U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

INTRODUCTION

This report contains field and laboratory data from a paleoseismic study of the Surprise Valley fault zone near Cedarville, California. The 85-km-long Surprise Valley fault zone forms the western active margin of the Basin and Range province in northeastern California (fig. 1). The down-to-the-east normal fault is marked by Holocene fault scarps along most of its length, from Fort Bidwell on the north to near the southern end of Surprise Valley (fig. 2). We studied the central section of the fault to determine ages of paleoearthquakes and to better constrain late Quaternary slip rates, which we hope to compare to deformation rates derived from a recently established geodetic network in the region (Hammond and Thatcher, 2005; 2007). We excavated a trench in June 2005 across a prominent fault scarp on pluvial Lake Surprise deltaic sediments near the mouth of Cooks Canyon, 4 km north of Cedarville (figs. 3 and 4). This site was chosen because of the presence of a well-preserved fault scarp and its development on lacustrine deposits thought to be suitable for luminescence dating. We also logged a natural exposure of the fault in similar deltaic sediments near the mouth of Steamboat Canyon, 11 km south of Cedarville (fig. 5), to better understand the along-strike extent of surface ruptures. The purpose of this report is to present photomosaics, trench, drill hole, and stream exposure logs; scarp profiles (figs. 6, 7, and 8); and fault slip (table 1), tephrochronologic (table 2), radiocarbon (table 3), luminescence (table 4), and unit description (table 5) data obtained during this investigation. We do not attempt to use the data presented herein to construct a paleoseismic history of this part of the Surprise Valley fault zone; that history will be the subject of a future report.

ACKNOWLEDGMENTS

The authors wish to thank Denise and Jim Harrower, Bill Duncan, and numerous other Surprise Valley landowners for permission to work on their properties. The report was improved by comments from reviewers William Schulz and Cal Ruleman.

RADIOCARBON, TEPHRA, AND LUMINESCENCE AGE DATA

We obtained five radiocarbon samples from fluvial and fault scarp colluvial deposits in the trench and stream exposure (table 2). The samples yielded calibrated ages indicating these sediments were deposited about 1–8 ka.

We encountered two beds of volcanic ash from a temporary exposure at the bottom of the trench. Chemical fingerprinting of these tephra (table 3; Elmira Wan, written commun., 2006) indicates that the younger deposit is the Mazama ash, dated elsewhere at about 7,630 ± 150 cal yr B.P. (Zdanowicz and others, 1999). The older ash could not be correlated with any known ash, but is likely a Mazama precursor of Cascade affinity.

We used luminescence dating techniques to determine the ages of lacustrine and colluvial sediments exposed in the trench that did not contain datable organic material (see logs and table 4). IRSL (infrared stimulated luminescence—a type of optically stimulated luminescence (OSL) unique to feldspars), and blue-light OSL techniques date the time since sediment was exposed to sunlight, presumably during deposition (Berger, 1988; Forman and others, 2000). Sampling was conducted with tubes of plastic electrical conduit driven into the freshly cleaned trench wall; after extraction, sample tubes were sealed with plastic tape and stored in airtight plastic bags. Dose rates were determined *in situ* with an Exploranium GR–256 gamma ray spectrometer placed in expanded sample holes drilled in the wall after sampling was completed. The dose rate component from cosmic ray bombardment and depth attenuations were calculated using the methods of Prescott and Hutton (1994). Field moisture contents of 3–16 percent by weight were determined in the laboratory for each sample. A polymineralic, fine-silt-size (4–11 mm) fraction was isolated for the IRSL samples and a fine-sand-size (90–250 mm) quartz fraction was isolated for the OSL samples. Samples were subjected to combinations of sunlight sensitivity tests, anomalous fading tests (Wintle, 1973), and additive dose experiments for IRSL (Aitken, 1998). Anomalous fading tests showed that the IRSL samples exhibited small amounts of fading (3–4 percent), so these ages were corrected using the anomalous fading correction technique of Huntley and Lamothe (2001). Problems with plagioclase contamination and meager quantities of clean quartz resulted in larger than usual uncertainties, but the luminescence data indicate that the colluvial sediments exposed in the trench probably were deposited <8 ka and the lacustrine sediments were deposited <30 ka. The latter age indicates that the lacustrine sediments were deposited during the Last Glacial Maximum cycle of pluvial Lake Surprise. The ages of Lake Surprise sediments are poorly known, but highstands in the nearby Chewaucan and Lahontan basins date to about 12,000–13,000 radiocarbon years ago (Adams and Wesnousky, 1998; Licciardi, 2001).

