

# **Quaternary Paleoseismology and Stratigraphy of the Yucca Mountain Area, Nevada**

William R. Keefer, John W. Whitney, and Emily M. Taylor, Editors

Prepared in cooperation with the  
U.S. Department of Energy, Nevada Operations Office  
(Interagency Agreement DE-A108-97NV12033)

Professional Paper 1689

**U.S. Department of the Interior**  
**U.S. Geological Survey**

**U.S. Department of the Interior**  
Gale A. Norton, Secretary

**U.S. Geological Survey**  
Charles G. Groat, Director

**U.S. Geological Survey, Reston, Virginia: 2004**

For sale by U.S. Geological Survey Information Services  
Box 25286, Denver Federal Center  
Denver, CO 80225

This report and any updates to it are available online at:  
<http://pubs.usgs.gov/pp/2004/1689/>

For additional information write to:  
Chief, Yucca Mountain Project Branch  
U.S. Geological Survey  
Box 25046, Mail Stop 421, Denver Federal Center  
Denver, CO 80225-0046

Additional USGS publications can be found at:  
<http://geology.usgs.gov/products.html>

For more information about the USGS and its products:  
Telephone: 1-888-ASK-USGS (1-888-275-8747)  
World Wide Web: <http://www.usgs.gov/>

Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement of the U.S. Government.

Although this report is in the public domain, it contains copyrighted materials that are noted in the text. Permission to reproduce those items must be secured from the individual copyright owners.

**Cataloging-in-publication data are on file with the Library of Congress (URL <http://www.loc.gov/>).**

Produced in the Western Region, Menlo Park, California  
Manuscript approved for publication, December 23, 2003  
Text edited by George A. Havach  
Layout and design by Sara Boore and Susan Mayfield

## Foreword

The U.S. Geological Survey has conducted a comprehensive series of fault studies to determine the history and extent of Quaternary deformation in the Yucca Mountain area of southwestern Nevada as part of a broad, multidisciplinary site-characterization program to evaluate the suitability of the mountain to host a geologic repository for the safe and permanent storage of high-level radioactive wastes. The results of the detailed studies reported here provide basic data that are fundamental to assessing the risks posed by potential future earthquakes and fault displacements with respect to the design and long-term performance of the proposed facilities. The scope and objectives of fault investigations were largely guided by regulations established by the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy for the siting of geologic repositories for the storage of high-level radioactive wastes.

This report focuses primarily on eight faults within and near Yucca Mountain that are known to have been active during Quaternary time, as well as on two other conspicuous fault systems in nearby areas that also demonstrate neotectonic activity. The overall objective was to obtain, for each individual fault or fault system, definitive information on the number, magnitude, and estimated dates of surface-rupturing paleoearthquakes. Compiling such information involved extensive field investigations, excavation and logging of trenches, detailed descriptions of surficial deposits and soils, and selected sampling and analyses for numerical age determinations, all of which were performed in accordance with a rigorous set of technical procedures and guidelines that were formulated to comply with quality-assurance standards—an essential requirement for activities related to the siting of nuclear facilities.

Beyond the specific purpose of providing a basis for the seismic-risk analysis of Yucca Mountain, the accumulated data and resulting interpretations constitute a valuable contribution to our knowledge and understanding of the neotectonics in this part of the Basin and Range Province. Faults in few other parts of the region have been studied as thoroughly and comprehensively, and so the pattern of Quaternary deformation within this limited area may serve as an example of the structural relations and the locations and magnitudes of potential future earthquakes elsewhere in the Great Basin.



# Contents

[Numbers designate chapters]

