Lund, Black

PALEOSEISMIC INVESTIGATION AT ROCK CANYON, PROVO SEGMENT, WASATCH FAULT ZONE, UTAH COUNTY, UTAH

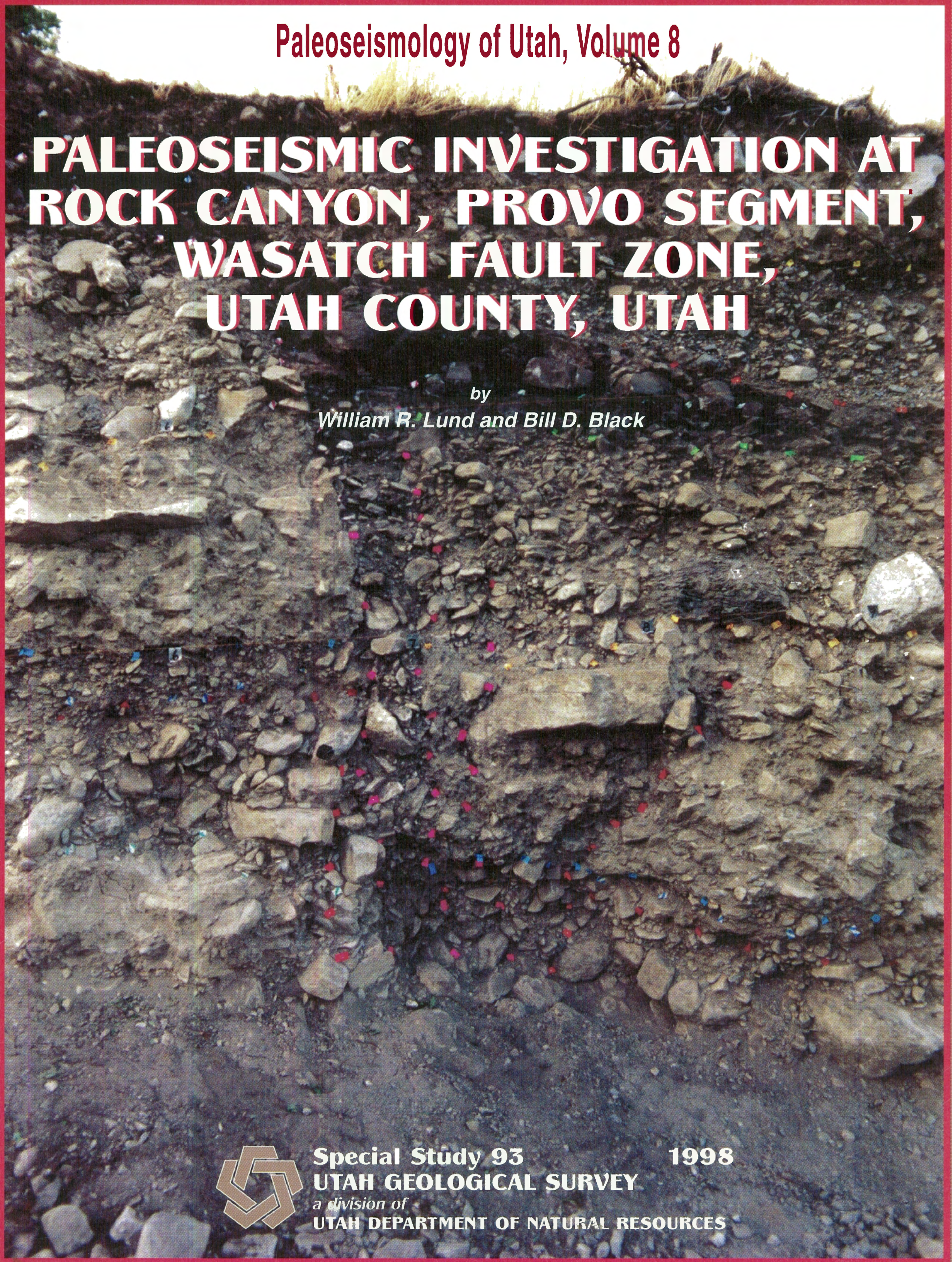
UGS Special Study 93

Paleoseismology of Utah, Volume 8

PALEOSEISMIC INVESTIGATION AT ROCK CANYON, PROVO SEGMENT, WASATCH FAULT ZONE, UTAH COUNTY, UTAH

by

William R. Lund and Bill D. Black



Special Study 93 1998

UTAH GEOLOGICAL SURVEY

a division of

UTAH DEPARTMENT OF NATURAL RESOURCES

UTAH GEOLOGICAL SURVEY

The **UTAH GEOLOGICAL SURVEY** is organized into five geologic programs with Administration, Editorial, and Computer Resources providing necessary support to the programs. The **ECONOMIC GEOLOGY PROGRAM** undertakes studies to identify coal, geothermal, uranium, hydrocarbon, and industrial and metallic resources; initiates detailed studies of these resources including mining district and field studies; develops computerized resource data bases, to answer state, federal, and industry requests for information; and encourages the prudent development of Utah's geologic resources. The **APPLIED GEOLOGY PROGRAM** responds to requests from local and state governmental entities for engineering-geologic investigations; and identifies, documents, and interprets Utah's geologic hazards. The **GEOLOGIC MAPPING PROGRAM** maps the bedrock and surficial geology of the state at a regional scale by county and at a more detailed scale by quadrangle. The **GEOLOGIC EXTENSION SERVICE** answers inquiries from the public and provides information about Utah's geology in a non-technical format. The **ENVIRONMENTAL SCIENCES PROGRAM** maintains and publishes records of Utah's fossil resources, provides paleontological and archeological recovery services to state and local governments, conducts studies of environmental change to aid resource management, and evaluates the quantity and quality of Utah's ground-water resources.

The UGS Library is open to the public and contains many reference works on Utah geology and many unpublished documents on aspects of Utah geology by UGS staff and others. The UGS has several computer data bases with information on mineral and energy resources, geologic hazards, stratigraphic sections, and bibliographic references. Most files may be viewed by using the UGS Library. The UGS also manages a sample library which contains core, cuttings, and soil samples from mineral and petroleum drill holes and engineering geology investigations. Samples may be viewed at the Sample Library or requested as a loan for outside study.

The UGS publishes the results of its investigations in the form of maps, reports, and compilations of data that are accessible to the public. For information on UGS publications, contact the Natural Resources Map/Bookstore, 1594 W. North Temple, Salt Lake City, Utah 84116, (801) 537-3320. E-mail: nrugs.geostore@state.ut.us and visit our web site at http://utstdpwww.state.ut.us/~ugs/bookstor.htm.

UGS Editorial Staff

J. Stringfellow	Editor
Vicky Clarke, Sharon Hamre	Graphic Artists
Patricia H. Speranza, James W. Parker, Lori Douglas	Cartographers

2/98

FOREWORD

This Utah Geological Survey Special Study, Paleoseismic Investigation at Rock Canyon, Provo Segment, Wasatch Fault Zone, Utah County, Utah, is the eighth report in the Paleoseismology of Utah Special Studies series. This series makes the results of paleoseismic investigations in Utah available to geoscientists, engineers, planners, public officials, and the general public. These studies provide critical information on earthquake timing, recurrence, displacement, slip rate, and fault geometry which can be used to characterize potential seismic sources and evaluate the long-term earthquake hazard presented by Utah's Quaternary faults.

Field work for this paleoseismic investigation at Rock Canyon was performed in 1988. It was one of three studies conducted in the late 1980s and early 1990s to determine if the Provo segment of the Wasatch fault zone (Schwartz and Coppersmith, 1984) should be subdivided into three smaller segments as tentatively proposed by Machette and others (1986) on the basis of their geologic mapping. This investigation was the last of the three studies performed, and initial study results were reported by Lund and Black (1990) to the 43rd Annual Meeting of the Rocky Mountain Section of the Geological Society of America in Jackson, Wyoming. Those results, combined with the results of paleoseismic investigations at American Fork Canyon (Machette and Lund, 1987) and Mapleton (Lund and others, 1991), showed that the Wasatch fault where it passes through Utah Valley probably consists of a single, almost 70-kilometer-long fault segment (Machette and others, 1992). Publication of the details of the Rock Canyon study has been delayed for several years, chiefly due to the press of new job duties on the part of the investigators. The information remains important and is presented here for the use of those individuals interested in earthquake hazards and seismic-source characteristics of the Wasatch fault in Utah Valley.

William R. Lund, Series Editor
Utah Geological Survey

Other reports in the ***Paleoseismology of Utah*** series

Special Study 75. Paleoseismology of Utah, Volume 1: Fault behavior and earthquake recurrence on the Provo segment of the Wasatch fault zone at Mapleton, Utah County, Utah, by W.R. Lund, D.P. Schwartz, W.E. Mulvey, K.E. Budding, and B.D. Black, 41 p., 1991

Special Study 76. Paleoseismology of Utah Volume 2: Paleoseismic analysis of the Wasatch fault zone at the Brigham City trench site, Brigham City, Utah and the Pole Patch trench site, Pleasant View, Utah, by S.F. Personius, 39 p., 1991

Special Study 78. Paleoseismology of Utah Volume 3: The number and timing of paleoseismic events on the Nephi and Levan segments, Wasatch fault zone, Utah, by Michael Jackson, 23 p., 3 pl., 1991

Special Study 82. Paleoseismology of Utah Volume 4: Seismotectonics of north-central Utah and southwestern Wyoming, by Michael W. West, 93 p., 5 pl., 1:100,000, 1994

Special Study 83. Paleoseismology of Utah Volume 5: Neotectonic deformation along the East Cache fault zone, Cache County, Utah, by J.P. McCalpin, 37 p., 1994

Special Study 88. Paleoseismology of Utah Volume 6: The Oquirrh fault zone, Tooele County, Utah - Surficial geology and paleoseismicity, W.R. Lund, editor, 64 p., 2 pl., 1:24,000, 1996

Special Study 92. Paleoseismology of Utah, Volume 7: Paleoseismic investigation on the Salt Lake City segment of the Wasatch fault zone at the South Fork Dry Creek and Dry Gulch sites, Salt Lake County, Utah, by Black, B.D., Lund, W.R., Schwartz, D.P., Gill, H.E., and Mayes, B.H., 22 p., 1 pl., 1996

Paleoseismology of Utah, Volume 8

PALEOSEISMIC INVESTIGATION AT ROCK CANYON, PROVO SEGMENT, WASATCH FAULT ZONE, UTAH COUNTY, UTAH

by
William R. Lund and Bill D. Black
Utah Geological Survey

Special Study 93 **1998**
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

CONTENTS

FIGURES

TABLES

PLATES

PALEOSEISMIC INVESTIGATION AT ROCK CANYON, PROVO SEGMENT, WASATCH FAULT ZONE, UTAH COUNTY, UTAH

by
William R. Lund and Bill D. Black

ABSTRACT

A trench and a natural stream cut at Rock Canyon near Provo, Utah expose fault-scarp-derived colluvium and faulted Holocene debris-flow and fluvial deposits that provide new information on the size and timing of the most recent surface-faulting earthquake on the Provo segment of the Wasatch fault zone. At the trench site, the Wasatch fault is expressed by a single, 5-meter-high scarp. The scarp becomes progressively lower to the north as displacement is partially transferred to a more westerly subparallel trace. Both fault traces intersect the stream cut about 50 meters north of the trench.

The trench exposed a single main fault, an antithetic fault, and an intervening 15-meter-wide graben. A single, wedge-shaped deposit of scarp-derived colluvium was present on the downthrown side of both the main and antithetic faults. The association of only one colluvial-wedge deposit with each of the faults is evidence for a single surface-faulting earthquake at the site in late Holocene time. Several geologic units, including three organic-rich paleosols, could be traced the entire length of the trench and are displaced across the main and antithetic faults. Net vertical tectonic displacement across the fault zone is 3.3 meters. Apparent-mean-residence-time (AMRT) radiocarbon ages on concentrated organics from the three paleosols provide broad constraints on earthquake timing. The event postdates burial of the middle paleosol at 1,600 cal yr B.P. and predates burial of the youngest (uppermost) paleosol by a post-event debris flow at 550 cal yr B.P. Precisely when the faulting occurred within the resulting 1,050-year window is unknown, but stratigraphic relations indicate it was probably closer to the end of the window (550 cal yr B.P.) than to the beginning.

Two fault strands are exposed in the Rock Creek stream cut. At the East fault, a single wedge of scarp-derived colluvium rests directly on an organic-rich paleosol. Concentrated organics from a bulk sample of the paleosol from beneath the colluvial wedge yielded an AMRT radiocarbon age of 1,330 $\pm$ 60 ^{14}C yr B.P., which represents an average age for all the carbon in the paleosol. In 1995, the uppermost 5 centimeters of the paleosol directly beneath the colluvial wedge were sampled to better constrain the age of the youngest carbon in the buried soil. Based on the resulting radiocarbon age of 830 $\pm$ 60 ^{14}C yr B.P., the paleosol was buried at about 650 cal yr B.P. Because the paleosol was buried by scarp-derived colluvium, the most recent surface-faulting earthquake at Rock Canyon occurred just prior to that time. Net vertical tectonic displacement across the East fault is 1.2 meters.

At the West fault, fluvial erosion has removed the fault scarp and all but the lower and distal parts of the scarp-derived colluvial wedge associated with the fault. An organic-rich paleosol is preserved on the downthrown side of the fault. Stratigraphic and structural relations show that two thin units (a debris flow and a fluvial deposit) overlying the paleosol were deposited after the earthquake. The two units are in turn overlain by the distal part of the colluvial wedge. Concentrated organics from a bulk sample of the paleosol collected from beneath the two units and the colluvial wedge gave an AMRT radiocarbon age of 1,520 $\pm$ 80 ^{14}C yr B.P., which represents an average age for all the carbon in the paleosol. Based on stratigraphic relations in the stream cut, the paleosols beneath the colluvial wedges at the East and West faults are believed to be the same soil unit. The approximate 200 ^{14}C year difference in their ages is within the expected resolution of the AMRT dating method and is attributed to natural variations in the soil-forming process at the two sample locations.

Extensive sloughing of the stream cut at the West fault precluded re-sampling the paleosol in 1995 to better constrain the age of the youngest carbon in the buried soil. Based on the available AMRT age (1,520 $\pm$ 80 ^{14}C yr B.P.), the paleosol was buried by the post-event debris-flow and fluvial units at about 1,100 cal yr B.P., and the earthquake would be somewhat older than that age. However, because of the large age span of the carbon in the paleosol, the calendric age provides

a maximum limiting age for the event. The actual time of burial could be tens to hundreds of years younger than the calendric age estimate. Stratigraphic relations make radiocarbon ages on detrital charcoal from fluvial and debris-flow units adjacent to and overlying the West fault equivocal and of no use in constraining the time of most recent surface faulting. Because of extensive erosion of key deposits, net vertical tectonic displacement could not be determined across the West fault.

The new paleoseismic information obtained on the timing of the most recent surface-faulting earthquake at Rock Canyon indicates the event occurred shortly before 650 (+50 -100) cal yr B.P. The timing of the most recent event at Rock Canyon is in general agreement with the timing of the most recent events at American Fork Canyon (500 ±200 cal yr B.P.) and Mapleton (600 ± 80 cal yr B.P.) to the north and south, respectively, of the Rock Canyon site. The close similarity in earthquake timing at the three sites suggests that all three locations experienced the same surface-faulting earthquake and are situated on a single rupture segment.