REFERENCES

Adams, K.D., and Wesnousky, S.G., 1998, Shoreline processes and the age of the Lake Lahontan highstand in the Jessup embayment, Nevada: Geological Society of America Bulletin, v. 110, p. 1318-1332.
Aitken, M.J., 1998, An introduction to optical dating—The dating of Quaternary sediments by the use of photon-stimulated luminescence: New York, Oxford University Press, 267 p.
Berger, G.W., 1988, Dating Quaternary events by luminescence, *in* Easterbrook, D.J., ed., Dating Quaternary sediments: Geological Society of America Special Paper 227, p. 13–50.
Birkeland, P.W., 1999, Soils and Geomorphology (3rd ed.): New York, Oxford University Press, 430 p.
Bronk Ramsey, C., 1995, Radiocarbon calibration and analysis of stratigraphy—The OxCal program: Radiocarbon, v. 37, p. 425–430.
Bronk Ramsey, C., 2001, Development of the radiocarbon program OxCal: Radiocarbon, v. 43, p. 355–363.
Bucknam, R.C., and Anderson, R.E., 1979, Estimation of fault-scarp ages from a scarp-height-slope-angle relationship: Geology, v. 7, p. 11–14.
Caskey, S.J., 1995, Geometric relations of dip slip to a faulted ground surface—New nomograms for estimating components of fault displacement: Journal of Structural Geology, v. 17, p. 1197–1202.
Forman, S.L., Pierson, J., and Lepper, K., 2000, Luminescence geochronology, *in* Noller, J.S., Sowers, J.M., and Lettis, W.R., eds., Quaternary geochronology—Methods and applications: American Geophysical Union Reference Shelf 4, p. 157–176.
Geyh, M.A., and Schleicher, H., 1990, Absolute age determination: New York, Springer-Verlag, 503 p.
Hammond, W.C., and Thatcher, W., 2005, Northwest Basin and Range tectonic deformation observed with the Global Positioning System, 1999–2003: Journal of Geophysical Research, v. 110, B10405, doi: 10.1029/2005JB003678.
Hammond, W.C., and Thatcher, W., 2007, Crustal deformation across the Sierra Nevada, northern Walker Lane, Basin and Range transition, western United States measured with GPS, 2000-2004: Journal of Geophysical Research, v. 112, B05411, doi: 10.1029/2006JB004625.
Hedel, C.W., 1984, Maps showing geomorphic and geologic evidence for late Quaternary displacement along the Surprise Valley and associated faults, Modoc County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF–1429.
Huntley, D.J., and Lamothe, M., 2001, Ubiquity of anomalous fading in K-feldspars and the measurement and correction for it in optical dating: Canadian Journal of Earth Sciences, v. 38, p. 1093–1106.
Licciardi, J.M., 2001, Chronology of latest Pleistocene lake-level fluctuations in the pluvial Lake Chewaucan basin, Oregon, USA: Journal of Quaternary Science, v.16, p. 545–553.
Machette, M.N., Haller, K.M., Dart, R.L., and Rhea, S.B., 2003, Quaternary fault and fold database of the United States: U.S. Geological Survey Open-File Report 03–417 (online database at http://earthquake.usgs.gov/regional/qfaults/).
Munsell Color, 1994, Munsell soil color charts: New Windsor, N.Y., Kollmorgen Corp., Macbeth Division.
Prescott, J.R. and Hutton, J.T., 1994, Cosmic ray contributions to dose rates for luminescence and ESR dating—Large depths and long-term time variations: Radiation Measurements, v. 23, p. 497–500.
Reimer, P.J., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Bertrand, C.J.H., Blackwell, P.G., Buck, C.E., Burr, G.S., Cutler, K.B., Damon, P.E., Edwards, R.L., Fairbanks, R.G., Friedrich, M., Guilderson, T.P., Hogg, A.G., Hughen, K.A., Kromer, B., McCormac, F.G., Manning, S.W., Bronk Ramsey, C., Reimer, R.W., Remmele, S., Southon, J.R., Stuiver, M., Talamo, S., Taylor, F.W., van der Plicht, J., and Weyhenmeyer, C.E., 2004, IntCal04 terrestrial radiocarbon age calibration, 26–0 ka BP: Radiocarbon v. 46, p. 1029–1058.
Soil Survey Staff, 1999, Soil Taxonomy (2nd ed.): U.S. Department of Agriculture Agricultural Handbook no. 436, 869 p.
Wintle, A.G., 1973, Anomalous fading of thermoluminescence in mineral samples: Nature, v. 245, p. 143–144.
Zdanowicz, C.M., Zielinski, G.A., and Germani, M.S., 1999, Mount Mazama eruption—Calendrical age verified and atmospheric impact assessed: Geology, v. 27, p. 621–624.