Foreword .....	iii
1. Introduction to Quaternary Paleoseismology and Stratigraphy of the Yucca Mountain Area... By John W. Whitney, Emily M. Taylor, and Christopher M. Menges	1
2. Quaternary Stratigraphy and Mapping in the Yucca Mountain Area .....	11
By John W. Whitney, Emily M. Taylor, and John R. Wesling	
3. Distribution of Quaternary Faults at Yucca Mountain .....	23
By Christopher M. Menges and John W. Whitney	
4. Summary of Studies in Midway Valley .....	33
By John R. Wesling, John W. Whitney, Frank H. Swan, and Michael M. Angell	
5. Summary of Quaternary Faulting on the Paintbrush Canyon, Bow Ridge, and Stagecoach Road Faults .....	41
By Christopher M. Menges, Emily M. Taylor, John R. Wesling, Frank H. Swan, Jeffrey A. Coe, Daniel J. Ponti, and John W. Whitney	
6. Results of Paleoseismic Investigations on the Ghost Dance Fault .....	71
By Emily M. Taylor, Christopher M. Menges, and David C. Buesch	
7. Quaternary Faulting on the Solitario Canyon Fault .....	89
By Alan R. Ramelli, John A. Oswald, Giovanni Vadurro, Christopher M. Menges, and James B. Paces	
8. Quaternary Faulting on the Fatigue Wash Fault .....	111
By Jeffrey A. Coe, John Oswald, Giovanni Vadurro, and Scott C. Lundstrom	
9. Quaternary Faulting on the Windy Wash Fault .....	125
By John W. Whitney, F. William Simonds, Ralph R. Shroba, and Michele Murray	
10. Quaternary Faulting on the Southern Crater Flat Fault .....	135
By Emily M. Taylor	
11. Quaternary Faulting on the Northern Crater Flat Fault .....	145
By Jeffrey A. Coe	
12. Quaternary Faulting on the Bare Mountain Fault .....	155
By Larry W. Anderson and Ralph E. Klinger	
13. Paleoseismic Investigations on the Rock Valley Fault System .....	175
By Jeffrey A. Coe, James C. Yount, Dennis W. O'Leary, and Emily M. Taylor	
14. Summary of the Temporal and Spatial Relations of Quaternary Faulting During the Past 100 k.y. at Yucca Mountain: Evidence for Distributive Surface Ruptures on Multiple Faults ...	197
By William R. Keefer and Christopher M. Menges	
References Cited .....	201

## Plates

- 1–26. Logs of:
1. South wall of trench MWV–T7
  2. Trench A1
  3. Trench T14
  4. Trench WBR
  5. South wall of trench T4
  6. South wall of trench T4A
  7. South wall of trench T2
  8. South wall of trench SCF–T1
  9. South wall of trench SCF–T4
  10. South wall of trench SCF–T2
  11. Trenches CF1 and CF1A
  12. North wall of trench CF2
  13. South wall of trench CF2
  14. North wall of trench CF2.5
  15. North wall of trench CF3
  16. South wall of trench CF3
  17. North wall of trench CFF–T1A
  18. North wall of trench CFF–T1
  19. South wall of trench CFF–T2A
  20. Trench BMT–1
  21. Trench BMT–2
  22. Trench BMT–3
  23. Trenches RV3, RV3CT, and RV3A
  24. Trenches RV4 and RV4A
  25. Trench RV5
  26. West wall of the trench in Frenchman Flat

## Figures

1. Map of southwestern Nevada, showing location of Yucca Mountain area, geographic features, general distribution of major rock types, and locations of trenches outside site area ..... 2
2. Index map of Yucca Mountain area, showing locations of major faults and trench sites ..... 3
3. Schematic stratigraphic column showing age distribution of mapped Quaternary deposits in Midway Valley and Fortymile Wash ..... 17
4. Map showing faults in the Yucca Mountain area ..... 24
5. Schematic cross section showing stratigraphic relations among bedrock, alluvium, and colluvium in western Midway Valley, southwestern Nevada ..... 34
6. Maps of test pits shown in figure 8 ..... 35
7. Cross section showing structure across Exile Hill and western Midway Valley ..... 36

