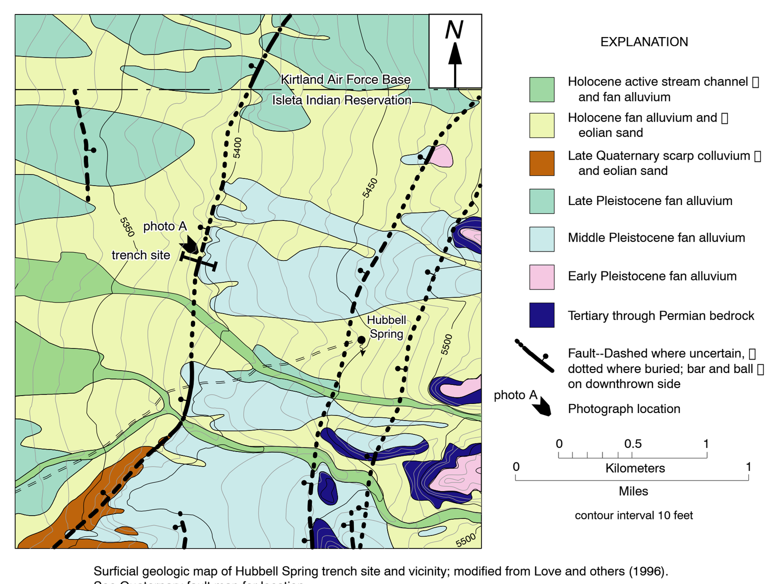
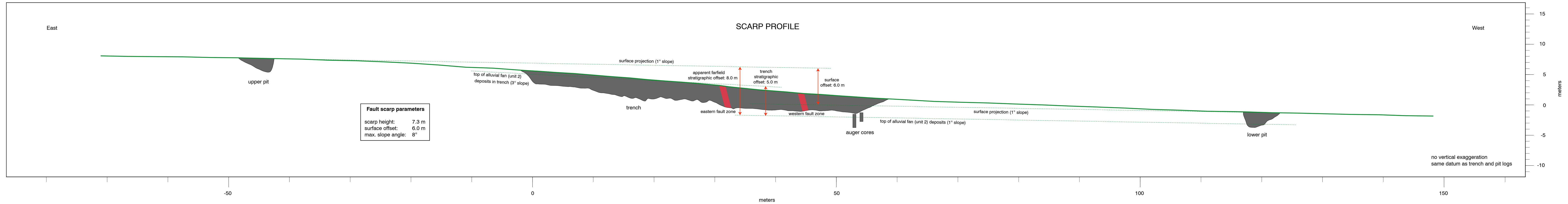
USGS
science for a changing world

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

MISCELLANEOUS FIELD STUDIES MAP MF- 2348
VERSION 1.1



Surficial geologic map of Hubbell Spring trench site and vicinity; modified from Love and others (1996). See Quaternary fault map for location.



INTRODUCTION

This report contains field and laboratory data resulting from a trench study of the Hubbell Spring fault zone near Albuquerque, New Mexico. This trench was excavated in September, 1997, as part of earthquake hazards investigations of Quaternary faults in the Albuquerque metropolitan area. The trench was excavated across the youngest of several fault strands near the northern end of the Hubbell Spring fault zone. The site is located on Pueblo of Isleta tribal lands, approximately 1 km south of the southern boundary of Kirtland Air Force Base. Thus the paleoearthquake data derived from investigations at the Hubbell Spring site will be useful in assessing potential earthquake hazards in Isleta Pueblo, Kirtland Air Force Base/Sandia National Laboratories, and the Albuquerque metropolitan area. The purpose of this report is to present a detailed trench log, a scarp profile, soils data (table 1), magnetic susceptibility data (table 2), luminescence and uranium-series ages (tables 3 and 4), and detailed unit descriptions (table 5) obtained in this investigation. S.F. Personius had primary responsibility for siting, excavating, describing, and interpreting the trench; S.A. Mahan did the luminescence dating, and James B. Paces did the uranium-series dating. M.C. Eppes and D.W. Love assisted with trench logging and mapping; and M.C. Eppes, D.K. Mitchell, and A. Murphy did the soils analyses.

ACKNOWLEDGMENTS

This research was supported by the Earthquake Hazards Reduction and National Cooperative Geologic Mapping Programs of the U.S. Geological Survey. The authors wish to thank then-Governor Fred R. Lujon and the people of the Pueblo of Isleta for permission to conduct this research on tribal lands, and in addition, we acknowledge the assistance of John Hostak, former Director of the Isleta Environment Department, and Randy Lujon and staff of the Isleta Range Patrol. We also wish to thank Eric Brunneman of Petroglyph National Monument for archeological assessment of the trench site. The report was improved by comments from reviewers Janet Slate and Charles Narwold, and USGS editor Craig Brunstein.

