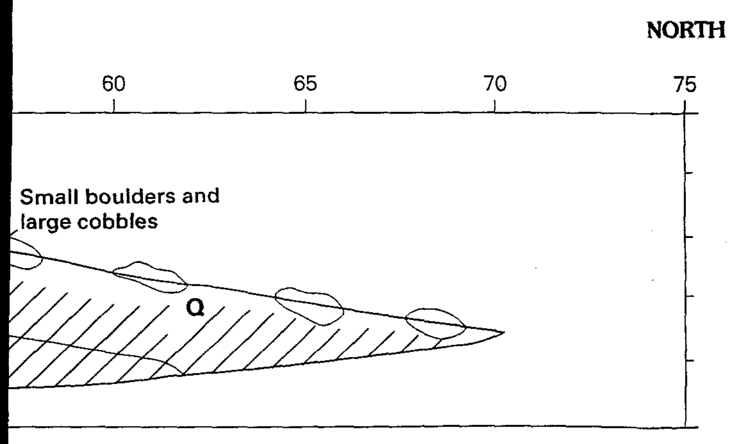


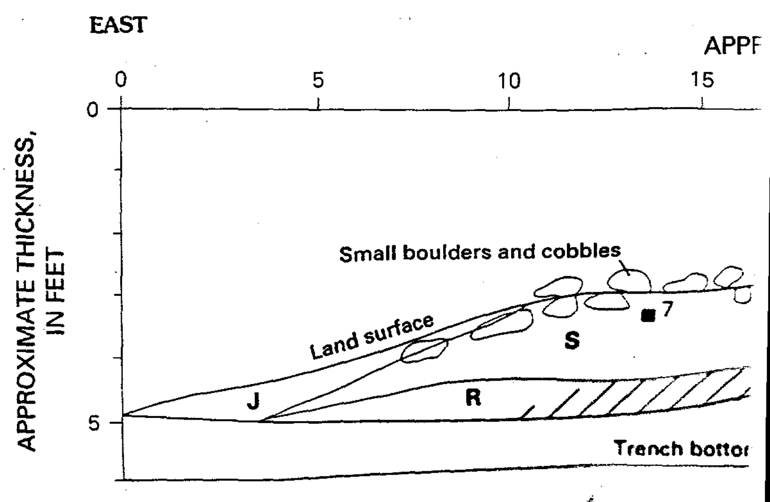


ch
ed
is
is
00
nd

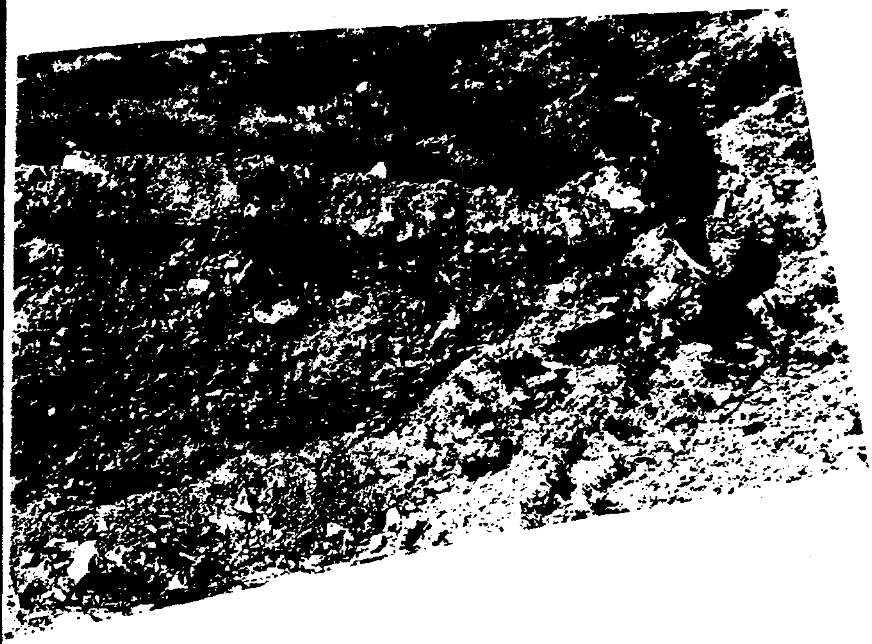


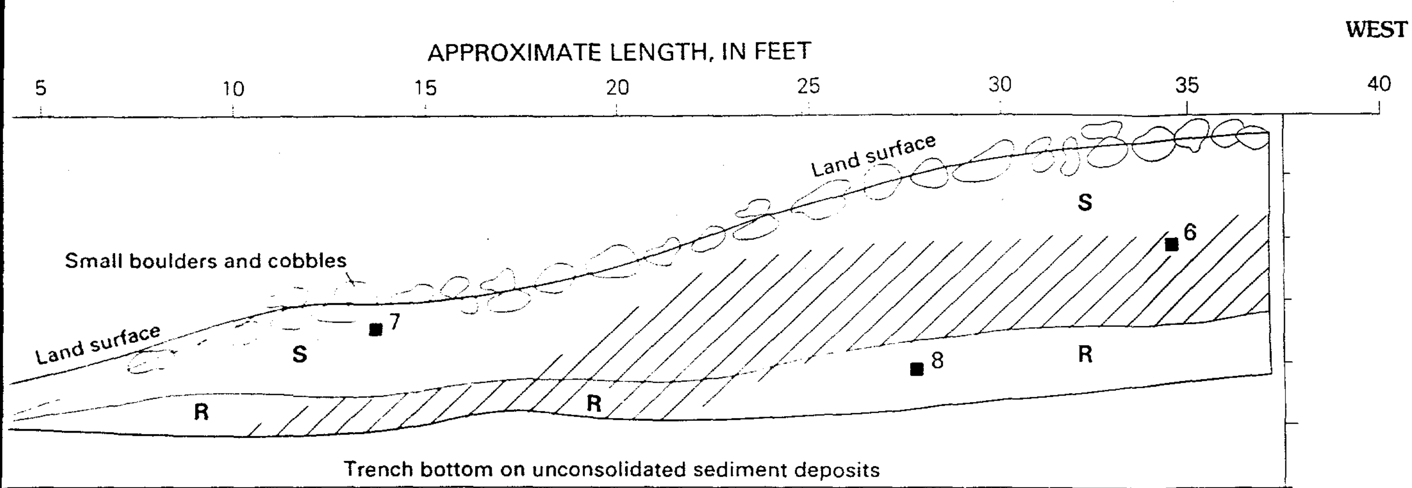
B. T-BAR TRENCH (West Wall)


NORTH
60
65
70
75
Small boulders and large cobbles
Q


EAST
APPF
0
5
10
15
0
5
APPROXIMATE THICKNESS, IN FEET
Small boulders and cobbles
Land surface
7
S
J
R
Trench bottor

C. T-LE





C. T-LEG TRENCH (South Wall)

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 inches in diameter; plentiful sand- and finer size matrix; contains many small cobbles and occasional large cobbles as large as 9 inches 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

J — **Slopewash deposit**—Mixture of mostly gravel and fines with numerous cobbles; occasional large cobbles and small boulders as much as 6 inches 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 partly 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 feet in average diameter; fines mainly fine-to-medium sand including probable reworked eolian material; unconsolidated and unbedded internally; fairly young

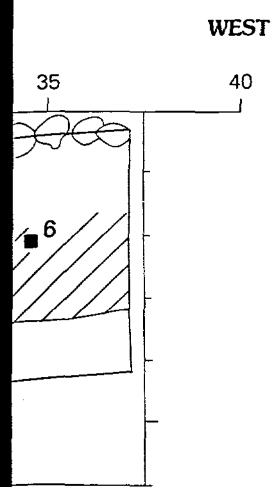
G — **Debris-flow deposit**—Heterogeneous mixture of mainly cobbles, gravel, and sand; contains some boulders as large as 1.5 feet in average diameter; matrix largely fine sand, most of which probably is reworked eolian material; unconsolidated with only a very slight internal bedding; visibly prominent stage-I carbonate coating of coarse particles

F — **Water-dominated flow deposit**—Largely pebbles, 1 to 2 inches in average diameter, with a plentiful sand matrix; abundant 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 might be largely of eolian origin; a few scattered clasts as large as about 2 inches in diameter; unconsolidated and weakly stratified internally; upper and northern part of unit contains clasts coated with a stage-I carbonate precipitate