8.	Map of Exile Hill area, southwestern Nevada, showing general geology and locations of faults, trenches, test pits, and boreholes .....	37
9–10.	Simplified logs of natural exposures across the Paintbrush Canyon Fault at:	
9.	Busted Butte wall 4 .....	44
10.	Busted Butte wall 1 .....	48
11–12.	Topographic profile of:	
11.	Sand-ramp geomorphic surface on interfluvium across the Paintbrush Canyon Fault on west side of Busted Butte .....	50
12.	Colluvial footslope south of trench MWV–T4 .....	55
13.	Simplified log of north wall of trench MWV–T4, which exposes western splay of the Paintbrush Canyon Fault .....	56
14–15.	Topographic profile of colluvial footslope:	
14.	At north edge of trench A1 .....	57
15.	Across the Bow Ridge Fault south of trench T14D .....	59
16–17.	Logs of south wall of:	
16.	Northern section of trench T14D across the Bow Ridge Fault .....	60
17.	Southern section of trench T14D across the Bow Ridge Fault .....	62
18.	Topographic profiles of geomorphic surfaces across the Stagecoach Road Fault ...	63
19–20.	Simplified logs of central part of:	
19.	Trench SCR–T1 across the Stagecoach Road Fault .....	64
20.	Trench SCR–T3 across the Stagecoach Road Fault .....	66
21.	Aerial photograph of east slope of Yucca Mountain, showing locations of topographic features, Ghost Dance and Sundance Fault traces, and trenches .....	72
22.	Photographs showing the Ghost Dance and Northern Solitario Canyon Faults along slopes of Yucca Mountain .....	73
23.	Aerial photograph of Whale Back and Antler Ridges in Split Wash along slopes of Yucca Mountain, showing locations of topographic profiles across the Ghost Dance Fault .....	74
24.	Topographic profiles across the Ghost Dance Fault on Whale Back and Antler Ridges in Split Wash along slopes of Yucca Mountain, showing locations of bedrock samples collected for determinations of whole-rock cosmogenic <sup>10</sup> Be estimated ages .....	75
25.	Photographs showing exposures of the Ghost Dance Fault .....	76
26–29.	Diagrams showing:	
26.	Simplified lithostratigraphy and structural features in trench WBR across the Ghost Dance Fault .....	77
27.	Generalized stratigraphic column of crystal-rich member of the Tiva Canyon Tuff .....	78
28.	Ti contents in samples of Tiva Canyon Tuff .....	80
29.	Zr contents in samples of Tiva Canyon Tuff .....	80
30.	Surficial geologic map of area of trench T8 across the Solitario Canyon Fault.....	91
31–32.	Logs of:	
31.	South wall of trench T8 across the Solitario Canyon Fault .....	92
32.	North wall of trench T8 across the Solitario Canyon Fault.....	94
33.	Diagram showing simple model for estimating fault displacement .....	97
34.	Log of south wall of trench SCF–T3 across the Solitario Canyon Fault .....	100
35.	Aerial photograph showing distribution of surficial deposits in the vicinity of trenches CF1 and CF–1 across the Fatigue Wash Fault .....	113

36.	Schematic diagram illustrating parameters measured for topographic profiles .....	114
37.	Diagrams showing topographic profiles SP1 through SP7 across west-facing scarp of the Fatigue Wash Fault .....	115
38–40.	Photographs showing:	
38.	Stratigraphy and faulting-event horizons exposed on south wall of trench CF1A across the Fatigue Wash Fault .....	120
39.	Stratigraphy and faulting-event horizons exposed on south wall of trench CF1 across the Fatigue Wash Fault .....	123
40.	Photograph of surface rupture from a late Holocene coseismic event on the Windy Wash Fault .....	127
41–42.	Aerial photographs showing:	
41.	Offset of 3.7-Ma basalt along the Windy Wash Fault.....	133
42.	Distribution of surficial deposits along the Southern Crater Flat Fault and locations of trenches CFF–T1 and CFF–T1A .....	136
43.	Schematic diagrams showing sequential development of structures on north wall of trench CFF–T1A across the Southern Crater Flat Fault .....	143
44–45.	Photographs of part of south wall of trench CFF–T2A across the Northern Crater Flat Fault zone, showing:	
44.	Main fault zone, mapped surficial deposits, and event horizons marking Quaternary faulting events .....	150
45.	Stratigraphic relations bearing on event X on upthrown block .....	152
46.	Aerial photograph of the Bare Mountain Fault along east side of Bare Mountain.....	156
47–49.	Geologic maps of Bare Mountain Fault area along east side of Bare Mountain, showing:	
47.	Tarantula Canyon trench site .....	158
48.	Wildcat Peak trench site .....	162
49.	Stirling trench site .....	163
50.	Plot of scarp height versus maximum scarp-slope angles for topographic profiles of Stirling and Tarantula Canyon scarps along the Bare Mountain Fault along east side of Bare Mountain, in comparison with scarps of known age in the Basin and Range Province .....	165
51–52.	Maps showing:	
51.	Location of the Rock Valley Fault system in Rock Valley .....	176
52.	Surficial geology of area surrounding trenches RV–1 and RV–2 across medial fault of the Rock Valley Fault system .....	178
53–54.	Aerial photographs showing surficial geology of area surrounding:	
53.	Trenches RV3, RV3CT, and RV3A across the northern fault of the Rock Valley Fault system .....	181
54.	Trenches RV4, RV4A, and RV5 on northern and southern strands of the southern fault of the Rock Valley Fault system .....	182
55–58.	Photographs showing geologic features exposed on:	
55.	West wall of trench RV3 across northern fault of the Rock Valley Fault system ...	187
56.	East wall of trench RV3A across northern fault of the Rock Valley Fault system ...	188
57.	West wall of trench RV4A across northern fault of the Rock Valley Fault system ...	189
58.	East and west walls of trench RV5 across northern fault of the Rock Valley Fault system .....	191
59.	Plot showing ranges in estimated dates of Quaternary faulting events identified in trenches excavated in the Yucca Mountain area .....	198