SOILS DATA

The soils data described in this report were collected as part of a class project at the University of New Mexico, and include detailed field descriptions of five soil profiles. Profile locations (one in each of the soil pits and three in the trench) were chosen to avoid the most obvious zones of disturbance by burrowing animals. No detailed grain-size analyses were done, but total $CaCO_3$ values were determined for each horizon described in the five profiles because these values may be useful for soil age determination. For the calcium carbonate analysis, each horizon was sampled (two samples were taken for horizons >100 cm thick) and the fine-earth fractions (< 2 mm) were separated for laboratory analysis. The weight-percent $CaCO_3$ for each sample was determined with the Chittick method, and bulk density for each sample was determined with the paraffin-clod method (Machette, 1986; Singer, 1986). Total carbonate contents for each horizon were calculated using the methods of Machette (1978, 1985), and are the product of the weight-percent $CaCO_3$, bulk density, thickness, and percent fine-earth fraction of each horizon. Soil carbonate data are summarized in table 1 and shown graphically adjacent to their locations on the trench and pit logs.

Soil carbonate data are potentially useful as a chronologic tool, if secondary (pedogenic) carbonate contents and regional rates of carbonate accumulation can be accurately determined (Machette, 1978, 1985). Several aspects of our soil carbonate data, however, prevent us from performing extensive age analyses: (1) our total carbonate values do not include secondary carbonate accumulated as rinds on gravel clasts; (2) our total carbonate values include both secondary (pedogenic) as well as an unknown amount of primary carbonate present in the parent materials prior to soil formation--we could not determine the primary carbonate content because no unaltered parent materials were exposed in the trench; and (3) degradation of soils in the upper pit and upper part of the trench, and the presence of relatively large amounts of carbonate in some of the younger trench deposits (see profiles HS2, HS3, HS5) probably indicate significant erosion and redeposition of carbonate on the face of the fault scarp. Detailed soils studies elsewhere in the Albuquerque basin enable us to estimate the contribution of carbonate rinds and primary carbonate to total soil carbonate values. For example, carbonate rinds in most gravelly soils in New Mexico probably do not contribute more than a few percent of the total carbonate in most well-developed calcic soil horizons (M.N. Machette, oral commun., 1999), and primary carbonate contents are low (2-10%) in most alluvial and eolian deposits in the Albuquerque basin (Machette, 1978; Machette and others, 1997; J.P. McCalpin, written commun., 1999). Reasonable estimates of these parameters may allow calculation of apparent ages for the soils in the fan alluvium (unit 2) exposed in the upper pit, where input of reworked carbonate is probably minimal. Unfortunately, probable recycling of carbonate into sediments deposited across the fault scarp prevents the use of this technique for estimating the ages of soils in the younger eolian/colluvial deposits (units 3-7). Thus, future determinations of the ages of surface-faulting events on the Hubbell Spring fault zone will rely primarily on our numerical age determinations (luminescence and uranium-series ages), and to a lesser extent on qualitative and quantitative soils data.

MAGNETIC SUSCEPTIBILITY DATA

Recently acquired high-resolution aeromagnetic data show prominent magnetic anomalies that coincide with most strands of the Hubbell Spring fault zone and many other faults in the Albuquerque basin (U.S. Geological Survey and Sander Geophysics, Ltd., 1998; Grauch, 1999; Maldonado and others, 1999). We took magnetic susceptibility measurements from most units exposed in the Hubbell Spring trench (table 2) to help determine the source of these linear anomalies. The minor differences in magnetic properties measured across the trench indicate that the abrupt gradients seen in the aeromagnetic data probably are related to juxtaposition of bedrock units with differing magnetic properties (Grauch, 1999) located at much greater depths than the sediments exposed in the trench.

Although the magnetic susceptibility data were not useful in explaining the aeromagnetic anomalies, they were useful as a correlation tool in the trench. For instance, burrowing has isolated sediments exposed in the westernmost part of the trench, but comparisons of the magnetic data support our correlation of these deposits with units 4 and 5 in the central part of the trench. The magnetic susceptibility data also indicate that several deposits exposed in the lower pit (units lp2-lp5) have no obvious correlatives in the trench.