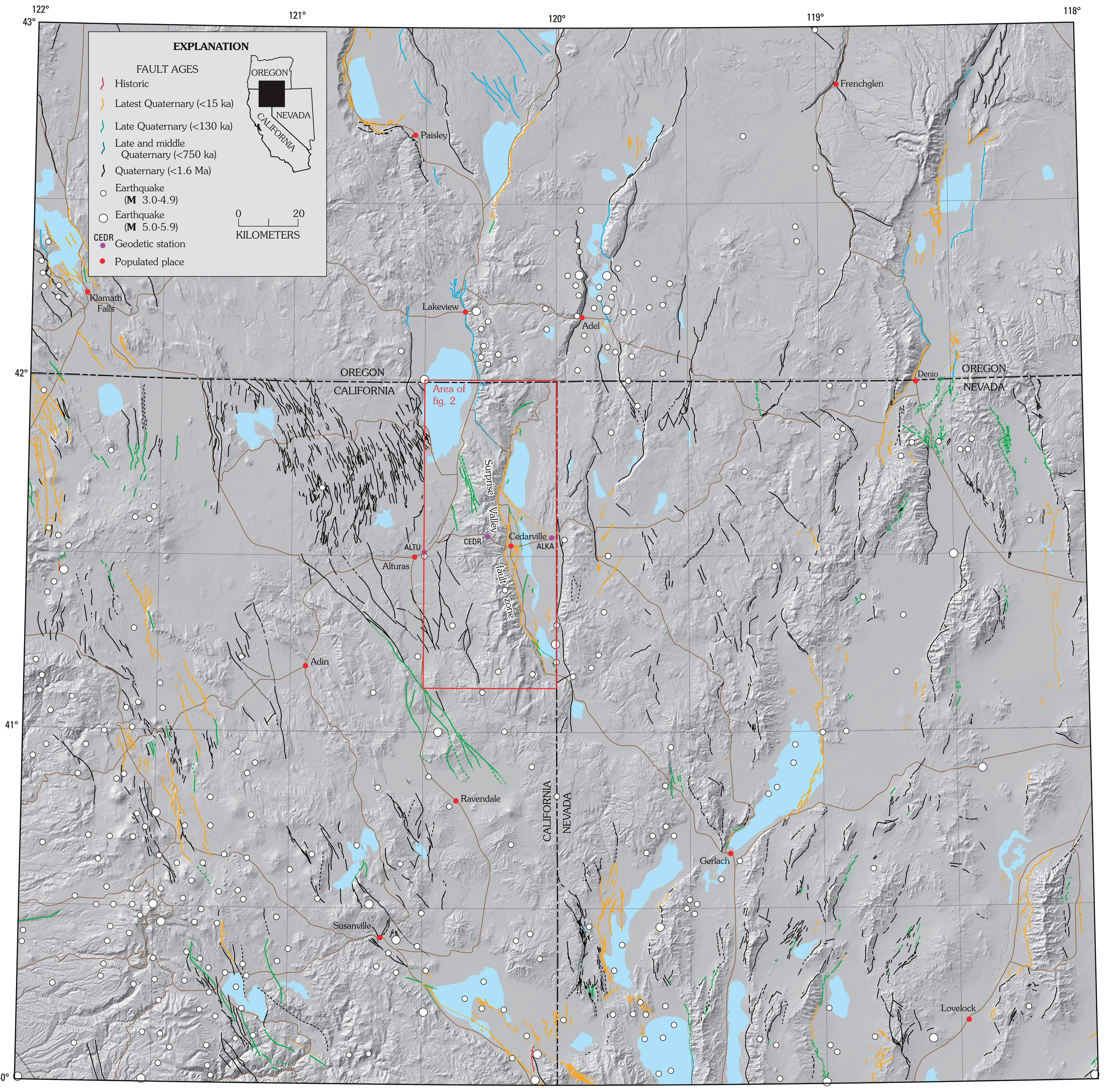

Figure 1. Regional map of Quaternary faults. Faults are from Quaternary fault and fold database of USGS (Machette and others, 2003; available online at: http://earthquake.usgs.gov/regional/qfaults/). Seismicity compiled from USGS catalogs Eastern, Central, and Mountain states of the United States (SRA), 1534-1986, Significant U.S. Earthquakes (SHIS), 1568-1989, California (CDMG), 1735-1974, and USGS/NEIC (PDE), 1973-present. GPS