Using a variety of fault parameters and paleomagnitude relations, magnitude estimates for the most recent surface-faulting earthquake at Rock Canyon range from M_W/M_S 7.2 to M_S 7.6. Because uncertainty exists regarding the maximum displacement and rupture length produced by the earthquake, we consider a magnitude range of 7.2 to 7.4 a conservative best estimate for the magnitude of the event.

INTRODUCTION

Purpose and Scope

This study provides new information on the size and timing of the most recent surface-faulting earthquake on the Wasatch fault zone at Rock Canyon near Provo, Utah (figure 1). The purpose of the study was to help determine if subdivision of the original Provo segment of the Wasatch fault (Schwartz and Coppersmith, 1984; figure 2) into the proposed American Fork, Provo (restricted sense), and Spanish Fork segments of Machette and others (1986) could be substantiated on the basis of differences in timing of past surface-faulting earthquakes on the three proposed segments.

Trenching studies on the proposed American Fork segment at American Fork Canyon (figure 1; Machette and Lund, 1987; Machette, 1988; Forman and others, 1989; Machette and others, 1992) and the proposed Spanish Fork segment at Mapleton (Lund and others, 1991) are complete. Those study results show a strong correlation between the timing of the two most recent surface-faulting earthquakes at those sites. The Rock Canyon site is on the Provo (restricted sense) segment approximately midway between the other two sites (figure 1) and near the middle of the original Provo segment. Determining the timing of past surface-faulting earthquakes at Rock Canyon is necessary to conclusively demonstrate either the continuity of the original Provo segment by showing a similarity in the timing of paleoearthquakes on all three of the proposed subsegments or, if the timing is different, to show that multiple segments exist where the Wasatch fault zone passes through Utah Valley.

Previous Investigations

G.K. Gilbert, pioneer Utah geologist, was the first to recognize the tectonic significance of the Rock Canyon site, discussing the fault scarps and surficial deposits there at some length (Gilbert, 1890, p. 344-345). Nearly one hundred years later, Hintze (1978) mapped the geology of the "Y Mountain" area (approximate 1:24,000 scale) which includes the Rock Canyon site. Machette (1992) mapped the surficial geology along the original Provo segment of the Wasatch fault zone (1:50,000 scale) from the Traverse Mountains to south of Payson (figure 1).

Schwartz and Coppersmith (1984) divided the Wasatch fault zone into six independent, seismogenic segments (figure 2) based on scarp morphology, patterns of surface faulting, range-crest morphology, geophysical evidence, and limited trenching information from Hobble Creek (figure 1) near Spanish Fork, Utah (Swan and others, 1980; Hanson and Schwartz, 1982; Schwartz and others, 1983). Schwartz and Coppersmith (1984) named the longest of their segments, where the Wasatch fault zone passes through Utah Valley, the Provo segment.

In 1983, the U.S. Geological Survey (USGS) initiated an earthquake hazard study of the Wasatch Front area under the Regional Earthquake Hazards Assessment element of the National Earthquake Hazards Reduction Program. Based on preliminary geologic mapping (1:24,000 scale, later compiled at 1:50,000 scale [Machette, 1992]), scarp-morphology studies, and limited radiocarbon dating, Machette and others (1986) subdivided the original Provo segment into the American Fork, Provo (restricted sense), and Spanish Fork segments (figure 2). Subsequent trenching studies to determine the timing of past surface-faulting earthquakes on the three proposed segments were conducted on the proposed American Fork (Machette and Lund, 1987; Machette, 1988) and Spanish Fork (Lund and others, 1991) segments. This report presents the results of the trenching study conducted on the proposed Provo (restricted sense) segment in 1988. Preliminary results of this study were reported by Lund and others (1990).

During the mid-1980s, the U.S. Bureau of Reclamation, as part of their geotechnical investigations for the Central Utah Project, excavated several trenches across the Wasatch and subsidiary faults in the extreme southeastern corner of Utah Valley near Dry Mountain. Results of their investigations at the Water Canyon and Woodland Hills sites (figure 1) are summarized in Machette and others (1992).

Benson and others (1995) used seismic-refraction, gravity, and magnetic data collected along Rock Canyon Road at the mouth of Rock Canyon (figure 3) to identify buried faults in the Wasatch fault zone. Data obtained where the survey lines crossed the prominent fault scarp on the Rock Creek floodplain were used to calibrate their geophysical models and enabled them to identify numerous shallow buried faults elsewhere in the fault zone.

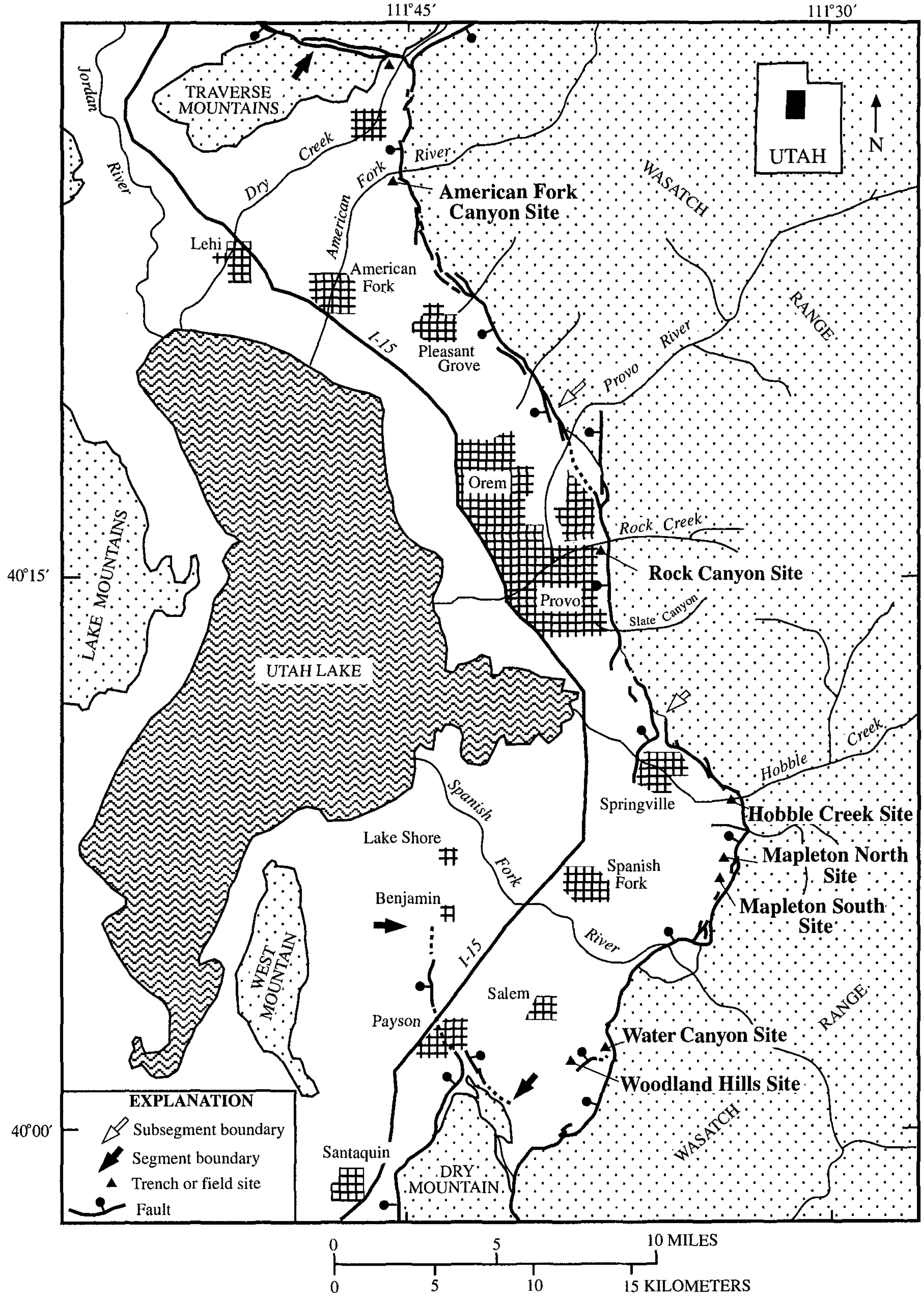


Figure 1. *Main trace of the Provo segment of the Wasatch fault zone between the Traverse Mountains and Dry Mountain showing trench site locations. North end of Nephi segment extends southward from near Benjamin. Open arrows show boundaries of the American Fork, Provo (restricted sense), and Spanish Fork subsegments of Machette and others (1986). Modified from Machette and others (1992).*

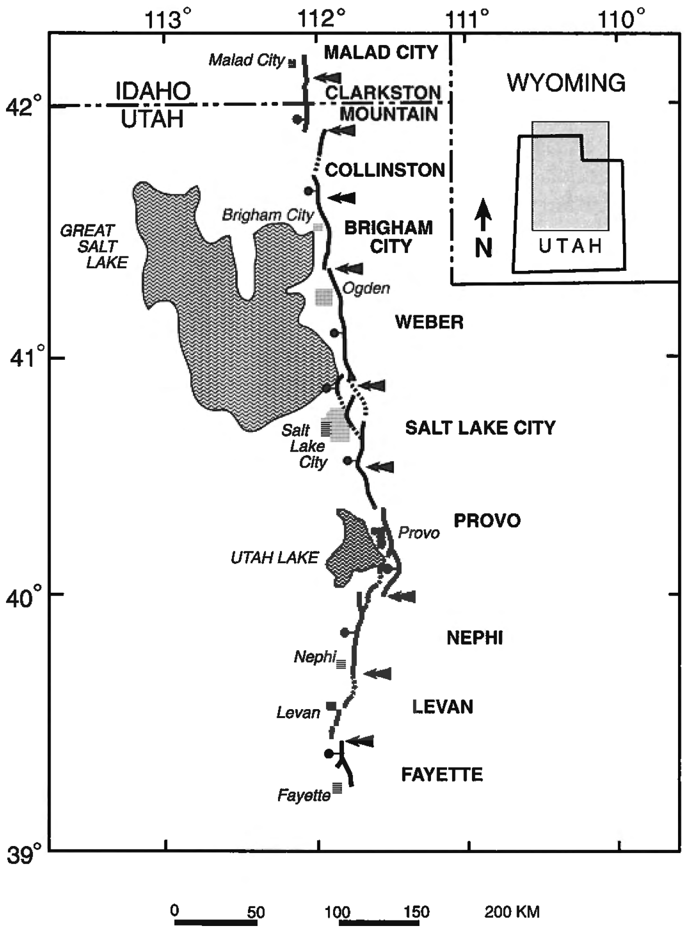


Figure 2. Map of the Wasatch fault zone showing proposed segment boundaries.

GEOLOGIC SETTING

The Rock Canyon site is at the mouth of Rock Canyon, a narrow, steep-walled drainage in the precipitous Wasatch Range east of Provo in Utah County (figure 1). Bedrock in the Wasatch Range at Rock Canyon consists of Paleozoic and Proterozoic sedimentary rocks (figure 3), predominantly quartzite, limestone, dolomite, shale, and tillite (Hintze, 1978). Rock Creek has incised its channel into Pleistocene-age Lake Bonneville deltaic sediments deposited at the mouth of Rock Canyon (figure 3) when the lake stood at its highest level (Bonneville shoreline; approximate elevation 1,573 meters) about 15,500 to 14,500 ^{14}C yr B.P. (Donald Currey, University of Utah, written communication to J.W. Gwynn, UGS, 1995). The delta remnant rises as a steep-sided bluff south of the present Rock Creek floodplain. The deltaic sediments are displaced down-to-the-west in stair-step fashion by several north-trending, west-dipping traces of the Wasatch fault zone (Hintze, 1978; Machette, 1992; figure 3). A down-to-the-east antithetic fault forms a well-defined graben parallel to the westernmost of the west-dipping faults. The entire fault zone is about 400 meters wide in the deltaic deposits.

Gilbert (1890, p. 345) shows two faults, a west-dipping main trace and an east-dipping antithetic fault, extending northward from the Pleistocene-age delta deposits onto the Holocene-age Rock Creek floodplain (figure 4). Both Hintze (1978) and Machette (1992) show a single west-dipping fault extending from the deltaic deposits onto the floodplain; neither shows an antithetic fault displacing floodplain deposits. Likewise, we were unable to identify an antithetic fault on the floodplain during this study. Benson and others (1995), using a variety of geophysical techniques, identified an east-dipping fault in the shallow subsurface along Rock Canyon Road at about the location of Gilbert's antithetic fault, but they reported no evidence for the fault at the ground surface.

In the deltaic deposits south of Rock Creek, the scarp formed by the west-dipping fault that extends onto the Rock Creek floodplain is more than 15 meters high and represents multiple (probably 3 or 4) surface-faulting earthquakes. However, on the floodplain, the scarp is only 5 meters high, indicating that the younger deposits have been displaced by fewer surface-faulting earthquakes than the older deltaic sediments. Continuing northward across the floodplain, the scarp becomes progressively lower as displacement is partially transferred to a western, subparallel, branching fault (figure 3). The two faults are exposed in the south wall of the modern Rock Creek stream channel where they displace coarse-grained Holocene debris-flow and fluvial deposits. Neither fault displaces fluvial deposits in the active Rock Creek stream channel.

Fault scarps north of Rock Creek are mostly obscured by roads and trails, a large flood-control debris basin, and a variety of other cultural features (figure 3). However, several faults observed in Lake Bonneville deltaic deposits to the south can be identified north of the creek. They displace middle to late Holocene alluvial fans and isolated remnants of Lake Bonneville sediments. Scarps in Lake Bonneville deposits are 10 or more meters high, whereas those in the younger alluvial-fan deposits are smaller and less well defined.

PALEOSEISMIC INVESTIGATION

To establish the continuity (or lack thereof) of the Provo segment through Utah Valley, it was necessary to determine, at a minimum, the timing of the most recent surface-faulting earthquake at Rock Canyon. To that end, we excavated a 31.5-meter-long, 3- to 4-meter-deep trench across the west-dipping fault that extends northward from the Lake Bonneville delta deposits onto the Rock Creek floodplain. We located the trench just north of Rock Canyon Road where the fault displaces Holocene-age floodplain deposits (figure 3). We made a detailed log of the trench (plate 1) and collected samples for radiocarbon analysis. Additionally, we logged (plate 2) and sampled the 3- to 4-meter-high south wall of the Rock Creek stream channel where the two bifurcating fault strands are exposed (figure 3).