RADIOMETRIC AGE DATA

We used luminescence dating techniques to determine the ages of post-alluvial fan sediments (units 4-7) exposed in the trench (table 3). TL (thermoluminescence) and IRSL (infrared stimulated luminescence a type of optically stimulated luminescence or OSL unique to feldspars) techniques date the last time sediment is exposed to sunlight, presumably during deposition (Berger, 1988). Trench units 4-7 consist primarily of eolian sand, and thus should be reliable luminescence recorders (Wintle, 1993). Kilogram-size blocks or cores were collected from the freshly cleaned trench walls and stored in lightproof and airtight plastic bags. A polymineralic, fine-silt-size (4-11μm) fraction was isolated for each sample. Dose rates were determined by laboratory analyses (high-resolution gamma spectrometry) of extra sediment collected with each set of samples, and field moisture contents of 0.5-10 percent by weight were determined for each sample. Samples were subjected to combinations of sunlight sensitivity tests, anomalous fading tests (Wintle, 1973), total bleach and partial bleach experiments (Wintle and Huntley, 1980; Singhvi and others, 1982) for TL, and additive dose experiments for IRSL (Aitken, 1998).

Our TL and IRSL ages (table 3) are generally consistent and in stratigraphic order. The youngest eolian/colluvial deposit (unit 7) yielded TL and IRSL ages of 11-14 ka, and the underlying eolian/colluvial deposit (unit 5) yielded ages of 27-34 ka. Dating results are less certain for an older eolian/colluvial deposit (unit 4), but our most consistent ages are 52-60 ka. These results clearly indicate that most of the post-alluvial fan sediment exposed in the trench is late Pleistocene in age.

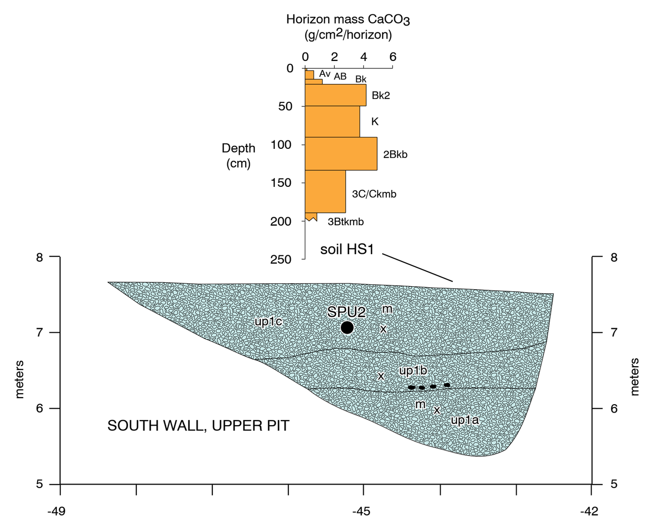
We used uranium-series (uranium/thorium disequilibrium) dating in an attempt to determine the age of the alluvial fan sediment (unit 2) exposed in the trench (table 4). Uranium and thorium isotopic data were obtained by mass spectrometry on four samples of pedogenic calcium carbonate rinds formed on cobble gravel clasts from unit 2. These clasts were sampled at three sites, from the best-developed parts of carbonate soils formed in the fan sediment. The application of this technique relies on the assumption that uranium-bearing carbonate rinds begin to form on gravel clasts in soils that develop soon after stabilization of the alluvial fan surface. U-series analyses of the innermost rinds thus should yield ages that are similar to or slightly younger than the age of fan-surface abandonment.

Significant corrections for detrital thorium components in all four samples, and evidence of uranium loss in two samples, complicate our limited U-series analyses. Our four samples yielded three divergent ages ranging from 70 to 244 ka; only one of these (92 ± 7 ka) may be a reasonable estimate of the age of carbonate rind formation. However, an age of ~90 ka is younger than the middle Pleistocene age assigned to the fan deposits during recent mapping in the area (Love and others, 1996). This age is also younger than similarly developed calcic soils in other parts of the Albuquerque basin (Machette, 1985; Machette and others, 1997).

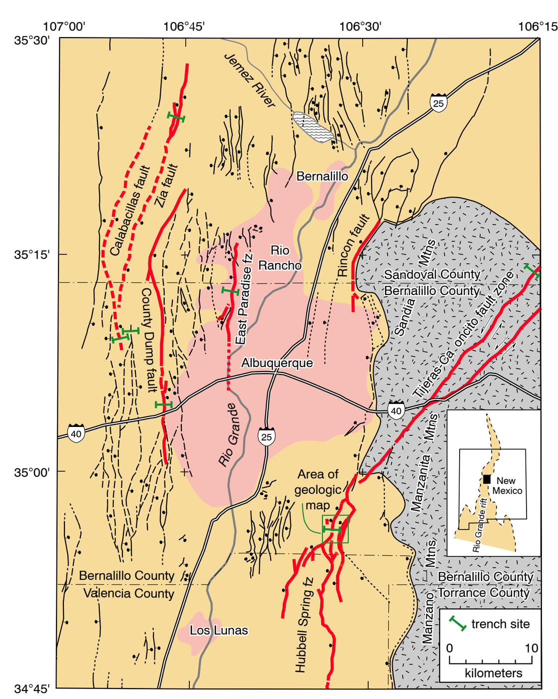
Solution and reprecipitation of pedogenic carbonate are commonly cited problems in previous U-series dating studies of carbonate soils (Slate and others, 1991; Geyh and Eitel, 1998), and evidence of soil erosion, in the form of brecciated carbonate soil horizons, partially dissolved carbonate rinds, and numerous rodent burrows, is present throughout the trench. Erosion and redeposition of pedogenic carbonate in the fan sediment may help explain the wide range of U-series ages we obtained, but much more detailed U-series studies will be required before any definitive conclusions can be made about the age of carbonate soils at the Hubbell Spring trench site.