stations are from Hammond and Thatcher (2005, 2007). Base is from 30 m digital elevation (DEM) data of U.S. Geological Survey.

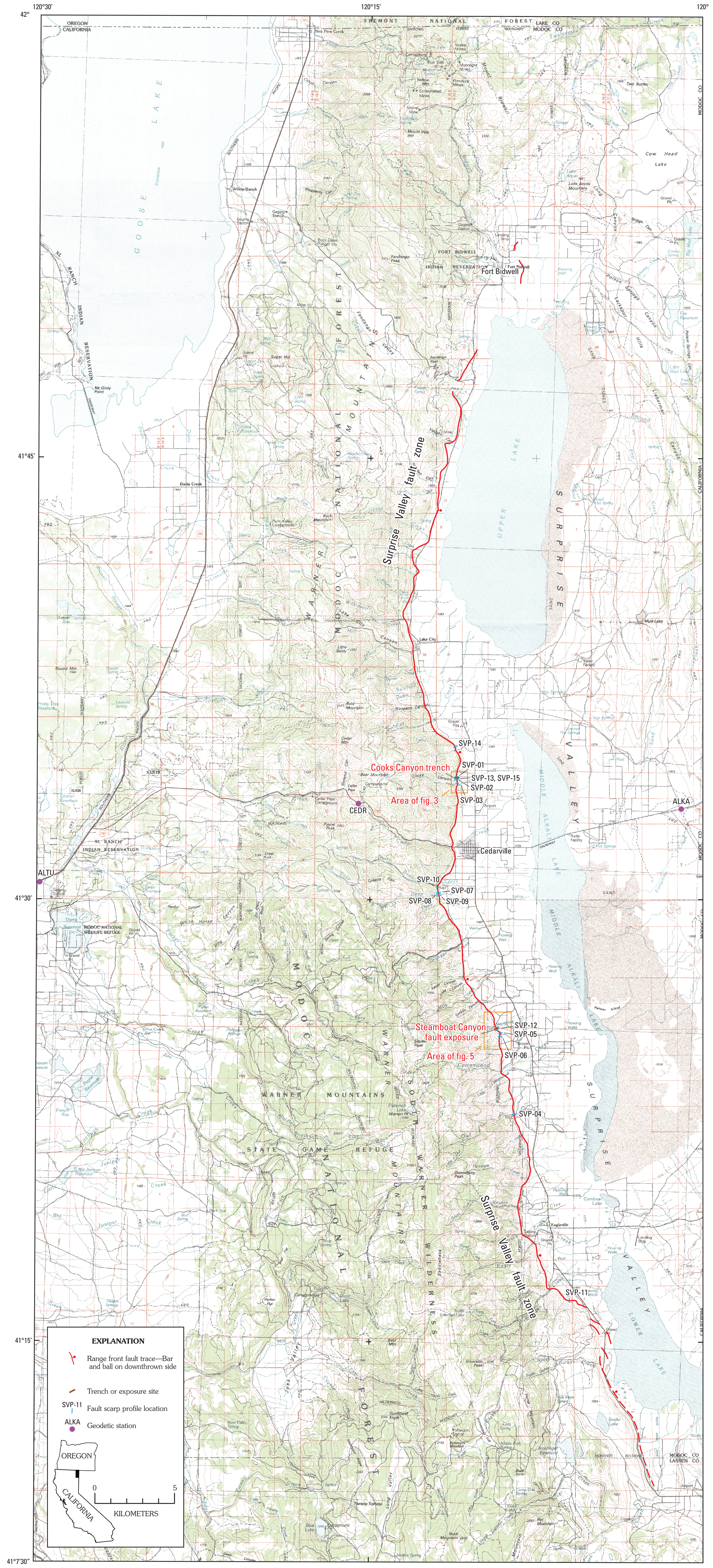

Figure 2. Map showing locations of trench and stream exposure sites, scarp profiles, geodetic stations, and range front trace of the Surprise Valley fault zone, northeastern California. Fault trace is simplified from Hedel (1984). GPS stations are from Hammond and Thatcher (2005, 2007).