## Tables

1. Trench excavations across faults in the Yucca Mountain area, southwestern Nevada .....	4
2. Comparison of surficial deposits in the Yucca Mountain area, southwestern Nevada, with local and regional surficial stratigraphic sequences .....	12
3. Summary of diagnostic surface and soil properties of Quaternary map units in the Yucca Mountain area, southwestern Nevada .....	13
4. Numerical ages of samples collected from Quaternary deposits in Midway Valley and Fortymile Wash in the Yucca Mountain area, southwestern Nevada .....	16
5. Summary of characteristics of major faults in the Yucca Mountain area, southwestern Nevada .....	26
6. Estimated dates and numbers of surface-rupturing paleoearthquakes on the Paintbrush Canyon, Bow Ridge, and Stagecoach Road Faults in the Yucca Mountain area, southwestern Nevada .....	50
7. Summary of measured displacements on the Paintbrush Canyon, Bow Ridge, and Stagecoach Road Faults in the Yucca Mountain area, southwestern Nevada .....	50
8. Dip-slip and net displacements for individual faulting events on the Paintbrush Canyon, Bow Ridge, and Stagecoach Road Faults in the Yucca Mountain area, southwestern Nevada .....	51
9. Numerical ages of Quaternary deposits in trenches MWV–T4, A1, T14, and T14D and at Busted Butte in the Yucca Mountain area, southwestern Nevada .....	52
10. Estimated dates of selected faulting events on the Paintbrush Canyon, Bow Ridge, and Stagecoach Road Faults in the Yucca Mountain area, southwestern Nevada .....	53
11. Recurrence intervals and slip rates calculated for the Paintbrush Canyon, Bow Ridge, and Stagecoach Road Faults in the Yucca Mountain area, southwestern Nevada .....	54
12. Fault-slip rates calculated for selected dated reference horizons in trenches across the Paintbrush Canyon, Bow Ridge, and Stagecoach Road Faults in the Yucca Mountain area, southwestern Nevada .....	55
13. Lithostratigraphic features in bedrock units of the Tiva Canyon Tuff exposed in trench WBR across the Ghost Dance Fault in the Yucca Mountain area, southwestern Nevada .....	79
14. Quaternary stratigraphy exposed in trench WBR across the Ghost Dance Fault in the Yucca Mountain area, southwestern Nevada .....	82
15. Numerical ages of deposits in trenches T2, T4A, and WBR across the Ghost Dance Fault in the Yucca Mountain area, southwestern Nevada .....	82
16. Quaternary stratigraphy exposed in trench T4 across the Ghost Dance Fault in Split Wash in the Yucca Mountain area, southwestern Nevada .....	84
17. Particle-size distribution, carbonate content, and pH in soils exposed in trenches T2, T4, and T4A across the Ghost Dance Fault in the Yucca Mountain area, southwestern Nevada .....	86
18. Quaternary stratigraphy exposed in trench T4A across the Ghost Dance Fault in Split Wash in the Yucca Mountain area, southwestern Nevada .....	87
19. Quaternary stratigraphy exposed in trench T2 across the Ghost Dance Fault in Drill Hole Wash in the Yucca Mountain area, southwestern Nevada .....	88
20. Summary of stratigraphic relations and correlations in trenches across the Solitario Canyon Fault in the Yucca Mountain area, southwestern Nevada .....	90
21. Numerical ages of deposits exposed in trenches T8, T8A, and SCF–T3 across the Solitario Canyon Fault in the Yucca Mountain area, southwestern Nevada .....	90