REFERENCES

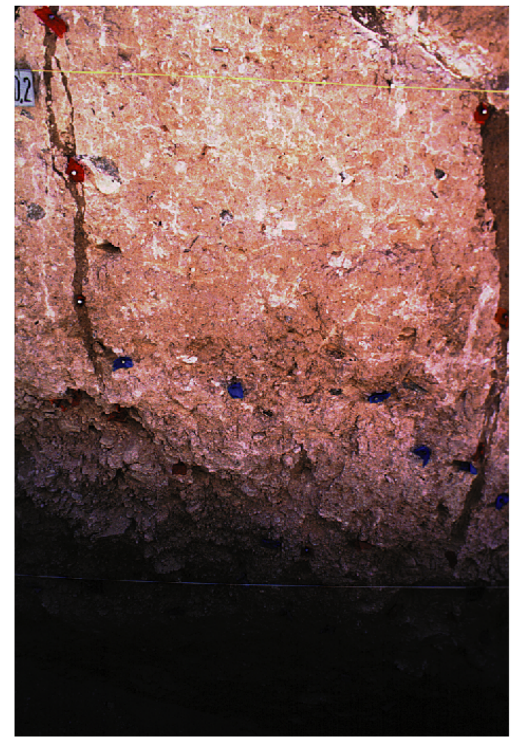
Aitken, M.J., 1998, An introduction to optical dating--The dating of Quaternary sediments by the use of photon-stimulated luminescence: New York, Oxford University Press, 267 p.
Berger, G.W., 1988, Dating Quaternary events by luminescence, *in* Easterbrook, D.J., ed., Dating Quaternary sediments: Geological Society of America Special Paper 227, p. 13-50.
Birkeland, P.W., 1999, Soils and Geomorphology, third edition: New York, Oxford University Press, 430 p.
Geyh, M.A., and Eitel, B., 1998, Radiometric dating of young and old calcrete, *in* Mook, W.G., and van der Plicht, J., eds., Proceedings of the 16th International Radiocarbon Conference: Radiocarbon, v. 40, p. 795-802.
Grauch, V.J.S., 1999, Principal features of high-resolution aeromagnetic data collected near Albuquerque, New Mexico, *in* Pazzaglia, F.J., and Lucas, S.G., eds., Albuquerque Geology: New Mexico Geological Society Fiftieth Annual Field Conference Guidebook, p. 115-118.
Ivanovich, M., and Harmon, R.S., 1992, Uranium-series disequilibrium: Applications to earth, marine, and environmental sciences (second edition): Oxford, Clarendon Press, 910 p.
Love, D.W., Hitchcock, C., Thomas, E., Kelson, K., Van Hart, D., Cather, S., Chamberlin, R., Anderson, O., Hawley, J., Gillentine, J., White, W., Noller, J., Sawyer, T., Nyman, M., and Harrison, B., 1996, Geology of the Hubbell Spring 7.5-min quadrangle, Bernalillo and Valencia Counties, New Mexico: New Mexico Bureau of Mines and Mineral Resources Open-File Digital Map OF-DM 5, 7 p. pamphlet, 1 sheet, scale 1:24,000.
Ludwig, K.R., 1991, ISOPLOT: A plotting and regression program for radiogenic-isotope data, Version 2.71: U.S. Geological Survey Open-File Report 91-445 (June 9, 1993 revision), 42 p.
Machette, M.N., 1978, Dating Quaternary faults in the southwestern United States by using buried calcic paleosols: U.S. Geological Survey Journal of Research, v. 6, no. 3, p. 369-381.
_____ 1985, Calcic soils of the southwestern United States; *in* Weide, D.L., ed., Soils and Quaternary geology of the southwestern United States: Geological Society of America Special Paper 203, p. 1-21.
_____ 1986, Laboratory methods Calcium and magnesium carbonates, *in* Singer, M.J., and Janitzky, P., eds., Field and laboratory procedures used in a soil chronosequence study: U.S. Geological Survey Bulletin 1628, p. 30-33.
Machette, M.N., Long, T., Bachman, G.O., and Timbel, N.R., 1997, Laboratory data for calcic soils in central New Mexico Background information for mapping Quaternary deposits in the Albuquerque Basin: New Mexico Bureau of Mines and Mineral Resources Circular 205, 63 p.
Machette, M.N., Personius, S.F., Kelson, K.I., Haller, K.M., and Dart, R.L., 1998, Map and data for Quaternary faults in New Mexico: U.S. Geological Survey Open-File Report 98-521, 443 p.
Maldonado, F., Connell, S.D., Love, D.W., Grauch, V.J.S., Slate, J.L., McIntosh, W.C., Jackson, P.B., and Byers, F.M. Jr., 1999, Neogene geology of the Isleta Reservation and vicinity, Albuquerque basin, central New Mexico, *in* Pazzaglia, F.J., and Lucas, S.G., eds., Albuquerque Geology: New Mexico Geological Society Fiftieth Annual Field Conference Guidebook, p. 175-188.
Personius, S.F., Machette, M.N., and Kelson, K.I., 1999, Quaternary faults in the Albuquerque area An update, *in* Pazzaglia, F.J., and Lucas, S.G., eds., Albuquerque Geology: New Mexico Geological Society Fiftieth Annual Field Conference Guidebook, p. 189-200.
Singer, M.J., 1986, Bulk density Paraffin clod method, *in* Singer, M.J., and Janitzky, P., eds., Field and laboratory procedures used in a soil chronosequence study: U.S. Geological Survey Bulletin 1628, p. 18-19.
Singhvi, A.K., Sharma, Y.P., and Agrawal, D.P., 1982, TL dating of dune sands in Rajasthana, India: Nature, v. 295, p. 313-315.
Slate, J.L., Bull, W.B., Ku, T.L., Shafiqullah, M., Lynch, D.J., and Huang, Y.P., 1991, Soil-carbonate genesis in the Pinacate volcanic field, northwestern Sonora, Mexico: Quaternary Research, v. 35, p. 400-416.
Soil Survey Staff, 1975, Soil Taxonomy: U.S. Department of Agriculture, Agriculture Handbook No. 436, 754 p.
U.S. Geological Survey and Sander Geophysics, Ltd., 1998, Digital data from the Isleta-Kirtland aeromagnetic survey, collected south of Albuquerque, New Mexico: U.S. Geological Survey Open-File Report 98-341, 1 compact disk.
Wintle, A.G., 1973, Anomalous fading of thermoluminescence in mineral samples: Nature, v. 245, p. 143-144.
_____ 1993, Luminescence dating of aeolian sands--An overview, *in* Pye, K., ed., The dynamics and environmental context of aeolian sedimentary systems: Geological Society of London Special Publication no. 72, p. 49-58.
Wintle, A.G., and Huntley, D.J., 1980, TL dating of ocean sediments: Canadian Journal of Earth Sciences, v. 17, p. 348-360.