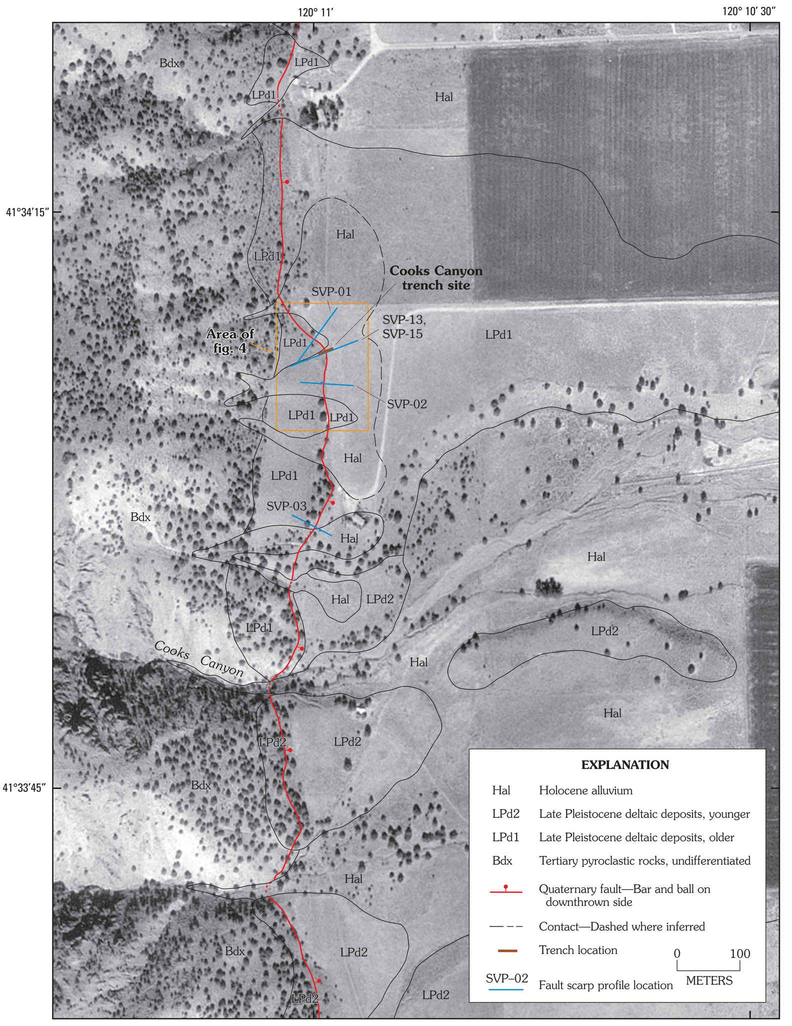

Figure 3. Surficial geologic map of Surprise Valley fault zone in the vicinity of Cooks Canyon trench site; geology modified from Hedel (1984). See figure 2 for location. Profiles SVP–13 and SP–15 are in same location. Base map is rectified digital orthophotograph of part of the U.S. Geological Survey Cedarville, California 7.5-minute quadrangle.