FAN ALLUVIUM

af_1	Fan alluvium, upper Holocene
afy	Younger fan alluvium undivided, Holocene to upper Pleistocene
afp	Fan alluvium related to the Provo phase of the Bonneville lake cycle

BONNEVILLE LAKE CYCLE LACUSTRINE DEPOSITS

lbs	Lacustrine sand, trangressive lake phase
lbg	Lacustrine gravel, transgressive lake phase

BEDROCK

Bdrx	Bedrock undifferentiated, primarily Paleozoic and Proterozoic sedimentary rocks

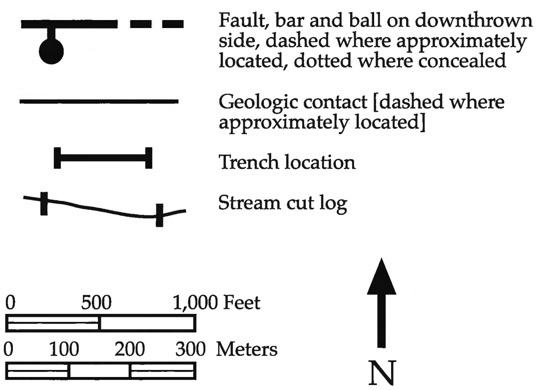


***Figure 3.** Aerial photograph/geologic map of the Rock Canyon site (geology modified from Hintze, 1978 and Machette, 1992).*

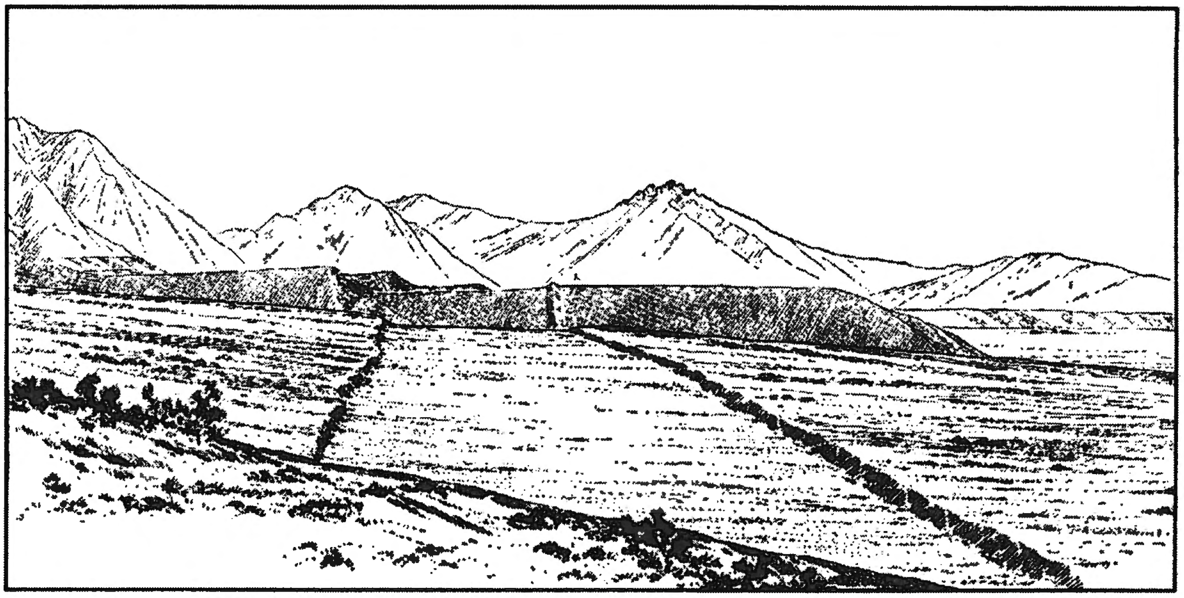


Figure 4. Rock Canyon delta and floodplain showing main and antithetic fault scarps and intervening graben (from Gilbert, 1890). View to the south.

Radiocarbon Ages

Radiocarbon ages in this study come from both charcoal (detrital material entrained in debris-flow and flood deposits) and concentrated organic material extracted from buried soil (paleosol) A horizons (table 1). We specified both conventional gas-proportional and accelerator-mass-spectrometer analytical methods depending on the characteristics of the material to be analyzed (table 1; note that not all samples collected for this study and shown on the logs were analyzed).

Laboratory ages are reported in radiocarbon years before present (^{14}C yr B.P.) with a one-standard-deviation laboratory error. By convention, ages in radiocarbon years are reported as years before A.D. 1950. We converted radiocarbon years to calendar years before present (cal yr B.P.) using a computer program (Stuiver and Reimer, 1993a, 1993b) based on studies of tree rings of known ages (Stuiver and Quay, 1979; Stuiver and Kra, 1986). We rounded calendric ages for charcoal to the nearest decade. Due to the complex nature of the soil-forming process, radiocarbon ages for concentrated soil organics are inherently less accurate than those from charcoal (Machette and others, 1992, appendix). Consequently, we rounded calendric ages from paleosol soil organics to the nearest half century to reflect their greater uncertainty. One sigma laboratory errors are reported for each sample and are similarly rounded.

Radiocarbon ages obtained from concentrated soil organics are termed apparent-mean-residence-time (AMRT) ages and are a measure of the total ^{14}C activity of the carbon in the soil. Machette and others (1992, appendix) include a discussion of the soil-forming process as it relates to dating the organic components of soils. In brief, soils serve as a kind of "carbon bank," accumulating a range of carbon of different ages over time. The age distribution of the carbon is a function of the turnover rate of carbon in the soil. Modern soils typically yield AMRT ages of a few tens to a few hundreds of years. The AMRT age of a soil before burial is termed the mean residence correction (MRC) of the soil (Machette and others, 1992, table A1). Machette and others (1992) estimate that modern soil A horizons from scarp slopes along the Wasatch fault zone have AMRT ages of 100 to 400 years depending on thickness, slope position, microclimate, and other considerations.

For purposes of paleoseismic analysis, it is often more useful to know when a soil stopped forming (no new carbon added to the soil) than it is to know the actual soil age. Pedogenic development stops when a soil is buried. It is possible to approximate the elapsed time since burial by estimating the MRC of the soil at burial and subtracting that value from the AMRT age of the paleosol organics (Machette and others, 1992). Subtracting the MRC "backs out" the age of the carbon at the time of burial; the remainder is an approximation of the elapsed time since burial. According to a procedure recommended by Minze Stuiver (University of Washington Quaternary Research Center, verbal communication to Lund, 1992), co-developer of the CALIB calendar-calibration computer program, MRCs estimated based on degree of soil development should be subtracted from the corresponding AMRT ages before calibration. This procedure differs from that of Machette and others (1992). They subtracted the estimated MRC after calendar calibrating the AMRT age. Several tests showed this variation in procedure results in at most a few tens of years difference in estimates of the time of soil burial. All such differences are well within the overall uncertainty limits associated with each calendric

Table 1.
Radiocarbon and calendar-calibrated ages for samples from the Rock Canyon trench and Rock Creek stream cut.

Field and laboratory numbers[1]	Sample material and unit sampled	^{14}C age and laboratory error (yr B.P.)[2]	Calibrated age and one-sigma uncertainty limit (cal yr B.P.)[3]	Time of paleosol burial (cal yr B.P.)[4]	Remarks
ROCK CANYON TRENCH					
RCT-AMRT1 Beta-35103	Soil organic concentrate[5] paleosol 8s A horizon, bulk sample	1,950 ± 70	1,900 (1,950 - 1,800)	1,650 (1,800 - 1,500)	West of graben, meter-mark 22.0 - 22.5, MRC = 200 yr
RCT-AMRT2 Beta-32869	Soil organic concentrate, paleosol 8s A horizon, bulk sample	1,880 ± 110	1,800 (1,950 - 1,700)	1,550 (1,800 - 1,350	In graben, meter-mark 12.75 - 13.0, MRC = 200 yr
RCT-AMRT3	Bulk sample, paleosol 8s A horizon	Not analyzed	—	—	East of main fault, meter-mark 0.5 - 1.0
RCT-AMRT4	Bulk sample paleosol 7s A horizon	Not Analyzed	—	—	East of main fault, meter-mark 0.0 - 0.25
RCT-AMRT5 Beta-32870	Soil organic concentrate, paleosol 7s A horizon, bulk sample	2,510 ± 90	2,600 (2,750 - 2,400)	2,400 (2,750 - 2,250)	West of graben, meter-mark 24.0 - 24.5, MRC = 100 yr
RCT-AMRT6 Beta-32871	Soil organic concentrate, paleosol 11s A horizon, bulk sample	590 ± 60	550 (650 - 500)	550 (600 - 500)	In graben, meter-mark 15.75 - 16.50, MRC = 100 yr
RCT-AMRT7	Bulk sample paleosol 11s A horizon	Not analyzed	—	—	In graben, meter-mark 8.25 - 9.25, not sufficiently organic
ROCK CREEK STREAM CUT					
RCSC-1 Beta-28145	Detrital charcoal from unit 12	540 ± 95	540 (680 - 460)	—	Incorporated in post-event fluvial deposit
RCSC-2	Detrital charcoal from unit 12	Not analyzed	—		Replicates RCSC-1
RCSC-3	Detrital charcoal from unit 12	Not analyzed	—	—	Replicates RCSC-1
RCSC-4 Beta-28103	Detrital charcoal from unit 12	130 ± 70	255, 225, 134, 28, 0 (300 - 0)[6]	—	Incorporated in post-event fluvial deposit
RCSC-5	Charcoal flecks from unit 15	Not analyzed	—	—	Detrital charcoal in a post-event debis flow
RCSC-6	Charcoal flecks from unit 9l	Not analyzed	—	—	Charcoal highly oxidized, not suitable for analysis
RCSC-7 Beta-27932	Detrital charcoal from unit 4	260 ± 55	340 (480 - 0)	—	Sample stratigraphically out of place or contaminated
RCSC-8 Beta-28341	Detrital charcoal from unit 5	2,815 ± 75	2,890 (3,130 - 2,780)	—	Incorporated in pre-event debris-flow deposit
RCSC-9 Beta-28342	Detrital charcoal from unit 7	660 ± 75	630 (720 - 530)	—	Incorporated in post-event debris-flow deposit
RCSC-AMRT1 Beta-32873	Soil organic concentrate, paleosol 6s A horizon, bulk sample	1,520 ± 80	1,400 (1,500 - 1,300)	1,100 (1,300 - 1,000)	Beneath West fault colluvial wedge, approx. meter-mark 47, MRC = 300 yr
RCSC-AMRT2 Beta-32874	Soil organic concentrate, paleosol 6s A horizon, bulk sample	1,330 ± 60	1,300 (1,300 - 1,200)	1,000 (1,050 - 800)	Beneath East fault colluvial wedge, approx. meter-mark 7, MRC = 300 yr
RCSC-AMRT3 Beta-87197	Soil organic concentrate from upper 5 cm of paleosol 6s A horizon	830 ± 60	725 (800 - 700)	650 (700 - 550)	Directly beneath East fault colluvial wedge, approx. meter-mark 7, MRC = 150 yr

[1]*All samples analyzed using conventional gas-proportional method except as follows: RCSC-7, RCSC-8, and RCSC-9 which were analyzed using an accelerator mass spectrometer.*

[2]*Laboratory radiocarbon ages are reported as "radiocarbon years before present" (present = A.D. 1950). Laboratory errors represent one standard deviation statistic (68% probability).*

[3]*All ages for bulk sediment samples rounded to the nearest half century, charcoal ages rounded to the nearest decade. Calibration procedure after Stuiver and Reimer (1993a, 1993b) using a laboratory error multiplier of 2, the 20-year atmospheric record, a carbon age span of 200 years, and the intercept method.*

[4]*AMRT radiocarbon age minus estimated MRC for the paleosol followed by calendar calibration according to Stuiver and Reimer (1993b).*

[5]*Soil organic concentrates are the fine organic fraction remaining after sieving and acid-wash pretreatment.*

[6]*Multiple curve intercepts, see Stuiver and Reimer (1993a, 1993b).*

age. Accordingly, we followed the procedure recommended by Stuiver.

Rock Canyon Trench

Geology

The Rock Canyon trench (approximate elevation 1,533 meters; figure 3) exposed a sequence of coarse-grained fluvial and debris-flow deposits (units 1 through 11; see appendix for geologic descriptions) and three intervening paleosol A horizons (units 7s, 8s, and 11s) displaced across a single, west-dipping main fault; an east-dipping antithetic fault; and the intervening 15-meter-wide graben (plate 1). Numerous cracks, a narrow shear zone with minimal displacement, and a small reverse fault were present in the graben. A single, post-event, scarp-derived, wedge-shaped colluvial deposit (unit 12, A through M, plate 1) was present on the downthrown side of the main fault. Similar colluvial deposits (unit 12, O through R, plate 1) were found filling a wide crack along the antithetic fault. These colluvial deposits result from the erosion of near-vertical fault scarps, and are the characteristic stratigraphic signature of a normal-slip, surface-faulting earthquake (Schwartz, 1988). A post-event debris-flow deposit in the graben (unit 13) overlies both the main and antithetic fault colluvial-wedge deposits, and unfaulted slopewash material (unit 14) drapes the main scarp and fault trace (plate 1).

The displaced Holocene-age sediments exposed in the trench are the youngest faulted deposits at the site, and provide evidence for the most recent surface faulting at Rock Canyon. Considering the height of the scarp (5 meters), we thought the trench might contain evidence for two or more events. However, the presence of a single colluvial wedge at the main and antithetic faults indicates that only the most recent surface-faulting earthquake is recorded in the trench.

Radiocarbon Age Estimates

The three paleosols in the Rock Canyon trench (units 7s, 8s, and 11s) are weakly to moderately developed soil A horizons formed on Holocene fluvial and debris-flow deposits. They represent periods of non-deposition on the Rock Creek floodplain, each sufficiently long for a soil to develop. All three paleosols contained organic material suitable for radiocarbon dating.

Paleosol 7s: Paleosol 7s is thin (<15 centimeters) and weakly developed (appendix). It is stratigraphically the lowest (plate 1) and therefore the oldest paleosol in the trench. It formed on a very coarse-grained fluvial deposit (unit 7) and is buried by a matrix-supported debris flow (unit 8). We collected a bulk sample for radiocarbon analysis west of the graben (plate 1, RCT-AMRT5, meter-mark 24.5) where the paleosol exhibited the darkest color and appeared the most organic. The paleosol organics yielded an AMRT age of 2,510 ± 90 ^{14}C yr B.P. (table 1). Soil formation ceased at the time of burial. Because paleosol 7s is weakly developed, we estimated a minimum MRC of 100 years for the soil at burial, subtracted the MRC from the AMRT age, and calendar calibrated that value. The resulting estimate of the burial time of paleosol 7s by unit 8 is 2,400 (+350,-150) cal yr B.P.

Paleosol 8s: Paleosol 8s is relatively thick (30-50 centimeters) and moderately developed (appendix). It formed on a matrix-supported debris-flow deposit (unit 8), and is the middle of the three paleosols in the trench (plate 1). It is overlain by fluvial (unit 9) and debris-flow (unit 10A) deposits, respectively. Two bulk samples of the paleosol, one from the graben near meter-mark 13 (RCT-AMRT2) and the other from west of the graben at meter-mark 22.5 (RCT-AMRT1, plate 1), yielded AMRT ages of 1,880 ± 110 and 1,950 ± 70 ^{14}C yrs B.P., respectively. Due to the complexity of the soil-forming process, variations of a hundred years or more in AMRT ages from the same soil unit are not uncommon. Matthews (1980) and Machette and others (1992) discuss AMRT age estimates and the complexities of their interpretation. Because paleosol 8s is thick and strongly organic, we subtracted an MRC of 200 years from each laboratory AMRT age prior to calibration. The resulting calendric age estimates for time of soil burial are 1,550 (+250,-200) cal yr B.P. in the graben and 1,650 (+150,-150) cal yr B.P. west of the graben. We averaged the two calendric ages to produce a composite age of 1,600 (+250,-200) cal yr B.P. for burial of paleosol 8s.