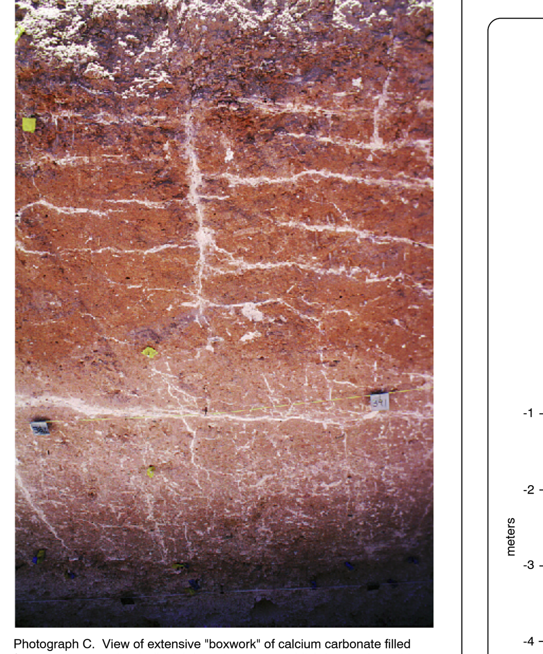
Photograph A. View of the upper part of the south wall of the Hubbell Spring trench. Note presence of both slope-parallel and subvertical calcium carbonate filled fractures. See surficial geologic map for location.