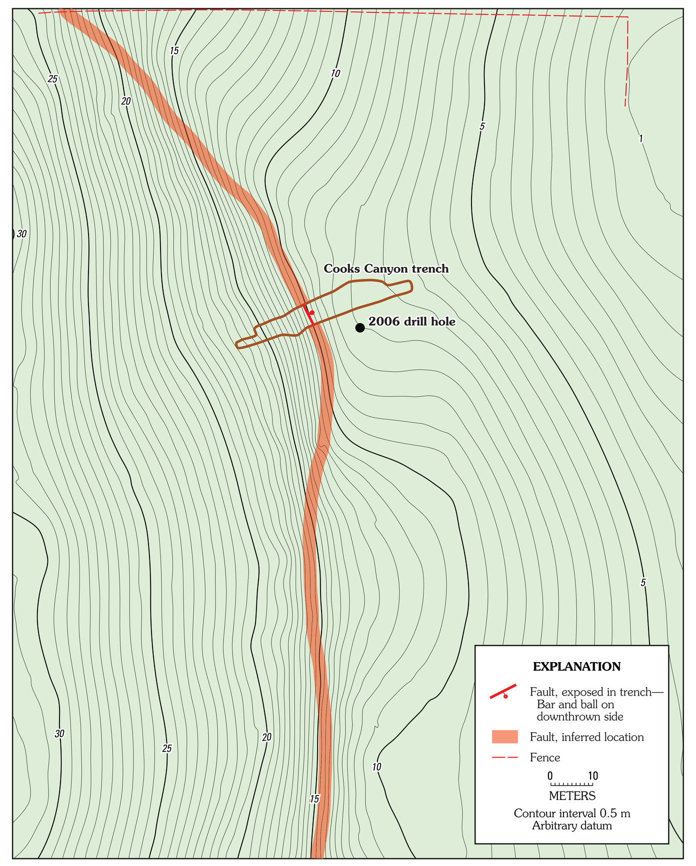

Figure 4. Topographic map of the Surprise Valley fault zone at the Cooks Canyon trench site; surveyed with total station. See figure 3 for location. Note location of drill hole described on sheet 2.

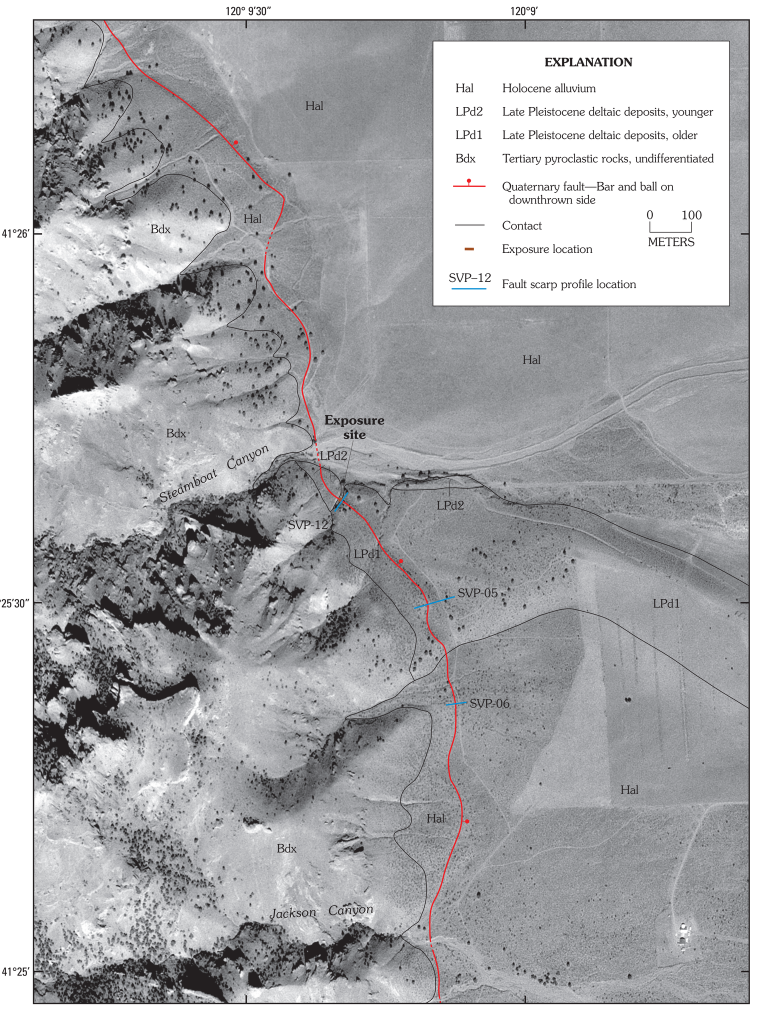

Figure 5. Surficial geologic map of Surprise Valley fault zone in the vicinity of Steamboat Canyon fault exposure; geology modified from Hedel (1984). See figure 2 for location. Base map is rectified digital orthophotograph of part of the U.S. Geological Survey Warren Peak, CA 7.5-minute quadrangle.