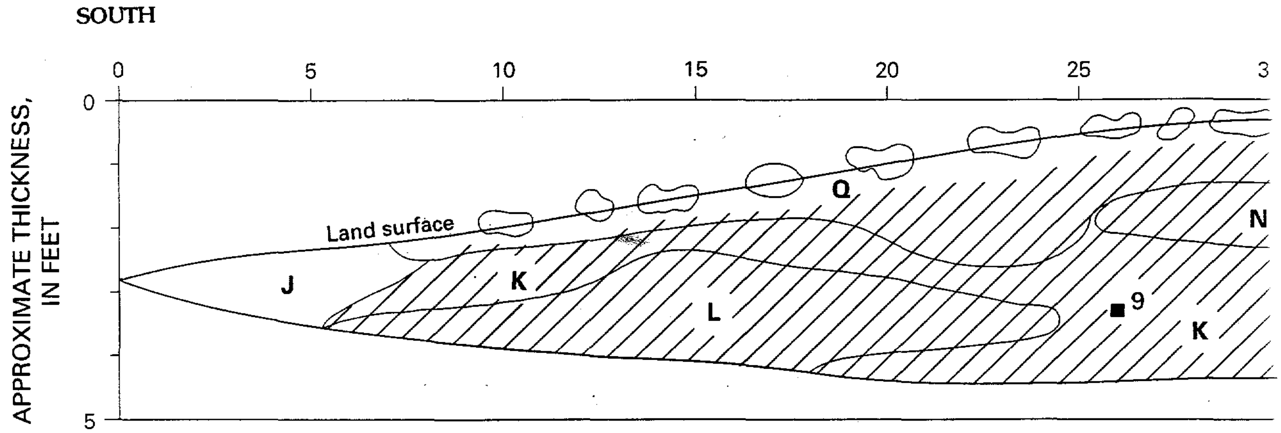
D — **Water-dominated flow deposit**—Dominantly gravel averaging about 3 inches in diameter; contains some scattered cobbles as large as 6 inches in diameter; sandy matrix; much likely of eolian origin; unconsolidated and very weakly bedded internally

C — **Debris-flow deposit**—Dominantly cobbles averaging 2 to 4 inches in diameter with a matrix of pebbles and sand; contains some cobbles as large as 8 inches in diameter; sand might be mostly reworked eolian material; unconsolidated and internally unstratified; 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