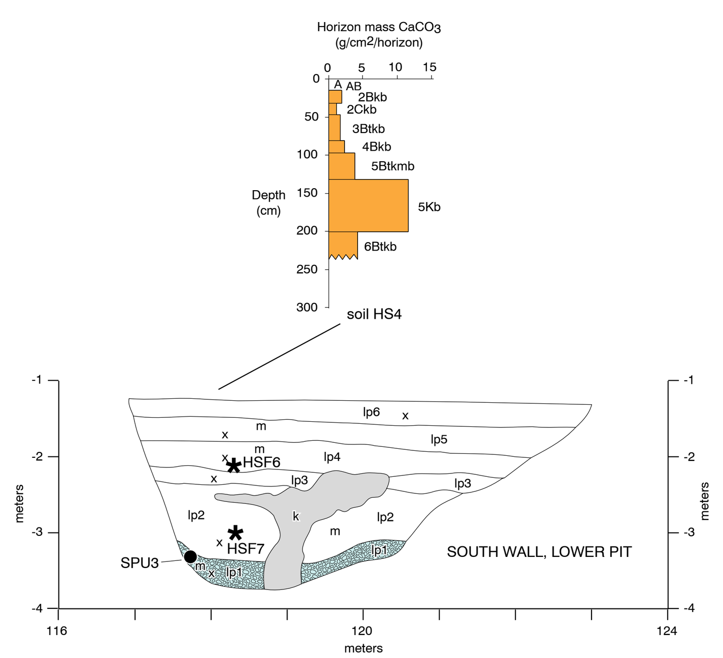
Map of Quaternary faults in the vicinity of Albuquerque, New Mexico (modified from Machette and others, 1998; Personius and others, 1999).

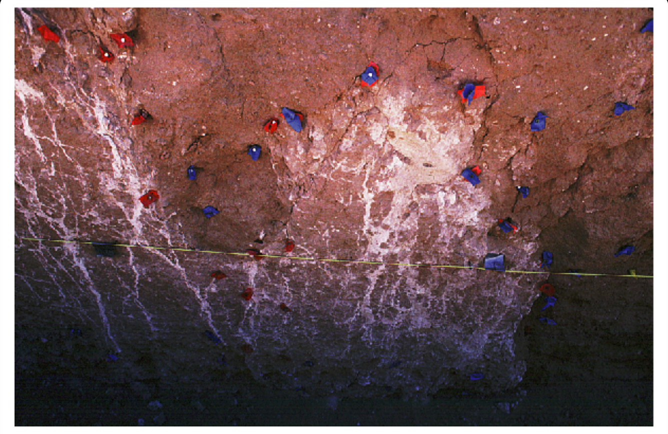


Photograph B. View of central part of eastern fault zone; red pins mark fault traces, blue pins mark stratigraphic contacts.



Photograph C. View of extensive "boxwork" of calcium carbonate filled fractures in two eolian/colluvial deposits.





Photograph D. View of burrowing near western fault zone.

Trench logged and described by S.F. Personius, M.C. Eppes, and D.W. Love, Sept.-Dec., 1997
Soils data collected and analyzed by M.C. Eppes, D.K. Mitchell, and A. Murphy, Nov.-Dec., 1997