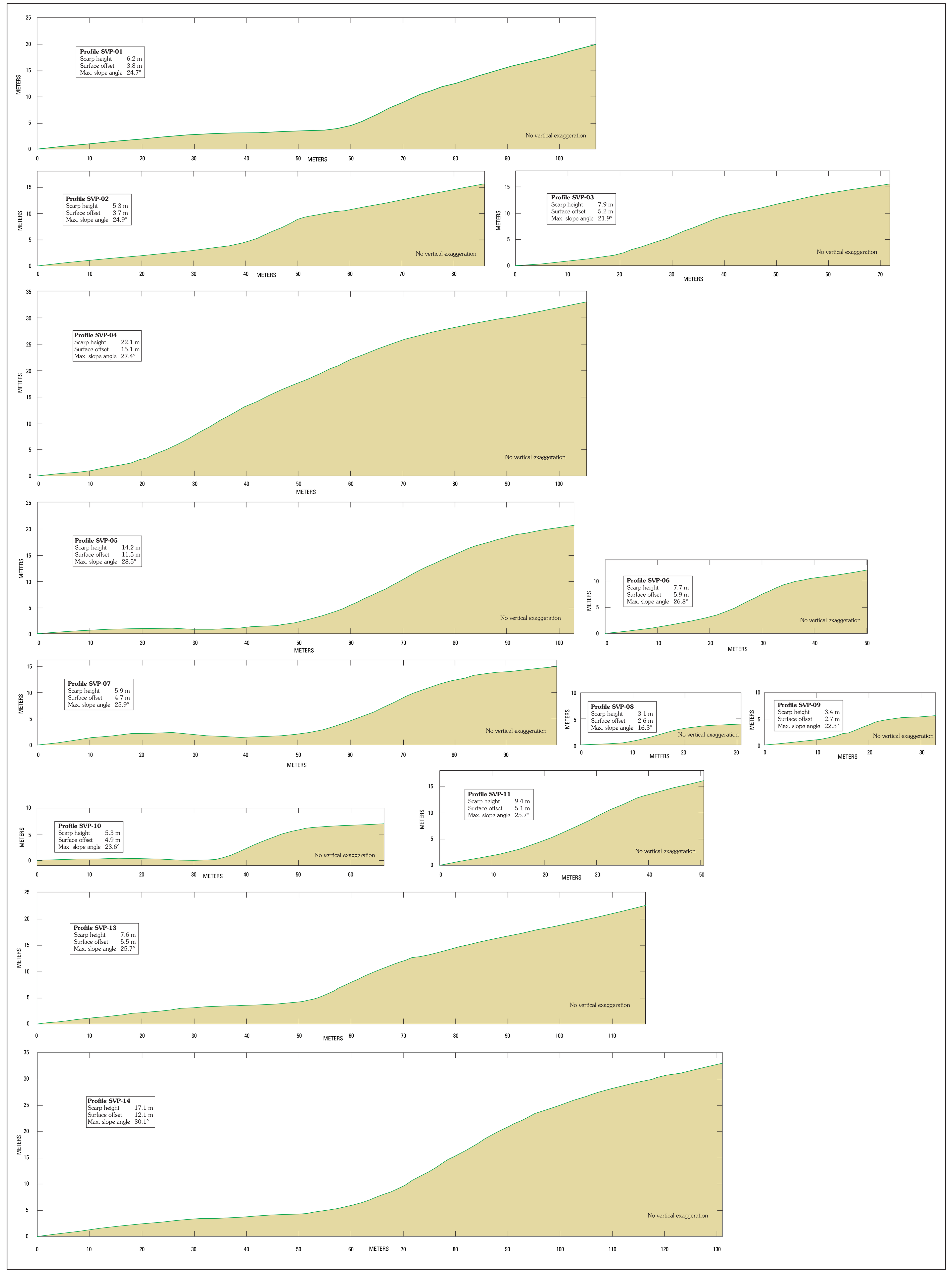

Figure 6. Fault scarp topographic profiles obtained during this study. See figure 2 for profile locations and table 1 for additional slip data. Profiles SVP-12 and SVP-15 (figs. 7 and 8) are shown on sheet 2.

Table 1. Fault scarp profile and slip data obtained during this study. See figure 2 for profile locations.