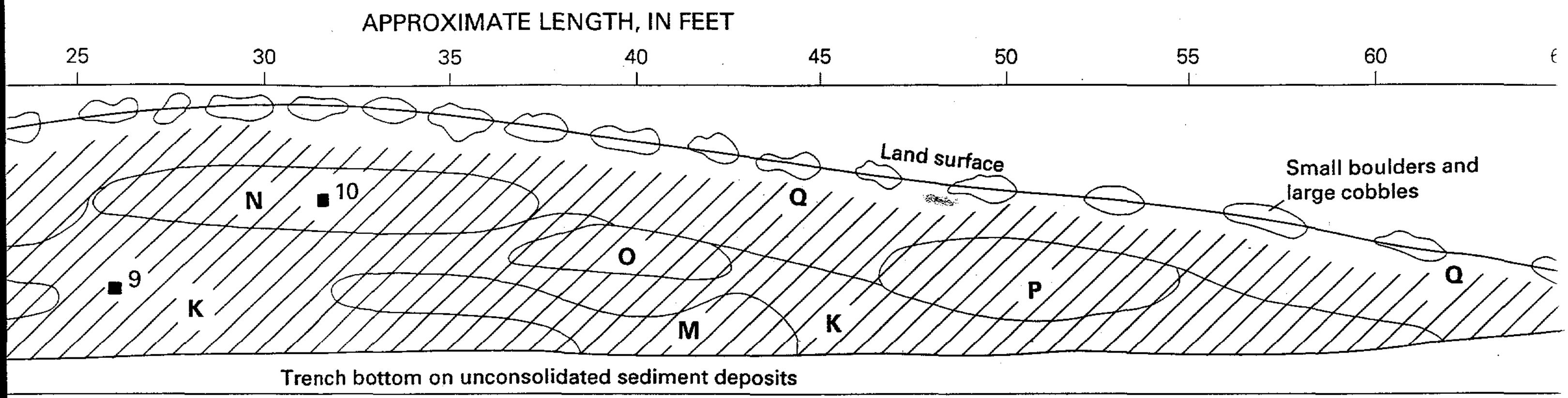


B — **Debris-flow deposit**—Heterogeneous mixture of particles of various size; few large particles average in the 0.7- to 1.5-foot-diameter range; coarse fraction is dominantly 2.5 to 4 inches in average diameter; dominantly sand and finer-size particles matrix; could be of eolian origin; slight induration 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

A — **Predominantly debris-flow deposit**—Heterogeneous mixture of coarse-size fragments and fines; contains some scattered boulders as large as 1.5 feet in maximum diameter; matrix contains higher percentage of clay than other units; deposit noticeably indurated and unstratified internally; induration largely result of carbonate cement; stringers of carbonate, filament-like precipitates throughout deposit; upper part of deposit is layer of cobbles that range in average diameter from 3 to 10 inches. Overall color more reddish or yellowish than units C–J; thin part at south is slopewash feet. Stratigraphy of deposits delineated and described on plate 1A.