Table 1. Soils data from Hubbell Spring trench

Profile location	Trench unit	Horizon[a]	Depth (cm)	Moist color	Dry color	Percent gravel	Texture[b]	Structure[c]	Dry[d] consistence	Wet[d] consistence	Boundary[e]	Roots[f]	Pores[f]	Horizon thickness (cm)	Bulk density (g/cm^3)	Total[g] $CaCO_3$ (grams)	$CaCO_3$[h] stage
HS1 (upper pit, meter -44)	upc1	Av	0-3	7.5YR 4/4	7.5YR 6/4	10	SL	2, m-c, sbk	sh	so, ps	a,s	3vf, 1f	3vf, 3f, 1m	3	1.50	0.13	-
	"	AB	3-14	7.5YR 4/3	7.5YR 5/4	40	L	2, c, sbk	sh	ss, ps	c,s	3vf, 2f, 2m	2f, 1m	11	1.46	0.61	-
	"	Bk	14-21	7.5YR 4/3	7.5YR 6/4	30	L	1, m, sbk	sh	ss, ps	c,s	1f, 2m	2m	7	1.46	1.18	-
	"	Bk2	21-49	10YR 6/4	10YR 7/4	60	L	1, m, sbk	h	ss, ps	c,w	3vf, 2f, 1m	1m	28	1.46	4.20	I
	"	K	49-90	7.5YR 6/3	7.5YR 8/3	60	LS	2-3, m, abk	h	so, po	c,w	3vf, 2f	3vf	41	1.46, 1.71	3.74, 4.26	IV
	up1b	2Bkb	90-133	7.5YR 5/4	7.5YR 7/4	50	SL	2, m, sbk	so	ss, ps	a,s	1f	none	43	1.50	4.94	-
	up1a	3C/Ckmb	133-189	7.5YR 5/6	7.5YR 7/4	70	LS	sg	lo	so, po	c,s	none	none	56	1.50	2.79	-
	"	3Btkmb	189-200	7.5YR 5/4	7.5YR 6/6	50	LS	1, f, sbk	sh	so, po	-	none	none	11	1.71	0.81	I
HS2 (trench, meter 38)	9	A	0-6	10YR 4/6	10YR 5/4	<10	SL	1, m, sbk	so	so, po	c,s	3vf, 2f, 1m	1f, 1m	6	1.50	0.22	-
	"	AB	6-25	10YR 4/4	7.5YR 6/6	10	fine SL	2, c, sbk	sh	so, ps	c,s	1f, 1m	2m	19	1.46	0.61	-
	5	2Bkb	25-63	7.5YR 6/4	7.5YR 6/4	<10	L	2, c, sbk	vh	ss, ps	c,s	1f, 1m	2f, 1m	38	1.46	5.57	II
	"	2Btkmb	63-125	10YR 5/8	7.5YR 6/6	<10	SL	massive	vh	ss, po	c,s	none	1m	62	1.85	3.98, 1.79	II
	4	3Bkmb	125-173	10YR 6/6	7.5YR 7/6	<10	L	massive	vh	ss, po	c,w	none	1m	48	1.85, 1.70	0.91, 3.31	III
	"	3Bkmb2	173-230	7.5YR 7/6	7.5YR 8/4	<10	L	massive	vh	ss, ps	c,s	none	1f	57	1.70	6.21, 7.41	III
	2c	4Btkb	230-246	7.5YR 7/6	10YR 8/4	60	L	2, m, sbk	vh	ss, ps	c,s	none	1m	16	1.52	1.78	II
	2b	4Kb	246-298	7.5YR 8/3	7.5YR 8/2	70	SL	2, c, sbk	h	ss, po	-	none	none	52	1.52	4.79	III
HS3 (trench, meter 46)	9	A	0-6	7.5YR 4/3	7.5YR 6/4	10	SL	2, m, sbk	so	ss, po	c,s	3vf, 1f, 1m	2f, 1m	6	1.46	0.14	-
	"	AB	6-22	10YR 4/6	7.5YR 4/4	15	L	2, m, sbk	sh	so, ps	c,s	3vf, 2f, 1m, 1c	2f, 1m, 1c	16	1.46	0.28	-
	7	2Bkb	22-48	7.5YR 4/3	7.5YR 5/4	<10	SL	2, m, sbk	sh	ss, ps	c,s	2 vf, 1m, 1c	2f, 1m, 1c	26	1.46	2.61	-
	"	2Bkb2	48-95	7.5YR 4/4	7.5YR 5/4	<10	L-SiL	3, m, sbk	h	ss, ps	c,s	1vf, 2f, 1m	1vf, 2f, 1m	47	1.72	2.81, 1.99	II+
	"	2Bkb3	95-135	10YR 5/6	10YR 6/4	<10	L	2, m, abk	vh	ss, ps	c,s	1f	1f, 1m	40	1.72	3.90	II+
	6	3Btkb	135-154	7.5YR 4/8	5YR 5/4	<10	SL	2, m, sbk	vh	ss, ps	c,s	none	2f, 1m	19	1.72	1.14	II
	"	3Bkb	154-182	10YR 4/6	7.5YR 6/4	<10	SL	2, m, sbk	sh	ss, po	c,s	none	2f, 1m, 1c	28	1.72	2.44	II
	k	4Bwb	182-200	7.5YR 5/4	7.5YR 5/4	<10	SL	2, m, sbk	sh	ss, ps	g,s	none	1f, 1m	18	1.46	0.78	-
	"	4Ckb	200-250	10YR 4/6	7.5YR 6/4	15	fine SL	2, m, abk	sh	so, po	-	none	1m	50	1.46	1.08, 1.01	-
HS4 (lower pit, meter 118)	lp6	A	0-4	7.5YR 3/3	7.5YR 5/3	10	fine SL	2, f-m, sbk	sh	ss, ps	a,s	3 vf, 1m, 1c	1f, 1c	4	1.50	0.08	-
	"	AB	4-15	7.5YR 4/4	7.5YR 5/4	5	SL	2, m, sbk	sh	ss, po	c,s	3vf, 1f, 1c	2m, 1c	11	1.46	0.12	-
	lp5	2Bkb	15-32	7.5YR 5/4	7.5YR 6/6	5	L	2, c, sbk	h	ss, p	c,s	2vf, 1f, 1m	2f, 1m, 1c	17	1.46	1.92	-
	"	2Ckb	32-47	7.5YR 4/3	7.5YR 6/4	15	L	2, m, sbk	sh	ss, po	a,s	2vf, 1f, 1m	1f, 1m	15	1.46	1.13	-
	lp4	3Btkb	47-81	7.5YR 3/4	7.5YR 5/4	<10	SC	3, c, sbk	sh	s, p	c,s	1f, 1m	1f, 2m, 1c	34	1.62	1.65	II-
	lp3	4Bkb	81-97	7.5YR 4/3	7.5YR 6/6	10	L	2, m, sbk	h	ss, ps	a,s	1vf	1f, 1m	16	1.62	2.29	III-
	lp2	5Btkmb	97-132	7.5YR 5/6	7.5YR 6/6	25	L	2, m, sbk	vh	ss, ps	c,s	none	1f	35	1.62	3.77	-
	"	5Kb	132-201	7.5YR 6/4	7.5YR 7/4	10	L	massive	sh	ss, ps	c,w	none	none	69	1.46	11.50	III
	lp1	6Btkb	201-230	7.5YR 5/6	7.5YR 7/4	10	SL	3, m, sbk	vh	ss, po	-	none	1f, 1m	29	1.46	4.22	I+
HS5 (trench, meter 54)	9	A	0-4	5YR 4/3	7.5YR 5/4	<10	L	2, f, sbk	so	ss, ps	a,s	3 vf, 1m, 1c	1f, 1c	4	1.52	0.12	-
	"	AB	4-22	5YR 4/6	7.5YR 5/6	0	L	2, m, sbk	sh	ss, ps	a,s	1f, 1m	1 vf	18	1.52	1.05	-
	7	2Bkb	22-44	10YR 5/4	10YR 6/3	<10	SiL	2,m, sbk	h	ss, ps	g,s	1f, 1m	1f, 1m	22	1.62	4.08	II
	5	3Bkb	44-90	7.5YR 5/4	7.5YR 6/4	<10	SL	3, m, sbk	vh	ss, po	g,s	none	1f-m	46	1.62	5.02	II+
	"	3Bkb2	90-157	7.5YR 6/4	7.5YR 6/6	<10	SL	massive	h/vh	so, po	c,w	none	1 vf	67	1.72	1.54, 0.59	II
	4	4Bkmb	157-218	7.5YR 6/4	7.5YR 7/4	<10	SL	massive	h	so, po	c,w	none	2 vf	61	1.72	8.26	III
	"	4Kb	218-242	7.5YR 7/6	7.5YR 7/4	<10	fine LS	3, m, sbk	h	so, po	c,s	none	3 vf	24	1.71	3.04	III
	"	4Btkb	242-251	7.5YR 6/4	7.5YR 6/6	<10	LS	2, m, sbk	sh	so, ps	-		2 vf	9	1.71	1.07	-