Profile[a] number	Scarp[b] height (m)	Surface[b] offset (m)	Max. slope angle (°)	Lower slope angle (°)	Upper slope angle (°)	Avg. slope angle (°)	Dip slip[c] (60°, m)	Dip slip[c] (65°, m)	Dip slip[c] (70°, m)	Comments
SVP–01	6.2	3.8	24.7	5.5	14.3	9.9	4.9	4.6	4.3	Northern profile on pluvial highstand delta at Cooks Canyon. Toe buried by alluvium.
SVP–02	5.3	3.7	24.9	5.6	10.4	8.0	4.7	4.4	4.2	Middle profile on pluvial highstand delta at Cooks Canyon. Toe buried by alluvium.
SVP–03	7.9	5.2	21.9	6.0	10.0	8.0	6.5	6.1	5.8	Southern profile on pluvial highstand delta at Cooks Canyon. Toe buried by alluvium.
SVP–04	22.1	15.1	27.4	7.7	10.8	9.3	19.3	18.1	17.1	Profile on pluvial highstand delta at Owl Creek.
SVP–05	14.2	11.5	28.5	3.6	8.3	6.0	14.1	13.3	12.7	Profile on pluvial highstand delta near Steamboat Canyon.
SVP–06	7.7	5.9	26.8	6.5	6.8	6.6	7.3	6.9	6.6	Profile on alluvial fan south of Steamboat Canyon pluvial highstand delta.
SVP–07	5.9	4.7	25.9	5.4	6.0	5.7	5.7	5.4	5.1	Profile on pluvial highstand delta at South Deep Creek.
SVP–08	3.1	2.6	16.3	2.7	2.5	2.6	3.1	2.9	2.8	Profile on fluvial terrace north of South Deep Creek.
SVP–09	3.4	2.7	22.3	5.7	4.1	4.9	3.3	3.1	3.0	Profile on fluvial terrace south of South Deep Creek.
SVP–10	5.3	4.9	23.6	1.5	2.5	2.0	5.7	5.4	5.2	Profile on fluvial terrace south of North Deep Creek.
SVP–11	9.4	5.1	25.7	11.3	13.3	12.3	6.8	6.3	5.9	Profile on pluvial highstand delta at Emerson Creek.
SVP–12	12.4	8.8	30.3	5.2	13.8	9.5	11.3	10.6	10.0	Profile on pluvial highstand delta at Steamboat Canyon stream exposure.
SVP–13	7.6	5.5	25.7	3.2	12.2	7.7	6.9	6.5	6.1	Profile on pluvial highstand delta at Cooks Canyon trench site. Toe buried by alluvium.
SVP–14	17.1	12.1	30.1	7.4	11.5	9.5	15.4	14.4	13.7	Profile on pluvial highstand delta at unnamed canyon 2 km north of Cooks Canyon trench site.
SVP–15	8.0	5.5	24.2	5.0	10.9	8.0	6.9	6.5	6.1	Profile on pluvial highstand delta at Cooks Canyon trench site. Toe buried by alluvium.

[a]Locations marked on fig. 2; all profiles measured with stadia rod and digital level except SVP–12 and SVP–13, which were measured with total station.
[b]Scarp height and surface offset (vertical separation) as defined by Bucknam and Anderson (1979).
[c]Calculated values using equations of Caskey (1995) based on surface offset (vertical separation), average slope of the ground surface, and fault dip estimates based on values of typical Basin and Range faults (60°), and measured dips in Surprise Valley trench (65°) and Steamboat Canyon fault exposure (70°).

LOGS AND SCARP DATA FROM A PALEOSEISMIC INVESTIGATION OF THE SURPRISE VALLEY FAULT ZONE, MODOC COUNTY, CALIFORNIA

By
Stephen F. Personius, Anthony J. Crone, Michael N. Machette, David J. Lidke, Lee-Ann Bradley, and Shannon A. Mahan
2007

Publishing support provided by:
Denver Publishing Service Center

For more information concerning this publication, contact:
Team Chief Scientist, USGS Geologic Hazards
Box 25046, Mail Stop 966
Denver, CO 80225
(303) 273-8579

Or visit the Geologic Hazards Team Web site at:
http://geohazards.cr.usgs.gov/

Suggested citation:
Personius, S.F., Crone, A.J., Machette, M.N., Lidke, D.J., Bradley, L.-A., and Mahan, S.A., 2007, Logs and scarp data from a paleoseismic investigation of the Surprise Valley fault zone, Modoc County, California: U.S. Geological Survey Scientific Investigations Map 2983, 2 sheets.

Manuscript approved for publication October 1, 2007
Minor revisions dated July 7, 2008

Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Government

This map was produced on request, directly from digital files, on an electronic plotter

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

1-888-ASK-USGS

A PDF for this map is available at http://pubs.usgs.gov/sim/2983