Paleosol 11s: Paleosol 11s is stratigraphically the highest and the youngest of the three paleosols in the Rock Canyon trench. In the graben, paleosol 11s is a thin (<15 centimeters), weakly developed A horizon (appendix) formed on coarse-grained debris-flow (unit 10B) and debris-flood (unit 11) deposits, respectively (plate 1). This paleosol correlates with the modern soil forming at the ground surface outside of the graben. Following the most recent surface-faulting earthquake, the displaced 11s soil continued to develop at the ground surface in the graben until buried by scarp-derived colluvium (unit 12) next to the main fault and by a post-event debris flow (unit 13) in the remainder of the graben. Stratigraphic relations show the colluvial wedge was deposited first (unit 13 overlies the toe of the wedge; meter-mark 8, plate 1), so soil formation terminated beneath the wedge first and some unknown amount of time later beneath the debris flow.

The organic content and degree of soil development of paleosol 11s is highly variable. Development is weakest: (1) beneath the colluvial wedge where the soil had less time to develop before burial, and (2) anywhere the underlying parent material (units 10B and 11) is coarse grained and contains little or no matrix. Unit 11 is particularly coarse grained beneath the colluvial wedge at the main fault. The combination of a short time for soil formation and coarse-grained parent material resulted in very weak soil development beneath the main fault colluvial wedge. There paleosol 11s is hardly more than an organic stain on the cobbles and gravel comprising unit 11 (figure 5). Lack of organic material beneath the wedge precluded obtaining a radiocarbon age for the paleosol at that location. Instead, we collected a bulk sample of paleosol 11s farther west in the graben between meter-marks 15.75 and 16.5 (RCT-AMRT6; plate 1) where visual examination showed the greatest percentage of fines and organics present. Radiocarbon analysis yielded an

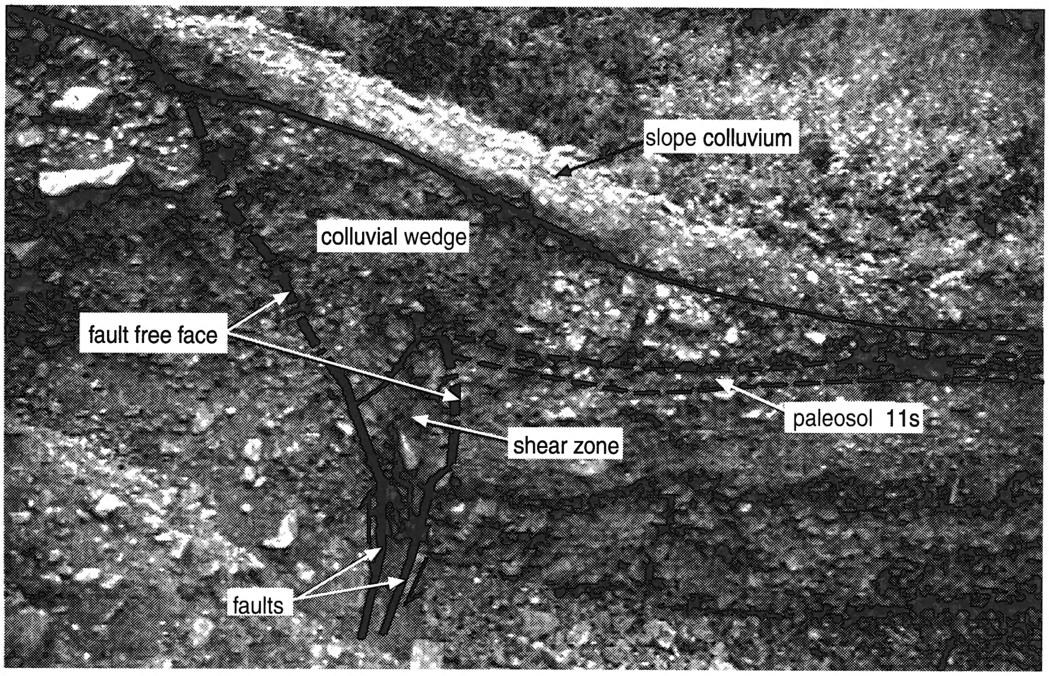


Figure 5. *Main fault in Rock Canyon trench; colluvial wedge lies directly on weakly developed paleosol 11s.*

AMRT age of 590 ± 60 ^{14}C yr B.P. for the paleosol organics. Although better developed where sampled than elsewhere in the graben, paleosol 11s was still thin and only weakly organic. Therefore, we estimated a minimum MRC of 100 years for the soil at the time of burial and subtracted that value from the AMRT age prior to calibration. The resulting calendric age of 550 (+50,-50) cal yr B.P. estimates the elapsed time since paleosol 11s was buried by the unit 13 debris flow.

Earthquake Timing

The calendric age estimates for the burial of the three paleosols exposed in the trench help constrain the timing of the most recent surface-faulting earthquake at Rock Canyon. The event displaced paleosols 7s and 8s and overlying geologic units 8, 9, 10A and 10B, and 11 (plate 1). Therefore, the event postdates burial of both paleosols and is younger than 1,600 cal yr B.P. (time of paleosol 8s' burial).

The surface faulting also displaced the soil forming at the ground surface at the time of the earthquake. The soil was later buried in the graben by post-event deposits and is now identified as paleosol 11s. Adjacent to the main fault at the east end of the graben, paleosol 11s is directly overlain by the most recent event colluvial wedge (unit 12, plate 1). A calendric age estimate for the time of soil burial there would have provided a close estimate of the time of faulting (just prior to burial). However, lack of sufficient organic material in the paleosol beneath the wedge precluded obtaining an AMRT age at that location. Farther west in the graben, a post-event debris flow (unit 13) buried the toe of the colluvial wedge and the remainder of the 11s paleosol at 550 cal yr B.P. The elapsed time between the earthquake and burial of the soil by the debris flow is not known. Therefore, radiocarbon evidence from the trench can only constrain the time of the most recent surface faulting at Rock Canyon to an approximate 1,050-year window between 1,600 and 550 cal yr B.P.

Stratigraphic relations in the trench provide additional information on the relative time of surface faulting within the window. Three fluvial/debris-flow units (9, 10A and B, and 11; plate 1) were deposited over paleosol 8s between 1,600 cal yr B.P. and the most recent surface faulting. The three units represent a period of elapsed time of unknown duration. Following the faulting, a second time period of unknown duration passed while the scarp-derived colluvial wedge formed at the main fault and the unit 13 debris flow was deposited in the graben at 550 cal yr B.P. The rate of fluvial/debris-flow sedimentation on the Rock Creek floodplain during the Holocene is unknown. However, it seems likely that the three pre-event fluvial/debris-flow units that overlie paleosol 8s represent a greater amount of time than do the most recent event colluvial wedge and single post-event deposit (unit 13 debris flow). Therefore, based on stratigraphic evidence, the most recent surface faulting at Rock Canyon probably occurred closer to the end of the 1,050-year window at 550 cal yr B.P. than to the beginning of the window at 1,600 cal yr B.P. How much closer is not known, but considering the weakly developed nature of the paleosol in the graben beneath the debris flow, the event probably predates burial of paleosol 11s by no more than a few hundred years at most, and possibly by as little as a few tens of years.

Displacement

Because several faulted geologic units extend the full length of the trench, we could directly measure the displacement produced by the most recent surface-faulting earthquake at Rock Canyon. The event produced 4.5 meters of slip (down-to-the-west) across the main fault and 0.8 meters of slip (down-to-the-east) across the antithetic fault. We determined net vertical tectonic displacement (total slip minus the effects of near-fault ground deformation [antithetic faulting, back tilting, and fault drag]) across the fault zone by projecting the contacts of units displaced across the fault from the upthrown block and the downdropped block west of the graben to the main fault and then measuring the vertical separation between them. In the Rock Canyon trench, the most recent surface faulting earthquake produced 3.3 meters of net vertical tectonic displacement across the Wasatch fault zone.

Rock Creek Stream Cut

Geology

The 3- to 4-meter-high Rock Creek stream cut exposes a sequence of late Holocene fluvial and debris-flow deposits and two strands of the Wasatch fault zone (hereafter referred to as the East and West faults). The two faults are approximately 40 meters apart in the stream cut (plate 2), and can be traced southward to a point where they merge to form the single fault scarp across which the Rock Canyon trench was excavated (figure 3). Displacement across both faults is down-to-the-west, and a single, scarp-derived colluvial-wedge deposit is associated with each fault (plate 2). Both colluvial wedges are buried by post-event debris-flow and fluvial deposits. Secondary deformation (antithetic faults, cracks, drag folding) associated with both faults is minor.

East fault: At the East fault (figure 6), the pre-earthquake ground surface is represented by a thick (40 centimeter), strongly organic paleosol A horizon (paleosol 6s, plate 2, appendix) formed on a coarse-grained debris-flow/debris-flood deposit (unit 6). Paleosol 6s was displaced by the most recent surface faulting on the East fault and is overlain on the downthrown side of the fault by a scarp-derived colluvial-wedge deposit (unit 9D, plate 2). The colluvial wedge is overlain in turn by unfaulted fluvial (units 11 and 12), slope-wash (unit 13), and debris-flow (units 15 and 18) deposits. The colluvial wedge is 0.7 meters thick and may be partially eroded by post-earthquake fluvial and debris-flow events. Alternatively, the small wedge size may reflect the distribution of slip over two faults rather than one as the fault split into two strands (figure 3).

A 40-centimeter-wide fissure at the base of the colluvial wedge is filled with loose, coarse-grained material (unit 9B) derived from the scarp. Below the fissure, sheared fault-zone material (unit 9A) extends to the base of the stream cut. The sheared zone is also about 40 centimeters wide. A small antithetic fault, with only a few centimeters of displacement and two cracks with no measurable offset, parallels the shear zone near the bottom of the stream cut (plate 2).

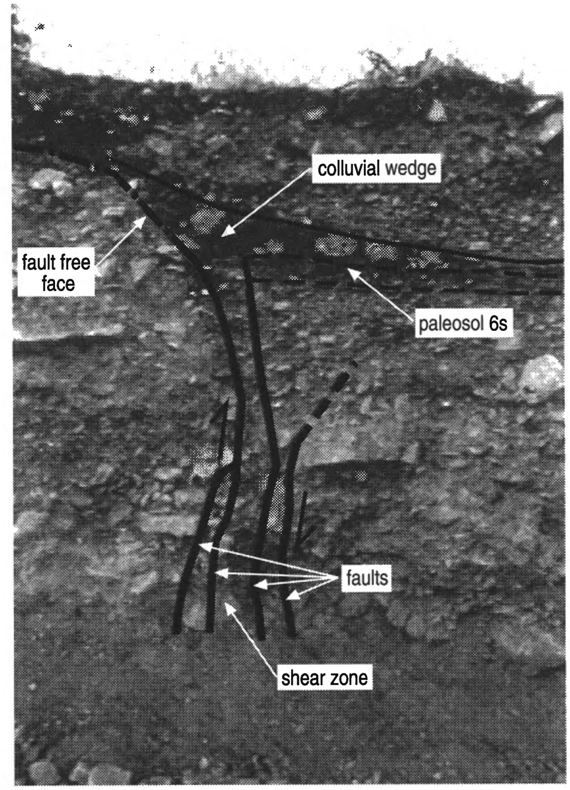


Figure 6. East fault in the Rock Creek stream cut; colluvial wedge rests directly on paleosol 6s.

Stream cut between the faults: The stream cut between the East and West faults exposes a sequence of pre- and post-event, coarse-grained fluvial and debris-flow deposits (plate 2). A pre-event debris-flow/debris-flood deposit (unit 6) pinches out to the west at approximately meter-mark 18. Thereafter, paleosol 6s is formed on a thick, pre-event, coarse-grained debris-flow deposit (unit 5). A short distance west of the unit 6 pinch out, paleosol 6s is truncated by erosion and subsequent deposition of a post-event, high-energy fluvial deposit (unit 12) that extends westward beyond the portion of the stream cut logged for this study (plate 2). Erosion preceding deposition of unit 12 truncated unit 5 at approximate meter-mark 38 (plate 2) and removed the scarp and most of the colluvial wedge associated with the most recent surface faulting on the West fault (meter-mark 42).

West fault: At the West fault (figure 7) most of the colluvial wedge is gone; basal (unit 9H) and distal (unit 9I) remnants remain and are exposed in the stream cut (plate 2). Dimensions of the remnants indicate the West fault's colluvial wedge was substantially larger than the East fault wedge. This observation is consistent with the hypothesis that the single fault crossing the Rock Creek floodplain split into two strands during the most recent surface-faulting event and that slip was preferentially transferred to the westernmost fault strand.

The wedge remnants are overlain by post-event, high-energy fluvial (units 10, 12, 14, and 19) and debris-flow (unit 15) deposits. Although eroded from the upthrown side of the

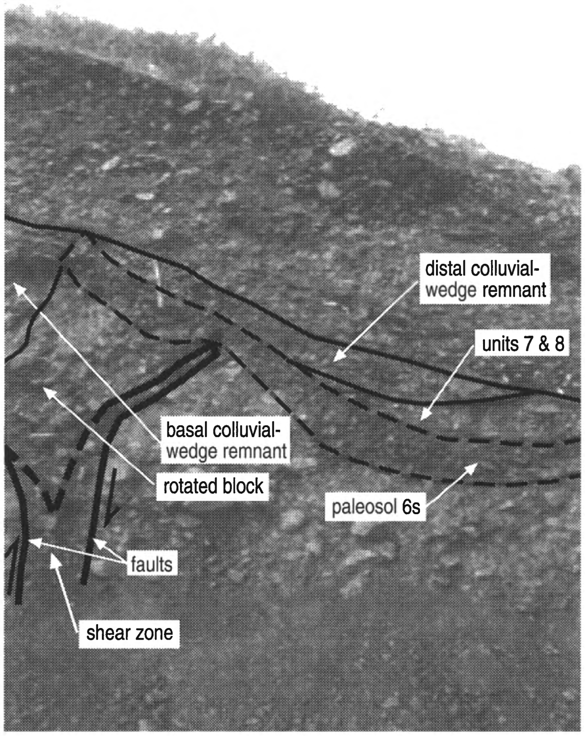


Figure 7. West fault in the Rock Creek stream cut; note basal and distal remnants of the eroded colluvial wedge. Distal remnant of the wedge overlies units 7 and 8 and paleosol 6s.

fault, paleosol 6s is preserved on the downthrown side. There, the paleosol is warped upward along the fault and is buried by thin debris-flow and fluvial deposits, respectively (units 7 and 8, plate 2). The onlapping stratigraphic relation between the two units and the deformed paleosol (approximate meter-mark 46, plate 2) shows that units 7 and 8 were deposited following the surface faulting. They are overlain by the distal part of the West fault colluvial wedge, demonstrating that the two units were deposited after the surface-faulting event but before the colluvial wedge had time to form. A thin (<15 centimeter), weakly developed soil A horizon on unit 8 (paleosol 8s; no relation to paleosol 8s in the Rock Canyon trench) does not extend beneath the colluvial wedge (plate 2), indicating that the wedge formed before the soil had time to develop. The rest of unit 8 remained at the ground surface for an unknown, but probably short, period of time while a weak soil developed. Unit 8 and the distal remnant of the colluvial wedge were then buried by a coarse-grained, post-event fluvial deposit (unit 10).

The West fault shear zone (unit 9E) is about 30 centimeters wide and strongly developed near the base of the stream cut (plate 2). It widens upward and becomes progressively less distinct. Rotated blocks of units 4 and 5 are recognizable (units 9F and 9G) within the shear zone. A secondary shear zone about 1 meter west of the main fault exhibits a few tens of centimeters of displacement near the base of the stream cut, but quickly dies out upward. Near the upper end of this shear zone (approximate meter-mark 46) the base of paleosol 6s is displaced a few centimeters down to the west.