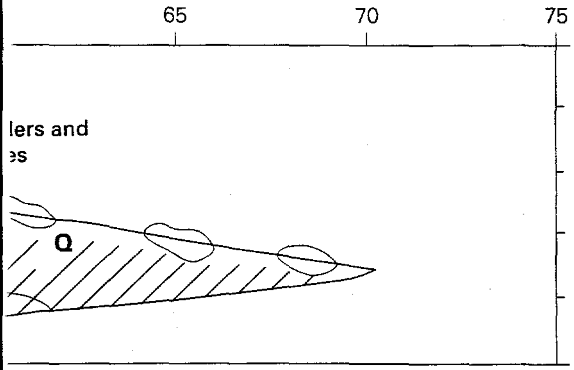


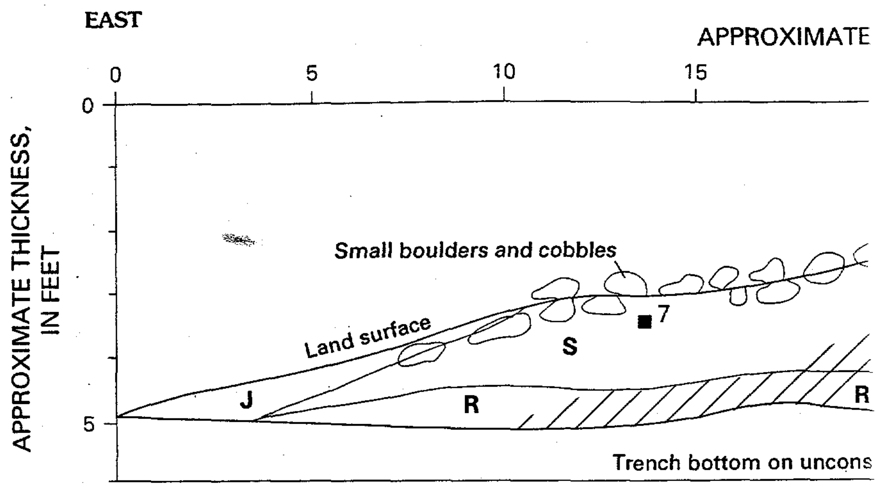
SKETCI



B. T-BAR TRENCH (West Wall)

SKETCHES OF TRENCH STRATIGRAPHY AND PH
TRENCH EXCAVATED IN NORTH





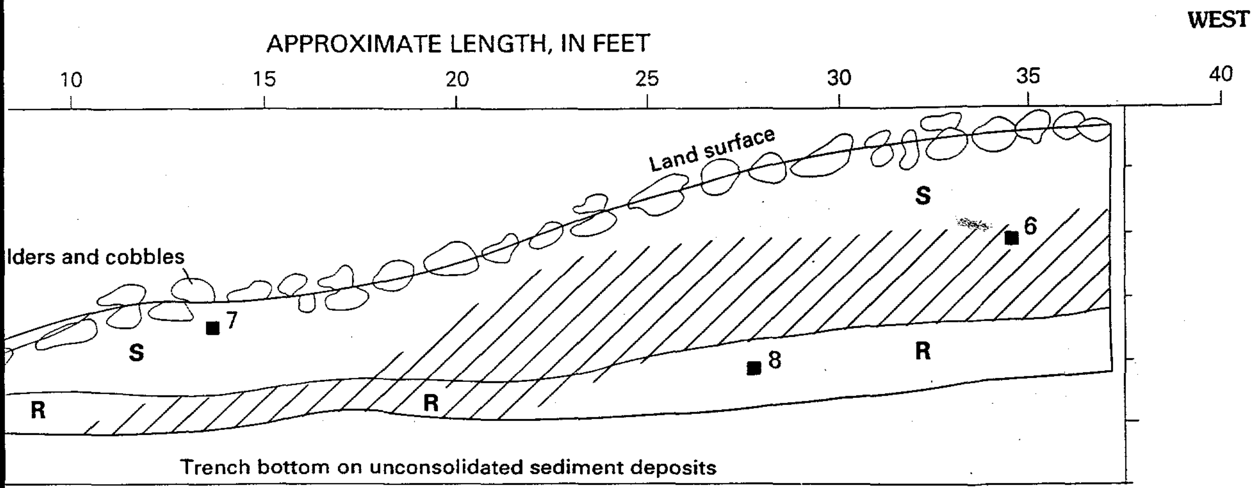
C. T-LEG TREN

ND PHOTOGRAPH SHOWING UPSTREAM (WEST) V ORTH FORK COYOTE WASH, YUCCA MOUNTAIN

By

Patrick A. Glancy

1994



C. T-LEG TRENCH (South Wall)

F Water
ave
like
be

E Water
fin
fev
un
pa

D Water
3
6
un

C Debri
dia
lar
ma
to
sta
ac

B Debri
fev
co
dc
or
ler
inc
ad
ca
un

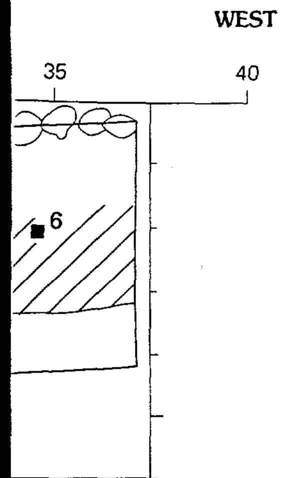
A Predc
siz
1.
cla
int
ca
de
10
thi

Stage
pa

Stage
siz

■ 6 Partic

EAM (WEST) WALL OF CROSS-CHANNEL
A MOUNTAIN, NEVADA



F — **Water-dominated flow deposit**—Largely pebbles, 1 to 2 inches in average diameter, with a plentiful sand matrix; abundant 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 might be largely of eolian origin; a few scattered clasts as large as about 2 inches 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 inches in diameter; contains some scattered cobbles as large as 6 inches 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 inches in diameter with a matrix of pebbles and sand; contains some cobbles as large as 8 inches in diameter; sand might be mostly reworked eolian material; unconsolidated and internally unstratified; 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; few large particles average in the 0.7- to 1.5-foot-diameter range; coarse fraction is dominantly 2.5 to 4 inches in average diameter; dominantly sand and finer-size particles matrix; could 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

A — **Predominantly debris-flow deposit**—Heterogeneous mixture of coarse-size fragments and fines; contains some scattered boulders as large as 1.5 feet in maximum diameter; matrix contains higher percentage of clay than other units; deposit noticeably indurated and unstratified internally; induration largely result of carbonate cement; stringers of carbonate, filament-like precipitates throughout deposit; upper part of deposit is layer of cobbles that range in average diameter from 3 to 10 inches. Overall color more reddish or yellowish than units C–J; thin part at south is slopewash

Stage-I carbonate developed on coarse (larger than sand-size) particles

Stage-II carbonate precipitate on and around most particles of all sizes

■ 6 — **Particle-size sample site and number**

CHANNEL