22.	Estimated displacements associated with mid-Quaternary to late Quaternary faulting events along the Solitario Canyon Fault in the Yucca Mountain area, southwestern Nevada .....	97
23.	Numerical ages of deposits exposed in trenches CF1 and CF1A across the Fatigue Wash Fault in the Yucca Mountain area, southwestern Nevada .....	114
24.	Data on topographic profiles across the west-facing scarp of the Fatigue Wash Fault near trench CF1 in the Yucca Mountain area, southwestern Nevada .....	114
25A.	Summary of characteristics of lithologic units exposed in trench CF1 across the Fatigue Wash Fault in the Yucca Mountain area, southwestern Nevada .....	116
25B.	Descriptions of topographic profiles across the west-facing scarp of the Fatigue Wash Fault near trench CF1 in the Yucca Mountain area, southwestern Nevada ...	117
26.	Estimated vertical displacements on the Fatigue Wash Fault in trenches CF1 and CF1A in the Yucca Mountain area, southwestern Nevada .....	121
27.	Numerical ages of deposits exposed in trenches CF2, CF2.5, and CF3 across the Windy Wash Fault in the Yucca Mountain area, southwestern Nevada .....	126
28.	Soil and stratigraphic units exposed on the north wall of trench CFF-T1A across the Southern Crater Flat Fault in the Yucca Mountain area, southwestern Nevada .....	137
29.	Soil and stratigraphic units exposed on the north wall of trench CFF-T1 across the Southern Crater Flat Fault in the Yucca Mountain area, southwestern Nevada .....	140
30.	Numerical ages of deposits exposed in trench CFF-T1A across the Southern Crater Flat Fault in the Yucca Mountain area, southwestern Nevada .....	141
31.	Numerical ages of deposits exposed in trench CFF-T2A across the Northern Crater Flat Fault in the Yucca Mountain area, southwestern Nevada .....	146
32.	Descriptions of stratigraphic units exposed on the south wall of trench CFF-T2A across the Northern Crater Flat Fault in the Yucca Mountain area, southwestern Nevada .....	147
33.	Descriptions of soil profiles in trench CFF-T2A across the Northern Crater Flat Fault in the Yucca Mountain area, southwestern Nevada .....	151
34.	Summary of faulting events on the Northern Crater Flat Fault in the Yucca Mountain area, southwestern Nevada .....	153
35.	Surface characteristics used to subdivide surficial deposits and geomorphic surfaces along the Bare Mountain Fault in southwestern Nevada .....	159
36.	Correlation chart for Quaternary alluvial deposits in the vicinity of the Bare Mountain Fault, southwestern Nevada .....	159
37.	Data from topographic profiles on fault scarps along the Bare Mountain Fault, southwestern Nevada .....	165
38.	Numerical ages of surficial deposits exposed in trenches BMT-1 and BMT-2 across the Bare Mountain Fault, southwestern Nevada .....	167
39.	Numerical ages of surficial deposits exposed in trenches RV2, RV3, RV3A, RV4, and RV5 and in the trench in Frenchman Flat across the Rock Valley Fault system in the Yucca Mountain area, southwestern Nevada .....	183
40.	Summary of the characteristics of lithologic units exposed in trenches across the Rock Valley Fault system in the Yucca Mountain area, southwestern Nevada ...	184
41.	Descriptions of soil profiles in trenches across the Rock Valley Fault system in the Yucca Mountain area, southwestern Nevada .....	186
42.	Summary of faulting events on the Rock Valley Fault system in the Yucca Mountain area, southwestern Nevada .....	192
43.	Estimated dates of faulting events during the past 100 k.y. in the Yucca Mountain area, southwestern Nevada .....	199

## Conversion Factors and Abbreviations

<b>Multiply</b>	<b>By</b>	<b>To obtain</b>
kilometers (km)	0.6214	miles
meters (m)	3.2808	feet
centimeters (cm)	0.3937	inches
millimeters (mm)	0.0394	inches

---

yr	years
k.y.	thousand years
ka	thousands of years before present
m.y.	million years
Ma	millions of years before present

---