Radiocarbon Age Estimates

East fault: In 1986, Mike Machette (USGS) and William Mulvey (UGS) made a preliminary log of the Rock Creek stream cut at the East fault and collected two bulk samples for radiocarbon analysis (Machette and others, 1992). The first sample was organic matrix material from the East fault colluvial wedge. It yielded an AMRT age of 1,110 ± 50 ^{14}C yr B.P. (Machette and others, 1992, page A40 and table A1). The second sample came from what they identified as a soil formed on the colluvial wedge following the most recent surface-faulting earthquake. It provided an AMRT age of 455 ± 35 ^{14}C yr B.P. Machette and Mulvey recognized that the two age estimates contained considerable geologic uncertainty due to the potentially large age span of the organics in the sampled material and the possibility of reworking by burrowing animals. Calendar calibration (see Machette and others, 1992 for details of their procedure) produced a calendric age of 1,005 (+145,-55) cal yr B.P. for the wedge matrix and 512 (+40,-55) cal yr B.P. for the soil on the wedge (age estimates are as reported in the literature and are not rounded). They concluded the calendric age for the wedge matrix provided a maximum limit for the time of faulting on the East fault. Using an estimated MRC of 100 years for the soil on the colluvial wedge, they further concluded that the soil was buried by post-event deposits about 400 years ago, thus bracketing the time of faulting within an interval between about 1.0 and 0.4 thousand years ago (Machette and others, 1992).

In 1988 during detailed logging of the Rock Creek stream cut for this study, we recognized that the East fault colluvial wedge rests directly on paleosol 6s (plate 2). A bulk sample of the paleosol from beneath the wedge (RCSC-AMRT2, approximate meter-mark 8, plate 2) yielded an AMRT age of 1,330 ± 60 ^{14}C yr B.P. This is considered an average age for the paleosol because the bulk sample contained carbon of different ages from throughout the soil profile. Because paleosol 6s is strongly developed, we estimated a MRC of 300 years at the time of soil burial, subtracted that value from the laboratory AMRT age, and calendar calibrated the remainder. The resulting calendric age of 1,000 (+50, -200) cal yr B.P. is similar to that obtained by Machette and Mulvey (Machette and others, 1992, p. A-39) for the organic matrix of the East fault colluvial wedge. This is not an unexpected result since much, if not most, of the organics in the wedge matrix came from erosion of paleosol 6s on the upthrown side of the fault.

In 1995, we revisited the East fault and again sampled paleosol 6s beneath the colluvial wedge (RCSC-AMRT3, approximate meter-mark 8, plate 2). We restricted the sampling to the uppermost 5 centimeters of the paleosol to collect only the youngest carbon in the soil profile. Analysis of the youngest carbon provides a more accurate estimate for the time of soil burial by the colluvial wedge. Organics in the sample provided an AMRT age of 830 ± 60 ^{14}C yr B.P. We subtracted an estimated MRC of 150 years (one-half the estimate previously used for the entire paleosol) for the young carbon and calendar calibrated. The resulting calendric age of 650 (+50,-100) cal yr B.P. estimates the time of soil burial by the scarp-derived colluvium.

We collected detrital charcoal from unit 4, a high-energy fluvial deposit, on the upthrown side of the East fault (RCSC-7, approximate meter-mark 3.5, plate 2). The charcoal has a radiocarbon age of 260 ± 55 ^{14}C yr B.P.; calendar calibration resulted in a calendric age of 340 (+140,-340) cal yr B.P. Unit 4 is displaced down to the west across the East fault and therefore is older than the most recent surface faulting. Calendric-age estimates from the paleosols in the Rock Canyon trench (units 7s, 8s, and 11s) show that the most recent surface faulting at Rock Canyon occurred sometime between 1,600 and 550 cal yr B.P. (see Rock Canyon Trench Earthquake Timing section). Stratigraphic and structural relations in the stream cut show that unit 4 is older than the surface faulting, so the 340 cal yr B.P. age for the charcoal is anomalously young. We believe the charcoal from unit 4 was either stratigraphically out of place (possibly imbedded in unrecognized younger sloughed material) or was contaminated with young carbon.

West fault: During field work for this study in 1988, we collected a bulk sample of paleosol 6s from beneath the distal remnant of the West fault colluvial wedge (RCSC-AMRT1, approximate meter-mark 47, plate 2). The paleosol organics yielded an AMRT age of 1,520 ± 80 ^{14}C yr B.P., which, due to the wide age span of the carbon in the sample, provides an average age for the paleosol. Subtracting an estimated MRC of 300 years and calendar calibrating gave a calendric age of 1,100 (+200,-100) cal yr B.P. for burial of the paleosol by post-event unit 7 (plate 2). However, because of the wide age span of the carbon in the sample, the actual time of burial could be tens to hundreds of years younger than the calendric age estimate. We also revisited the west fault in 1995, but sloughing and weathering of the stream cut precluded sampling the upper few centimeters of the paleosol 6s beneath the colluvial wedge to better constrain the time of soil burial at that location.

Detrital charcoal from pre-event debris-flow unit 5 (RCSC-8, approximate meter-mark 39.5, plate 2) yielded a radiocarbon age of 2,815 ± 75 ^{14}C yr B.P. and a calendric age of 2,890 (+240,-220) cal yr B.P. Detrital charcoal from post-event debris-flow unit 7 (RCSC-9, approximate meter-mark 47) gave a radiocarbon age of 660 ± 75 ^{14}C yr B.P. and a calendric age of 630 (+90,-100) cal yr B.P. Detrital charcoal from fluvial unit 12 yielded radiocarbon ages of 540 ± 95 ^{14}C yr B.P. (RCSC-1, approximate meter-mark 47) and 130 ± 70 ^{14}C yr B.P. (RCSC-4, approximate meter-mark 41). The corresponding calendric ages are 540 (+140,-80) cal yr B.P. and 255, 225, 134, 28 and 0 (+45,-255) cal yr B.P. (multiple curve intercepts; see Stuiver and Reimer, 1993a, 1993b). All of the calendric ages obtained from detrital charcoal are in proper stratigraphic and temporal order. However, the wide age difference between the two samples from post-event unit 12 (RCSC-1 and RCSC-4) illustrates how charcoal of different ages can be entrained as part of the sediment load of a debris flow or a flood, thus making the resulting age estimates unreliable indicators of the age of the deposit. All that can be conclusively said in such situations is that the deposit is younger than the detrital charcoal contained within it.

Earthquake Timing

East fault: Paleosol 6s on the downthrown side of the East fault was buried by scarp-derived colluvial-wedge material very soon, possibly instantaneously, after the most recent surface-faulting earthquake on the East fault. A calendar-calibrated AMRT age on organics from the upper 5 centimeters of the paleosol beneath the colluvial wedge places the time of soil burial at 650 (+50,-100) cal yr B.P. Because the colluvial-wedge material was derived from a fault scarp produced by the most recent surface faulting at the site, the faulting at Rock Canyon occurred just prior to that time.

West fault: A post-event debris-flow deposit (unit 7) buried paleosol 6s on the downthrown side of the West fault soon after the most recent surface-faulting earthquake. The time of soil burial, 1,100 (+200,-100) cal yr B.P., provides an upper limit for the time of surface faulting on the West fault because the calendric age was derived from a bulk sample of the paleosol that contained a wide age range of organics (see West Fault Radiocarbon Age Estimates section). The actual time of faulting may be tens to hundreds of years younger than 1,100 cal yr B.P. depending on the age span of the carbon in the paleosol.

The radiocarbon ages obtained from detrital charcoal in post-event units 7 and 12 (see West Fault Radiocarbon Age Estimates section) do not help constrain the time of faulting on the West fault. The charcoal in both units was entrained as part of the debris-flow/fluvial sediment load, and therefore is older than the deposit in which it is found; how much older is unknown. The longevity of charcoal at or near the ground surface following a fire can be hundreds of years or more (James Brown, U.S. Forest Service Intermountain Fire Science Laboratory, verbal communication, 1990). The charcoal in the two units may have resulted from fires that predate the surface faulting, and only later was incorporated into the units 7 and 12 debris-flow/fluvial deposits. Conversely, the fires could postdate the faulting; there simply is no way to determine the relation of the charcoal age to the time of faulting from the available evidence.

Displacement

East fault: We measured 1.2 meters of net vertical tectonic displacement across the East fault by projecting the upper contact of paleosol 6s from the upthrown and downdropped sides of the fault to the fault zone and measuring the vertical separation between the projection lines. Because there is no significant antithetic faulting or back tilting associated with the East fault, there was no need to compensate for those effects.

West fault: Post-event erosion has removed the scarp, several geologic units on the upthrown side of the fault, and most of the colluvial wedge associated with the West fault. Therefore, we could not correlate geologic units across the fault to make a direct measurement of net slip, nor could we estimate displacement using colluvial-wedge size relations (Ostenaa, 1984). Lacking a displacement value for the West fault, the total net vertical tectonic displacement across the Wasatch fault zone produced by the most recent surface faulting at the Rock Creek stream cut is unknown.

SUMMARY OF PALEOSEISMIC RESULTS

Earthquake Timing

Information on the timing of the most recent surface-faulting earthquake at Rock Canyon is available from the trench we excavated across the fault and from the two fault strands (East and West faults) exposed in the south bank of the Rock Creek stream cut. At two of these locations, the trench and the West fault, stratigraphic and structural relations and AMRT radiocarbon ages from the organic fraction of paleosol A horizons place broad constraints on the time of most recent surface faulting. From the trench we know faulting occurred sometime between 1,600 and 550 cal yr B.P., and that it probably took place closer to the 550 year age. From the West fault we know the faulting could be as old as just prior to 1,100 cal yr B.P., but that this is a maximum limiting age and the faulting could be considerably younger.

The exposure of the East fault in the stream cut provides the most concise information on the timing of surface faulting at Rock Canyon. There, a scarp-derived colluvial wedge rests directly on a paleosol (unit 6s). Burial of the paleosol by the colluvial wedge caused soil formation to cease. Based on an AMRT age from the uppermost 5 centimeters of the paleosol beneath the wedge (see section on Stream Cut Radiocarbon Ages), soil formation stopped (burial occurred) at about 650 (+50,-100) cal yr B.P. Because the wedge colluvium was derived from erosion of the scarp produced by the most recent surface faulting at Rock Canyon, the earthquake must have occurred just prior to soil burial at 650 cal yr B.P.

Timing of the most recent surface-faulting earthquake at Rock Canyon (just prior to 650 cal yr B.P.) corresponds well with the timing of the most recent surface-faulting earthquakes at the American Fork (500 ± 200 cal yr B.P.; Machette, 1990) and Mapleton (600 ± 80 cal yr B.P.; Lund and others, 1991) sites farther north and south, respectively, along the Wasatch fault zone in Utah Valley (figure 1). This close similarity in timing of the most recent surface-faulting earthquakes at these three widely spaced locations provides strong evidence that the Provo segment is a single, almost 70-kilometer-long rupture segment as originally defined by Schwartz and Coppersmith (1984; figure 2).

Displacement

Rock Canyon is one of only a few sites on the Wasatch fault zone where displaced geologic units (plate 1) can be correlated across the main fault and associated zone of deformation (graben and antithetic fault). As a result, our measurement of 3.3 meters of net vertical tectonic displacement in the Rock Canyon trench is one of the most accurate available for the Wasatch fault zone. The net slip produced by a normal slip, surface-faulting earthquake varies along strike between minimum and maximum values and is generally distributed in a non-uniform manner (Crone and others, 1985). Therefore, it is unlikely that the 3.3 meters of net slip measured in the trench represents either the maximum or minimum displacement produced by the most recent surface faulting at Rock Canyon, but rather is an intermediate value.

We could not measure the net vertical tectonic displacement across the Wasatch fault zone at the Rock Creek stream cut. However, the significant difference in size between the colluvial wedges at the East and West faults (plate 2) clearly shows that considerable slip was transferred during the most recent surface faulting from the East to the West fault trace.

Recurrence Interval and Slip Rate

Because we have evidence for only one surface-faulting earthquake at the Rock Canyon site, we could not determine a recurrence interval for surface-faulting or a fault slip rate. Machette and Lund (1987), Machette (1988), and Lund and others (1991) discuss these parameters at the American Fork and Mapleton sites, north and south, respectively, of Rock Canyon on the Provo fault segment.

PALEOMAGNITUDE ESTIMATES

Many relations have been developed to estimate paleoearthquake magnitudes from fault parameters (see dePolo and Slemmons, 1990 for discussion). Table 2 compares magnitude estimates for the Rock Canyon site based on surface-rupture length, measured displacements, estimated maximum displacement, and a combination of length and displacement (Hanks and Kanamori, 1979; Bonilla and others, 1984; Mason, 1992; Mason and Smith, 1993; Wells and Coppersmith, 1994). Because studies of earthquake timing at the Rock Canyon (this report), American Fork (Machette and Lund, 1987; Machette, 1992), and Mapleton (Lund and others, 1991) sites show that the entire Provo segment likely ruptured during a single event, we used a surface-rupture length of 69.5 kilometers (Machette and others, 1992, p. A13) for estimating paleomagnitudes. We used displacements of 3.3 meters, the net vertical tectonic displacement measured in the Rock Canyon trench; 4.0 meters, the largest displacement measured by Machette (1992) across a single-event fault scarp on the Provo segment; and 6.3 meters, a theoretical maximum displacement calculated using a regression of maximum displacement on surface-rupture length for normal-slip faults (Wells and Coppersmith, 1994).

Table 2 shows that estimates of M_W (moment magnitude) based on surface-rupture length (7.2) or displacement (7.3 to 7.4) are consistently lower than estimates of M_S (surface-wave magnitude) made using the same parameters (surface-rupture length, 7.5; displacement, 7.4 to 7.6. In comparison, estimates of M_W based on both length and displacement (7.3 - 7.4) are slightly higher than those of M_S using the same parameters (7.2 - 7.3). For this study, we consider relations that use both length and displacement (Hanks and Kanamori, 1979; Mason, 1992; Mason and Smith, 1993) to be the best estimators or eathquake paleomagnitude. Because uncertainty

Table 2. Magnitude estimates for surface-faulting earthquakes on the Provo segment of the Wasatch fault zone.

	Moment Magnitude (M_W)		Surface-Wave Magnitude (M_S)	
	Wells and Coppersmith (1994)[1]	*Hanks and Kanamori (1979)*[2]	*Bonilla and others (1984)*[3]	*Mason (1992); Mason and Smith (1993)*[4]
Based on Length[5]	7.2 (Ls = 69.5 km)[5]		7.5 (Ls = 69.5 km)	
Based on Displacement[6]	7.4 (d = 3.3 m)[6]		7.4 (d = 3.3 m)	
	7.4 (d = 4.0 m)[6]		7.4 (d = 4.0 m)	
	7.3 D = 6.3 m)[6]		7.3 D = 6.3 m)	
Based on Length and Displacement		7.3 Ls = 69.5 km; d = 3.3 m)		7.2 Ls = 69.5 km; d = 3.3 m)
		7.3 (Ls = 69.5 km; d = 4.0 m)		7.3 (Ls = 69.5 km; d = 4.0 m)
		7.4 (Ls = 69.5 km; D = 6.3 m)		7.3 (Ls = 69.5 km; D = 6.3 m)

[1]*Regression for all types of slip;* $M_w = 5.08 + 1.16 \log Ls$; $M_w = 6.93 + 0.82 \log d$; $M_w = 6.69 + 0.74 \log D$

[2]$M_w = 0.66 \log M_o - 10.7$: *where* $M_o = udA$; *u is shear modulus, d is average displacement, and A is rupture plane area. Assume* $u = 3.3 \times 10_{11}$ *dynes/cm*^{2}*, a fault dip of 45°, and a seismogenic depth of 15 kilometers.*

[3]*Ordinary least-squares relation for western North America:* $M_s = 5.17 + 1.237 \log L$, $M_s = 6.98 + 0.742 \log D$

[4]$M_s = 6.1 + 0.47 \log(DxLs)$; *D is in meters, Ls is in kilometers*

[5]*Ls is surface-trace distance for Provo segment taken from Machette and others (1992)*

[6]*3.3 meters is net slip across the Wasatch fault measured in Rock Canyon trench, 4.0 meters is the greatest net slip measured by Machette (1992) across a single-event scarp on the Provo segment; 6.3 meters is a theoretical maximum displacement from Wells and Coppersmith (1993),* $\log(MD) = -1.98 + 1.51 \times 1.84$

exists regarding the maximum displacement and surface rupture produced by the most recent surface-faulting earthquake on the Provo segment, a range of M 7.2 to 7.4 is considered a conservative "best estimate" for the magnitude of the most recent surface-faulting at Rock Canyon.

CONCLUSIONS

New paleoseismic information obtained on the timing of the most recent surface-faulting earthquake at Rock Canyon shows the event occurred shortly before 650 (+50,-100) cal yr B.P. The timing of the most recent event at Rock Canyon is in general agreement with the timing of the most recent events at American Fork Canyon (500 ± 200 cal yr B.P.) and Mapleton (600 ± 80 cal yr B.P.) to the north and south, respectively, of the Rock Canyon site. Considering the uncertainties associated with dating paleoseismic events, even those in the late Holocene, a variation of no more than 150 years in the timing of the three events is remarkable and strongly suggests that the Provo segment is a single, almost 70-kilometer-long rupture segment as originally defined by Schwartz and Coppersmith (1984; figure 2).

Using a variety of fault parameters and paleomagnitude relations, magnitude estimates for the most recent surface-faulting earthquake at Rock Canyon range from M_W/M_S 7.2 to M_S 7.6. Because uncertainty exists regarding the maximum displacement and rupture length produced by the earthquake, we consider a magnitude range of 7.2 to 7.4 a conservative best estimate for the magnitude of the event.

The trench and stream cut at Rock Canyon exposed evidence for only one paleoearthquake. Therefore, no new information was obtained from the Rock Canyon site on earthquake recurrence or slip rates on the Provo segment.

ACKNOWLEDGMENTS

This study benefitted from discussions with David Schwartz and Michael Machette of the U.S. Geological Survey. We thank the U.S. Forest Service for granting us permission to trench the Wasatch fault on Forest Service property. Janine Jarva and Bea Mayes of the UGS; Suzanne Hecker and Karen Budding formerly with the UGS but now with the USGS; and Becky Hylland also formerly with the UGS but now with the Utah Division of Oil, Gas and Mining provided field assistance. Gary Christenson reviewed this report and provided many helpful comments.

REFERENCES

Benson, A.K., Mustoe, N.B., and Carver, J.N., 1995, Integrating geophysical and trench data to analyze shallow faulting in the Wasatch fault zone near Provo, Utah County, Utah, *in* Lund, W.R., editor, Environmental and engineering geology of the Wasatch Front region: Utah Geological Association Publication 24, p. 65-75.

Bonilla, M.G., Mark, R.K., and Lienkaemper, J.J., 1984, Statistical relations among earthquake magnitude, surface rupture length, and surface fault displacement: Bulletin of the Seismological Society of America, v. 74, p. 2379-2411.

Crone, A.J., Machette, M.N., Bonilla, M.G., Lienkaemper, J.J., Pierce, K.L., Scott, W.E., and Bucknam, R.C.,1985, Characteristics of surface faulting accompanying the Borah Peak earthquake, central Idaho, *in* Stein, R.S., and Bucknam, R.C., editors and conveners, Proceedings of Workshop XXVIII On the Borah Peak, Idaho, Earthquake: U.S. Geological Survey Open-File Report 85-290, v. A, pp. 43-58.

dePolo, C.M., and Slemmons, D.B., 1990, Estimation of earthquake size for seismic hazards, *in* Krinitzsky, E.L., and Slemmons, D.B., Neotectonics in earthquake evaluation: Geological Society of America Reviews in Engineering Geology, v. 8, p. 1-27.

Forman, S.L., Machette, M.N., Jackson, M.E., and Maat, Paula, 1989, An evaluation of thermoluminescence dating of paleoearthquakes on the American Fork segment, Wasatch fault zone, Utah: Journal of Geophysical Research, v. 94, no. B2, p. 1622-1630.

Gilbert, G.K., 1890, Lake Bonneville: U.S. Geological Survey Monograph 1, 438 p.

Hanks, T.C., and Kanamori, Haroo, 1979, A moment magnitude scale: Journal of Geophysical Research, v. 84, no. B5, p. 2348-2350.

Hanson, K.L., and Schwartz, D.P., editors, 1982, Guidebook to late Pleistocene and Holocene faulting along the Wasatch Front and vicinity - Little Cottonwood Canyon to Scipio, Utah: American Geophysical Union Chapman Conference on Fault Behavior and the Earthquake Generation Process, Snowbird, Utah, October 11-15, 1982, 40 p.

Hintze, L.F., 1978, Geologic map of the Y Mountain area, east of Provo, Utah: Brigham Young University Geology Studies Special Publication 5, scale 1:24,369.

Lund, W.R., Black, B.D., and Schwartz, D.P., 1990, Late Holocene displacement on the Provo segment of the Wasatch fault zone at Rock Canyon, Utah County, Utah [abs.]: Geological Society of America Abstracts with Programs, v. 22, no. 6, p. 37.

Lund, W.R., Schwartz, D.P., Mulvey, W.E., Budding, K.E., and Black, B.D., 1991, Fault behavior and earthquake recurrence on the proposed Spanish Fork segment of the Wasatch fault zone at Mapleton, Utah County, Utah: Utah Geological and Mineral Survey Special Study 75, 41 p.

Machette, M.N., 1988, American Fork Canyon, Utah--Holocene faulting, the Bonneville fan-delta complex, and evidence for the Keg Mountain oscillation, *in* Machette, M.N., editor, In the footsteps of G.K. Gilbert--Lake Bonneville and neotectonics of the eastern Basin and Range Province: Utah Geological and Mineral Survey Miscellaneous Publication 88-1, p. 89-99.

—1992, Surficial geologic map of the Wasatch fault zone, eastern part of Utah Valley, Utah County and parts of Salt Lake and Juab Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-2095, scale 1:50,000, 30 p. pamphlet.

Machette, M.N., and Lund, W.R., 1987, Trenching across the American Fork segment of the Wasatch fault zone, Utah: Geological Society of America Abstracts with Programs, v. 19, no. 5, p. 317.

Machette, M.N., Personius, S.F., and Nelson, A.R., 1986, Late Quaternary segmentation and slip-rate history of the Wasatch fault zone, Utah: EOS [Transactions of the American Geophysical Union], v. 67, no. 44, p. 1107.

—1992, Paleoseismology of the Wasatch fault zone -- A summary of recent investigations, interpretations, and conclusions, *in* Gori, P.L., and Hays, W.W., editors, Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah: U.S. Geological Survey Professional Paper 1500-A-J, p. A1-A59.

Mason, D.B., 1992, Earthquake magnitude potential of active faults in the Intermountain seismic belt from surface parameter scaling: Salt Lake City, University of Utah, M.S. thesis, 110 p.

Mason, D.B., and Smith, R.B., 1993, Paleoseismicity of the Intermountain seismic belt from late Quaternary faulting and parameter scaling of normal faulting earthquakes [abs.]: Geological Society of America Abstracts with Programs, v. 25, no. 5, p. 115.

Matthews, J.A., 1980, Some problems and implication of ^{14}C dates from a podzol buried beneath an end moraine at Haugbbreen, southern Norway: Geografiska Annaler, v. 62A, p. 185-208.

Ostenaa, Dean, 1984, Relationships affecting estimates of surface fault displacement based on scarp-derived colluvial-wedge deposits [abs.]: Geological Society of America Abstracts with Programs, v.16, p. 327.

Schwartz, D.P., 1988, Geology and seismic hazards -- Moving into the 1990s, *in* Von Thun, J.L., editor, Earthquake engineering and soil dynamics II -- Recent advances in ground-motion evaluation: American Society of Civil Engineers Geotechnical Publication No. 20, p. 1-42.

Schwartz, D.P., and Coppersmith, K.J., 1984, Fault behavior and characteristic earthquakes--Examples from the Wasatch and San Andreas fault zones: Journal of Geophysical Research, v. 89, no. B7, p. 5681-5698.

Schwartz, D.P., Hanson, K.L., and Swan, F.H., III, 1983, Paleoseismic investigations along the Wasatch fault zone - An update, *in* Gurgel, K.D., editor, Geologic excursions in neotectonics and engineering geology in Utah, Guidebook - Part IV: Utah Geological and Mineral Survey Special Study 62, p. 45-48.

Stuiver, Minze, and Kra, R., editors, 1986, Calibration issue - Proceedings of the 12th International Radiocarbon Conference - Trondheim, Norway, 1985: Radiocarbon, v. 28, 225 p.

Stuiver, Minze, and Quay, P.D., 1979, Changes in atmospheric carbon-14 attributed to a variable sun: Science, v. 207, p. 11-19.

Stuiver, Minze, and Reimer, P.J., 1993a, Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program: Radiocarbon, v. 35, p. 212-230.

—1993b, CALIB user's guide, rev. 3.0.3 (to be used in conjunction with Stuiver and Reimer, 1993a): University of Washington, Quaternary Research Center AK-60, 37 p.

Swan, F.H., III, Schwartz, D.P., and Cluff, L.S., 1980, Recurrence of moderate to large magnitude earthquakes produced by surface faulting on the Wasatch fault zone, Utah: Bulletin of the Seismological Society of America, v. 70, p. 1431-1462

Wells, D.L., and Coppersmith, K.J., 1994, Updated empirical relationships among magnitude, rupture length, rupture area, and surface displacement: Bulletin of the Seismological Society of America, v. 84, no. 4, p. 974-1002.

APPENDIX

DESCRIPTION OF GEOLOGIC UNITS, ROCK CANYON TRENCH, WASATCH FAULT ZONE, UTAH COUNTY, UTAH

Percentage of clast size fractions are field estimates.
Plasticity estimated in the field; for coarse-grained units plasticity is reported for the matrix (fines portion) of the deposit.

Unit 1 FLUVIAL DEPOSIT (high energy)
Cobbly, sandy gravel with boulders: Light gray (10YR 7/2); 5 percent boulders (>305 mm), 20 percent cobbles (76 mm-305 mm), 45 percent gravel (4.75 mm-76 mm), 25 percent sand (0.074 mm-4.75 mm), <5 percent fines (<0.074 mm), maximum clast diameter 500 mm, subangular to subrounded; medium density; nonplastic; crudely stratified, alternating cobble and sand horizons; discontinuous $CaCO_3$ coatings on clasts, weakly to moderately cemented; a thick unit that may represent more than one fluvial event, exposed only in the upthrown block of the main fault zone.

Unit 2 FLUVIAL DEPOSIT (high energy)
Sandy, cobbly gravel: Pale brown (10YR 3/3); 20 percent cobbles, 65 percent gravel, 15 percent sand, maximum clast diameter 300 mm, subangular to subrounded; medium density (loose, openwork structure locally); nonplastic; nonstratified; discontinuous $CaCO_3$ coatings on clasts, weakly cemented; unit becomes more sandy to the east, exposed only in the upthrown block of the main fault zone.

Unit 3 FLUVIAL DEPOSIT
Silty sand with clay grading eastward to silty gravel with clay: Pale brown (10YR 6/3); <5 percent cobbles, 10-50 percent gravel, 10-50 percent sand, 30 percent fines, maximum clast diameter 150 mm, subangular to subrounded; dense; medium plasticity; non- to poorly stratified; weakly to moderately cemented; thin unit that pinches out to the east, exposed only in the upthrown block of the main fault zone.

Unit 4 DEBRIS-FLOOD DEPOSIT (clast supported)
Sandy gravel with silt and cobbles: Pale brown (10YR 6/3); 10 percent cobbles, 50 percent gravel, 25 percent sand, 15 percent fines, maximum clast diameter 250 mm, subangular to subrounded; medium dense; low plasticity; bedding moderately developed; discontinuous $CaCO_3$ coatings on clasts, weakly cemented; exposed only in the upthrown block of the main fault zone.

Unit 5 DEBRIS-FLOW/DEBRIS-FLOOD DEPOSIT
Sandy gravel with clay and cobbles: Light brownish gray (2.5Y 6/2); 5 percent cobbles, 60 percent gravel, 20 percent sand, 15 percent fines, maximum clast diameter 250 mm, subrounded to subangular; dense; medium plasticity; crudely stratified, imbricated; some discontinuous $CaCO_3$ coatings on clasts, weakly cemented; moderately sorted, average clast size 40 to 70 mm; exposed only in the upthrown block of the main fault zone.

Unit 6 FLUVIAL DEPOSIT (high energy)
Cobbly, sandy gravel with boulders: Gray (5Y 6/1); 10 percent boulders, 20 percent cobbles, 50 percent gravel, 15 percent sand, <5 percent fines, maximum clast diameter 820 mm, subrounded to subangular; dense; nonplastic; non-stratified; noncemented; very-coarse-grained, high-energy fluvial deposit exposed only in the upthrown block of the main fault zone.

Unit 7 FLUVIAL DEPOSIT (high energy)
Cobbly, sandy gravel with silt: Grayish brown (10YR 3/2); 25 percent cobbles, 50 percent gravel, 20 percent sand, 5 percent fines, maximum clast diameter 250 mm, subrounded; dense; nonplastic; nonstratified; discontinuous $CaCO_3$ coatings on clasts, weakly cemented; first unit exposed in both the up- and downthrown blocks of the main fault zone.

Paleosol 7s WEAK SOIL A HORIZON DEVELOPED ON UNIT 7
Thin, weakly developed organic soil A horizon: Similar to unit 7 but darker in color (dark gray, 10YR 4/1); forms a sharp contact with overlying unit.

Unit 8 DEBRIS-FLOW DEPOSIT (matrix supported)
Cobbly, clayey gravel with sand: Light brownish gray (2.5Y 6/2); <5 percent boulders, 20 percent cobbles, 25 percent gravel, 15 percent sand, 35 percent fines, maximum clast diameter 700 mm, subrounded to subangular; dense; medium plasticity; nonstratified; noncemented, occasional $CaCO_3$ coatings on clasts; distinct, persistent stratigraphic unit throughout the trench.

Paleosol 8s SOIL A HORIZON DEVELOPED ON UNIT 8
Well-developed organic soil A horizon: Similar to unit 8 but darker in color (dark grayish brown, 10YR 4/2); lower contact gradational with underlying unit, excellent stratigraphic marker horizon throughout the trench.

Unit 9 FLUVIAL DEPOSIT (low energy)

Clayey, silty sand/clayey, sandy silt: Light brownish gray (2.5Y 4/2); 5 percent gravel, 45 percent sand, 50 percent fines, maximum clast diameter 20 mm, subrounded; medium dense/stiff; medium plasticity; thinly bedded; noncemented; discontinuous, thin, fine-grained unit best developed on the downthrown block of the main fault zone.

Unit 10 DEBRIS-FLOW DEPOSIT

Unit 10A

Silty gravel with sand and cobbles: Light brownish gray (2.5Y 4/2); <5 percent boulders, 10 percent cobbles, 50 percent gravel, 15 percent sand, 25 percent fines, maximum clast diameter 400 mm, subangular to subrounded; dense; low plasticity; crudely stratified, imbricated; noncemented; lower, clast-supported portion of a complex debris flow.

Unit 10B

Cobbly, silty gravel with sand: Light brownish gray (2.5Y 4/2); <5 percent boulders, 20 percent cobbles, 40 percent gravel, 15 percent sand, 25 percent fines, maximum clast diameter 400 mm, subangular to subrounded; dense; low plasticity; nonstratified; non- to weakly cemented; upper, matrix supported portion of a complex debris flow.

Unit 11 DEBRIS-FLOOD/DEBRIS-FLOW DEPOSIT

Sandy gravel with silt and cobbles: Grayish brown (10YR 5/2); 5 percent cobbles, 50 percent gravel, 30 percent sand, 15 percent silt, maximum clast diameter 100 mm, subrounded; dense; low plasticity; nonstratified; noncemented.

Paleosol 11s SOIL A HORIZON DEVELOPED ON UNITS 11 AND 10B

Thin, well-developed organic A horizon: Similar to the units on which it formed but much darker in color (black, 10YR 2/1); this soil represents the ground surface prior to the most recent surface-faulting earthquake and correlates with the modern soil at the ground surface east of the main fault zone and west of the antithetic fault zone.

MOST RECENT SURFACE-FAULTING EARTHQUAKE

Unit 12 FAULT-ZONE MATERIAL AND FAULT-SCARP COLLUVIUM

Sheared material within the main and antithetic fault zones and colluvial and fissure-fill deposits derived from erosion of the fault scarps produced by the most recent surface-faulting earthquake.

MAIN FAULT ZONE

Unit 12A Fault-zone material

Cobbly, sandy gravel with silt: Grayish brown (10YR 5/2); <5 percent boulders, 20 percent cobbles, 40 percent gravel, 25 percent sand, 15 percent silt, maximum clast diameter 325 mm, subrounded to subangular; loose to medium dense; none to low plasticity; noncemented; strong shear fabric, elongate clasts aligned parallel to fault plane.

Unit 12B Rotated Blocks

Block of unit 10A or 11 derived from erosion of main fault scarp: Grayish brown (10YR 5/2); near vertical orientation of relict bedding.

Unit 12C Fissure Fill

Sandy gravel with cobbles: Grayish brown (10YR 5/2); possibly derived from the partial shattering or erosion of unit 12B.

Unit 12D Rotated Block

Vertically oriented, geologic unit of origin uncertain.

Unit 12E Fissure Fill

Sandy gravel: Grayish brown (10YR 5/2); derived from a variety of units on upthrown block

Unit 12F Rotated Block

Orientation and geologic unit of origin uncertain.

Unit 12G Fissure Fill

Sandy gravel with cobbles: Gray (5Y 6/1); darker color results from incorporation of material derived from paleosol 11S.

Unit 12H Fissure Fill
Sandy gravel: Grayish brown (10YR 5/2); coarse, openwork gravel with near-vertical alignment of clasts.

Unit 12I Fissure Fill
Sandy gravel: Gray (5Y 6/1); darker color results from incorporation of material derived from paleosols 8s and 11s.

Unit 12J Fault-Scarp Colluvium
Sandy gravel with cobbles: Grayish brown (10YR 5/2); basal part of colluvial wedge.

Unit 12K Block/Fault-Scarp Colluvium
Sandy gravel with cobbles: Grayish brown (10YR 5/2); possibly a shattered block of material incorporated into the scarp colluvium.

Unit 12L Fault-Scarp Colluvium
Sandy gravel with cobbles: Grayish brown (10YR 5/2); bedded, shows alignment of elongate clasts parallel to slope of free face, grades from fine to coarse in a downslope direction.

Unit 12M Fault-Scarp Colluvium
Sandy gravel with cobbles: Grayish brown (10YR 5/2); grades from sandy gravel to a coarse, openwork deposit of cobbles and boulders in a downslope direction, finer portions of unit show alignment of gravel and cobbles parallel to the slope of the free face.

ANTITHETIC FAULT ZONE

Unit 12N Fault-Zone Material
Cobbly, sandy gravel with boulders and silt: Grayish brown (10YR 5/2); 10 percent boulders, 20 percent cobbles, 35 percent gravel, 20 percent sand, 15 percent fines, maximum clast diameter 350 mm, subangular to subrounded; medium dense; nonplastic; noncemented; strong shear fabric, elongate clasts aligned parallel to fault plane.

Unit 12O Fissure Fill
Cobbly, sandy gravel: Grayish brown (10YR 5/2); coarse, openwork structure with small pods of more matrix-rich material.

Unit 12P Fissure Fill/Block
Silty, sandy gravel: Gray (5Y 6/1); possibly a block that shattered after tumbling from the scarp free face.

Unit 12Q Fissure Fill
Sandy gravel with cobbles: Gray (5Y 6/1); darker color results from incorporation of material derived from paleosol 11s.

Unit 12R Fault-Scarp Colluvium
Cobbly, sandy gravel with silt: Gray (10YR 5/1); grades downslope to a coarse, openwork deposit of gravel and cobbles; darker color results from incorporation of material derived from paleosol 11s; a very thin, weak soil A horizon has formed on this unit.

Unit 13 DEBRIS FLOW DEPOSIT (matrix supported)
Silty, sandy gravel with cobbles: Brown (10YR 5/3); 15 percent cobbles, 40 percent gravel, 25 percent sand, 20 percent fines, maximum clast diameter 300 mm, subrounded to subangular; dense; low plasticity; nonstratified; noncemented; post-most recent earthquake debris flow confined to the graben west of the main fault zone.

Unit 14 SLOPE COLLUVIUM
Sandy gravel with silt and cobbles: Gray (10YR 5/1); 5 percent cobbles, 50 percent gravel, 30 percent sand, 15 percent fines, maximum clast diameter 200 mm, subrounded to subangular; dense; low plasticity; crudely stratified, alignment of elongate clasts parallel to slope.

Soil 14s MODERN SOIL
Gravelly, silty sand: Dark grayish brown (10YR 4/2); <5 percent cobbles, 25 percent gravel, 45 percent sand, 30 percent fines; organic soil A horizon, degree of development greatest east of main fault zone and west of the antithetic fault zone.

Unit 15 ARTIFICIAL FILL
Coarse, angular fill placed in parking area.

DESCRIPTION OF GEOLOGIC UNITS, ROCK CANYON STREAM CUT WASATCH FAULT ZONE, UTAH COUNTY, UTAH

Unit 1 DEBRIS-FLOW DEPOSIT (matrix supported)

Gravelly, clayey sand with cobbles and boulders: Light gray (10YR 7/2); 10 percent boulders, 10 percent cobbles, 20 percent gravel, 35 percent sand, 25 percent fines, maximum clast diameter 600 mm, subrounded; dense; low to moderate plasticity; nonstratified (massive bedding); noncemented; unit exposed only in upthrown block of East fault zone, characteristic large boulders "floating" in a finer grained matrix.

Unit 2 FLUVIAL DEPOSIT (high energy)

Cobbly, sandy gravel with boulders: Grayish brown (10YR 5/2); 5 percent boulders, 20 percent cobbles, 40 percent gravel, 30 percent sand, <5 percent fines, maximum clast diameter 400 mm, subrounded; loose; nonplastic; crudely stratified, imbricated; noncemented; present chiefly as cut-and-fill deposits eroded into underlying debris-flow unit.

Unit 3 FLUVIAL DEPOSIT (low energy/slack water?)

Clayey sand with gravel: Grayish brown (10YR 5/2); 5 percent boulders and cobbles, 15 percent gravel, 50 percent sand, 30 percent fines, maximum clast diameter 400 mm, subrounded to subangular; dense; low to moderate plasticity; nonstratified; noncemented; slightly darker color, abundant vesicles (root holes), and partially decayed rootlets indicate weak soil development; unit becomes lighter colored and more silty to the west, pinches out locally.

Unit 4 FLUVIAL DEPOSIT (high energy)

Sandy gravel with cobbles: Grayish brown (10YR 5/2); <5 percent boulders, 10 percent cobbles, 60 percent gravel, 25 percent sand, <5 percent fines, maximum clast diameter 400 mm, subangular to subrounded; medium density; nonplastic; crudely stratified, imbricated; discontinuous, thin $CaCO_3$ coatings (probably ground-water related) on clasts, weakly cemented; thin, discontinuous unit.

Unit 5 DEBRIS-FLOW DEPOSIT (matrix supported)

Clayey, sandy gravel with cobbles and boulders: Light brownish gray (2.5YR 6/2); 5 percent boulders, 15 percent cobbles, 30 percent gravel, 20 percent sand, 30 percent fines, maximum clast diameter 900 mm, subangular to subrounded; dense; medium plasticity; nonstratified (massive); weakly cemented; lower contact marked by a distinct, thin band of iron-oxide staining (ground-water related), small, irregular blotches of iron-oxide staining also found throughout this unit.

Unit 6 DEBRIS-FLOW/DEBRIS-FLOOD DEPOSIT (clast supported)

Sandy, cobbly gravel with silt and boulders: Light brownish gray (10YR 6/2); <5 percent boulders, 25 percent cobbles, 40 percent gravel, 20 percent sand, 10 percent fines, maximum clast diameter 600 mm, subrounded; dense; very low plasticity; crudely stratified; discontinuous $CaCO_3$ coatings on clasts (ground-water related?), weakly cemented; deposited by a high-energy stream that eroded the underlying unit.

Paleosol 6s SOIL A HORIZON DEVELOPED ON UNIT 6

Texture similar to unit 6: Very dark gray (10YR 3/1) grading downward to light brownish gray (10YR 6/2) typical of unit 6; abundant root holes and rootlets; noncemented.

Unit $6s_1$

Coarse-grained lower part of unit 6s present in the upthrown block of the East fault zone: Very dark gray (10YR 3/1); similar to paleosol 6s on the downthrown block.

Unit $6s_2$

Thin (50-100 mm) layer of dark grayish brown (10YR 4/2) clayey sand with gravel; 15 percent gravel, 50 percent sand, 35 percent fines, maximum clast diameter 50 mm; finer grained than unit $6s_1$, possibly a layer of eolian material incorporated in the soil or a bioturbated zone; noncemented; present only in the upthrown block of the East fault zone.

MOST RECENT SURFACE-FAULTING EARTHQUAKE

Unit 7 DEBRIS-FLOW DEPOSIT (matrix supported)

Sandy, silty gravel: Pale brown (10YR 6/3); 40 percent gravel, 30 percent sand, 30 percent fines, maximum clast diameter 150 mm, subangular to subrounded; dense; very low plasticity; crudely stratified, imbricated; discontinuous $CaCO_3$ coatings on clasts, weakly cemented; thin unit deposited on downthrown block next to West fault scarp shortly after the most recent surface-faulting earthquake.

Unit 8 FLUVIAL DEPOSIT

Sandy gravel with silt: Grayish brown (10YR 5/2); <5 percent cobbles, 50 percent gravel, 35 percent sand, 15 percent fines, maximum clast diameter 300 mm, subrounded; dense; nonplastic; crudely stratified; discontinuous $CaCO_3$ coatings on clasts, weakly cemented; unit deposited on downthrown block next to West fault scarp shortly after most recent surface-faulting earthquake, overlain by distal portion of colluvial wedge formed along West fault scarp.

Paleosol 8s WEAK SOIL A HORIZON DEVELOPED ON UNIT 8

Texture similar to unit 8 but with less gravel (15 percent): Dark grayish brown (10YR 4/2); low plasticity; noncemented; distinguished by darker color and finer texture.

Unit 9 FAULT-SCARP COLLUVIUM AND FAULT-ZONE MATERIAL

Colluvial and fissure-fill deposits derived from erosion of fault scarps produced by the most recent surface-faulting earthquake, and sheared material within the East and West fault zones.

EAST FAULT ZONE

Unit 9A Fault-Zone Material

Sandy gravel with clay and cobbles: Grayish brown (10YR 5/2); 15 percent cobbles, 40 percent gravel, 30 percent sand, 15 percent fines, maximum clast diameter 300 mm, subrounded to subangular; loose to medium dense; low plasticity; noncemented; strong shear fabric aligned parallel to fault plane.

Unit 9B Fissure Fill

Clayey, sandy gravel with cobbles: Grayish brown (10YR 5/2); 10 percent cobbles, 40 percent gravel, 30 percent sand, 20 percent fines, maximum clast diameter 250 mm, subangular to subrounded; medium dense; low to medium plasticity; nonstratified; noncemented; locally darker in color (dark grayish brown, 10YR 4/2) due to material derived from paleosol 6s.

Unit 9C Fault-Scarp Colluvium

Sandy, cobbly gravel with clay and boulders: Very dark gray (10YR 3/1); 10 percent boulders, 25 percent cobbles, 30 percent gravel, 20 percent sand, 15 percent fines, maximum clast diameter 400 mm, subangular to subrounded; medium dense; low plasticity; non- to crudely stratified; noncemented; colluvial wedge developed at base of East fault scarp, dark color due to incorporation of material derived from paleosol 6s.

Unit 9D Block of Unit $6s_2$

Small block of pale brown (10YR 6/3) clayey sand derived from unit $6s_2$.

WEST FAULT ZONE

Unit 9E Fault-Zone Material

Cobbly, sandy gravel with silt: Grayish brown (10YR 5/2); 20 percent cobbles, 40 percent gravel, 25 percent sand, 15 percent fines, maximum clast diameter 350 mm, subrounded to subangular; medium dense; none to low plasticity; noncemented; shear fabric aligned parallel to fault plane.

Unit 9F Remnant of unit 4 fluvial deposit, disturbed by faulting

Unit 9G Remnant of unit 5 matrix-supported debris flow, disturbed by faulting

Unit 9H Fault-Scarp Colluvium (basal remnant)

Silty, sandy gravel with cobbles: Pale brown (10YR 6/3); 10 percent cobbles, 40 percent gravel, 30 percent sand, 20 percent fines, maximum clast diameter 300 mm, subangular to subrounded; dense; low plasticity; nonstratified; noncemented; basal portion of colluvial wedge developed along West fault scarp, upper portion of wedge removed by erosion.

Unit 9I Fault-Scarp Colluvium (distal remnant)

Silty, gravelly sand and silty, sandy gravel with cobbles: Grayish brown (10YR 5/2); texture of this unit is highly variable, ranging from relatively fine-grained gravelly sand to very coarse, openwork deposits of cobbles and boulders, maximum clast diameter 350 mm, subrounded to subangular; dense; none to low plasticity; crudely stratified; noncemented; distal portion of the colluvial wedge formed along the West fault scarp; remainder of wedge removed by erosion.

Unit 10 FLUVIAL DEPOSIT (high energy)

Sandy gravel with cobbles and silt: Pale brown (10YR 6/3); 10 percent cobbles, 60 percent gravel, 20 percent sand, 10 percent fines, maximum clast diameter 400 mm, subangular to subrounded; dense, nonplastic; crudely stratified, imbricated; noncemented; moderately well sorted; overlies distal colluvial wedge remnant.

Unit 11 FLUVIAL DEPOSIT (low energy, possibly ponded water)

Sandy silt: Grayish brown (10YR 5/2); <5 percent gravel, 35 percent sand, 55 percent silt, maximum clast diameter 50 mm, subrounded; stiff consistency; low plasticity; thinly bedded; weakly cemented; fine grain size indicates deposition from a slow-moving stream or possibly ponded water.

Unit 12 FLUVIAL DEPOSIT (very high energy)

Cobbly, sandy gravel with silt and boulders: Grayish brown (10YR 5/2); 5 percent boulders, 20 percent cobbles, 40 percent gravel, 20 percent sand, 15 percent silt, maximum clast size 600 mm, subrounded to subangular; dense; none to low plasticity; crudely stratified, imbricated; noncemented; unit becomes thicker and more silty toward the west, erodes underlying units, has removed most of unit 9 at the West fault zone.

Unit 13 SLOPE COLLUVIUM

Thin, discontinuous horizons of grayish brown (10YR 5/2) clayey sand with gravel derived from erosion of the 6s paleosol on the upthrown block of the East fault zone; shows that erosion associated with deposition of unit 12 did not affect the East fault-zone scarp.

Unit 14 FLUVIAL DEPOSIT (high energy)

Cobbly, sandy gravel: Light brownish gray (10YR 6/2); 30 percent cobbles, 40 percent gravel, 30 percent sand, maximum clast diameter 300 mm, subangular to subrounded; loose to medium dense; nonplastic; crudely stratified, imbricated; noncemented.

Unit 15 DEBRIS FLOW DEPOSIT (matrix supported)

Sandy, silty gravel with cobbles and boulders: Pale brown (10YR 6/3); <5 percent boulders, 10 percent cobbles, 30 percent gravel, 30 percent sand, 30 percent fines, maximum clast diameter 750 mm, subrounded to subangular; dense; low plasticity; nonstratified; noncemented; debris flow is present on both the up- and downthrown blocks of the East fault zone but does not overlie the fault itself.

Unit 16 ORGANIC ROOT MASS (KROTOVINA?)

Thick mass of scrub oak roots and other organic material occupying what appears to be an abandoned animal burrow.

Unit 17 KROTOVINA

Silty sand with gravel: Grayish brown (10YR 4/2); 15 percent gravel, 50 percent sand, 35 percent fines, maximum clast diameter 150 mm, subrounded to subangular; dense; low plasticity; nonstratified; noncemented; abandoned animal burrow, possibly an entrance to the burrow now occupied by the oak roots.

Unit 18 DEBRIS FLOW DEPOSIT (matrix supported)

Silty, sandy gravel with cobbles: Grayish brown (10YR 5/2); <5 percent boulders, 15 percent cobbles, 35 percent gravel, 25 percent sand, 25 percent fines, maximum clast diameter 700 mm, subrounded to subangular; dense; none to low plasticity; nonstratified; noncemented; recent debris flow containing abundant organic material.

Unit 19 FLUVIAL DEPOSIT (high energy)

Cobbly, sandy gravel with silt: Grayish brown (10YR 5/2); <5 percent boulders, 20 percent cobbles, 50 percent gravel, 20 percent sand, 10 percent fines, maximum clast diameter 450 mm, subrounded to subangular; dense; none to low plasticity; non- to crudely stratified; noncemented; recent stream-channel deposit.

LOG OF SOUTH WALL, ROCK CANYON TRENCH, PROVO SEGMENT, WASATCH FAULT ZONE, PROVO, UTAH

PLATE 1
SPECIAL STUDY 93
1998
Utah Geological Survey

Mapped by
W.R. Lund, B.D. Black, and K.E. Budding in 1988

EXPLANATION

SYMBOLS

- PALEOSOL AND SOIL A HORIZON
- ROCK
- FAULT (arrows indicate relative movement)
- CRACK, dashed where indistinct
- DEGRADED SCARP FREE FACE
- SHARP CONTACT (1-3 cm)
- GRADATIONAL CONTACT (3-5 cm)
- GRADATIONAL CONTACT (3-10 cm)
- INDISTINCT CONTACT
- RCT-AMRT2 1,550 cal yr B.P. (1,800 - 1,350) — BULK SOIL SAMPLE LOCATION, field number, and estimated time of paleosol burial (one-sigma uncertainty limit)

DESCRIPTION OF GEOLOGIC UNITS

Unit 15 ARTIFICIAL FILL
Coarse, angular fill placed in parking area adjacent to trench.

Soil 14S SOIL A HORIZON FORMED ON UNITS 13 AND 14
Gravelly, silty sand: Dark grayish brown (10YR 4/2)

Unit 14 SLOPE COLLUVIUM
Sandy gravel with silt and cobbles: Gray (10YR 5/1)

Unit 13 DEBRIS FLOW (matrix supported)
Silty, sandy gravel with cobbles: Brown (10YR 5/3)

MOST-RECENT SURFACE-FAULTING EARTHQUAKE

Unit 12 FAULT-ZONE MATERIAL AND FAULT-SCARP COLLUVIUM
Sheared material within the main and antithetic fault zones and colluvial and fissure-fill deposits derived from erosion of the fault scarps produced by the most-recent, surface-faulting earthquake.

MAIN FAULT ZONE

Unit 12A Fault-Zone Material
Cobbly, sandy gravel with silt: Grayish brown (10YR 5/2)

Unit 12B Rotated Blocks
Block of unit 10A or 11 derived from erosion of main fault scarp.

Unit 12C Fissure Fill
Sandy gravel with cobbles: Grayish brown (10YR 5/2)

Unit 12D Rotated Block
Vertically oriented, unit of origin uncertain.

Unit 12E Fissure Fill
Sandy gravel: Grayish brown (10YR 5/2)

Unit 12F Rotated Block
Orientation and unit of origin uncertain.

Unit 12G Fissure Fill
Sandy gravel with cobbles: Gray (5Y 6/1)

Unit 12H Fissure Fill
Sandy gravel: Grayish brown (10YR 5/2)

Unit 12I Fissure Fill
Sandy gravel: Gray (5Y 6/1)

Unit 12J Fault-Scarp Colluvium
Sandy gravel with cobbles: Grayish brown (10YR 5/2)

Unit 12K Block/Fault-Scarp Colluvium
Sandy gravel with cobbles: Grayish brown (10YR 5/2)

Unit 12L Fault-Scarp Colluvium
Sandy gravel with cobbles: Grayish brown (10YR 5/2)

Unit 12M Fault-Scarp Colluvium
Sandy gravel with cobbles: Grayish brown (10YR 5/2)

ANTITHETIC FAULT ZONE

Unit 12N Fault-Zone Material
Cobbly, sandy gravel with boulders and silt: Grayish brown (10YR 5/2)

Unit 12O Fissure Fill
Cobbly, sandy gravel: Grayish brown (10YR 5/2)

Unit 12P Fissure Fill/Block
Silty, sandy gravel: Gray (5Y 6/1)

Unit 12Q Fissure Fill
Sandy gravel with cobbles: Gray (5Y 6/1)

Unit 12R Fault-Scarp Colluvium
Cobbly, sandy gravel with silt: Gray (10YR 5/1)

Paleosol 11S PALEOSOL A HORIZON DEVELOPED ON UNITS 11 AND 10B
Thin, well-developed organic A horizon

Unit 11 DEBRIS FLOOD/DEBRIS FLOW
Sandy gravel with silt and cobbles: Grayish brown (10YR 5/2)

Unit 10 DEBRIS FLOW

Unit 10B Cobbly, silty gravel with sand: Light brownish gray (2.5Y 4/2)
Unit 10A Silty gravel with sand and cobbles: Light brownish gray (2.5Y 4/2)

Unit 9 FLUVIAL DEPOSIT (low energy)
Clayey, silty sand/clayey, sandy silt: Light brownish gray (2.5Y 4/2)

Paleosol 8S SOIL A HORIZON DEVELOPED ON UNIT 8
Well-developed organic soil A horizon

Unit 8 DEBRIS FLOW (matrix supported)
Cobbly, clayey gravel with sand: Light brownish gray (2.5Y 6/2)

Paleosol 7S WEAK SOIL A-HORIZON DEVELOPED ON UNIT 7
Thin, weakly developed organic soil A horizon

Unit 7 FLUVIAL DEPOSIT (high energy)
Cobbly, sandy gravel with silt: Grayish brown (10YR 3/2)

Unit 6 FLUVIAL DEPOSIT (high energy)
Cobbly, sandy gravel with boulders: Gray (5Y 6/1)

Unit 5 DEBRIS-FLOW/DEBRIS-FLOOD DEPOSIT
Sandy gravel with clay and cobbles: Light brownish gray (2.5Y 6/2)

Unit 4 DEBRIS-FLOOD DEPOSIT (clast supported)
Sandy gravel with silt and cobbles: Pale brown (10YR 6/3)

Unit 3 FLUVIAL DEPOSIT
Silty sand with clay grading eastward to silty gravel with clay: Pale brown (10YR 6/3)

Unit 2 FLUVIAL DEPOSIT (high energy)
Sandy, cobbly gravel: Pale brown (10YR 3/3)

Unit 1 FLUVIAL DEPOSIT (high energy)
Cobbly, sandy gravel with boulders: Light gray (10YR 7/2).

PLANIMETRIC BASE CONSTRUCTED ON A 1m x 1m GRID USING HORIZONTAL LEVEL LINES

LOG OF SOUTH BANK, ROCK CREEK STREAM CUT, PROVO SEGMENT, WASATCH FAULT ZONE, PROVO, UTAH

Mapped by
W.R. Lund, B.D. Black, and Suzanne Hecker in 1988

PREPARED FROM PHOTOGRAPHIC BASE

PLATE 2
SPECIAL STUDY 93
1998
Utah Geological Survey

EXPLANATION

DESCRIPTION OF GEOLOGIC UNITS

Unit 19 FLUVIAL DEPOSIT (high energy)
Cobbly, sandy gravel with silt: Grayish brown (10YR 5/2)

Unit 18 DEBRIS FLOW (matrix supported)
Silty, sandy gravel with cobbles: Grayish brown (10YR 5/2)

Unit 17 KROTOVINA (animal burrow)
Silty sand with gravel: Grayish brown (10YR 4/2)

Unit 16 ORGANIC ROOT MASS (KROTOVINA?)

Unit 15 DEBRIS FLOW (matrix supported)
Sandy, silty gravel with cobbles and boulders: Pale brown (10YR 6/3)

Unit 14 FLUVIAL DEPOSIT (high energy)
Cobbly, sandy gravel: Light brownish gray (10YR 6/2)

Unit 13 SLOPE COLLUVIUM
Clayey sand with gravel: grayish brown (10YR 5/2)

Unit 12 FLUVIAL DEPOSIT (very high energy)
Cobbly, sandy gravel with silt and boulders: Grayish brown (10YR 5/2)

Unit 11 FLUVIAL DEPOSIT (low energy, possibly ponded water)
Sandy silt: Grayish brown (10YR 5/2)

Unit 10 FLUVIAL DEPOSIT (high energy)
Sandy gravel with cobbles and silt: Pale brown (10YR 6/3)

Unit 9 FAULT-SCARP COLLUVIUM AND FAULT-ZONE MATERIAL
Colluvial and fissure-fill deposits derived from erosion of fault scarps produced by the most-recent, surface-faulting earthquake, and sheared material within the east and west fault zones.

EAST FAULT ZONE

Unit 9A Fault-Zone Material
Sandy gravel with clay and cobbles: Grayish brown (10YR 5/2)

Unit 9B Fissure Fill
Clayey, sandy gravel with cobbles: Grayish brown (10YR 5/2)

Unit 9C Fault-Scarp Colluvium
Sandy, cobbly gravel with clay and boulders: Very dark gray (10YR 3/1)

Unit 9D Block of Unit $6S_2$

WEST FAULT ZONE

Unit 9E Fault-Zone Material
Cobbly, sandy gravel with silt: Grayish brown (10YR 5/2)

Unit 9F Remnant of unit 4 fluvial deposit, disturbed by faulting.

Unit 9G Remnant of unit 5 matrix supported debris flow, disturbed by faulting.

Unit 9H Fault-Scarp Colluvium (basal portion)
Silty, sandy gravel with cobbles: Pale brown (10YR 6/3)

Unit 9I Fault-Scarp Colluvium (distal portion)
Silty, gravelly sand and silty, sandy gravel with cobbles: Grayish brown (10YR 5/2)

Paleosol 8S WEAK SOIL A HORIZON DEVELOPED ON UNIT 8
Dark grayish brown (10YR 4/2); distinguished by darker color and finer texture.

Unit 8 FLUVIAL DEPOSIT
Sandy gravel with silt: Grayish brown (10YR 5/2)

Unit 7 DEBRIS FLOW (matrix supported)
Sandy, silty gravel: Pale brown (10YR 6/3)

MOST-RECENT SURFACE-FAULTING EARTHQUAKE

Paleosol 6S SOIL A HORIZON DEVELOPED ON UNIT 6
Very dark gray (10YR 3/1) grading downward to light brownish gray (10YR 6/2)

Unit $6S_1$ Coarse-grained part of unit 6S present in the upthrown block of the east fault zone

Unit $6S_2$ Thin layer of eolian or bioturbated material; present only in the upthrown block of the east fault zone.

Unit 6 DEBRIS-FLOW/DEBRIS-FLOOD DEPOSIT (clast supported)
Sandy, cobbly gravel with silt and boulders: Light brownish gray (10YR 6/2)

Unit 5 DEBRIS FLOW (matrix supported)
Clayey, sandy gravel with cobbles and boulders: Light brownish gray (2.5YR 6/2)

Unit 4 FLUVIAL DEPOSIT (high energy)
Sandy gravel with cobbles: Grayish brown (10YR 5/2)

Unit 3 FLUVIAL DEPOSIT (low energy/slack water?)
Clayey sand with gravel: Grayish brown (10YR 5/2)

Unit 2 FLUVIAL DEPOSIT (high energy)
Cobbly, sandy gravel with boulders: Grayish brown (10YR 5/2)

Unit 1 DEBRIS FLOW (matrix supported)
Gravelly, clayey sand with cobbles and boulders: Light gray (10YR 7/2)

SYMBOLS

- **PALEOSOL A HORIZON**
- **ROCK**
- **FAULT, dotted where indistinct (arrows indicate relative movement)**
- **CRACK, dashed where indistinct**
- **DEGRADED SCARP FREE FACE**
- **SHARP CONTACT (1-3 cm)**
- **GRADATIONAL CONTACT (3-5 cm)**
- **GRADATIONAL CONTACT (5-10 cm)**
- **INDISTINCT CONTACT**
- RCSC-1 540 cal yr B.P. (680 - 460) **CHARCOAL SAMPLE LOCATION, field number, and calendar-calibrated age estimate (one-sigma uncertainty limit)**
- RCSC-AMRT2 1000 cal yr B.P. (1,050 - 800) **BULK SOIL SAMPLE LOCATION, field number, and estimated time of paleosol burial (one-sigma uncertainty limit)**