[a]Nomenclature from Soil Survey Staff (1975) and Birkeland (1999).
[b]Texture classes: L--loam, SL--sandy loam, LS--loamy sand, SiL--silt loam, SC--sandy clay.
[c]Structure: grade: sg--single grain, 1--weak, 2--moderate, 3--strong; size class: f--fine (5-10 mm), m--medium (10-20 mm), c--coarse (20-50 mm); type: abk--angular blocky, sbk--subangular blocky.
[d]Consistence: (dry) lo--loose, so--soft, sh--slightly hard, h--hard, vh--very hard; (wet) so--nonsticky, ss--slightly sticky, s--sticky, po--nonplastic, ps--slightly plastic, p--plastic.
[e]Boundary: (distinctness) a--abrupt, c--clear, g--gradual; (topography) s--smooth, w--wavy (see Birkeland, 1999).
[f]Roots and Pores: (abundance) 1--few, 2--common, 3--many; (size) vf--very fine, f--fine, m--medium, c--coarse.
[g]Total carbonate: weight in grams of calcium carbonate in a 1 cm^2 vertical column of soil in each horizon, using methods of Machette (1978, 1985).
[h]Nomenclature from Birkeland (1999); some stage designations vary slightly from table 5 because of differences in profile locations and investigator interpretations.

Table 4. Uranium-series ages from Hubbell Spring trench

Sample number	Location (x,y)	Trench unit	Sample weight (grams)	Sample concentrations[a] (U, μg/g)	(Th, μg/g)	Measured activity ratios[b] $^{234}U/^{238}U$ (±2σ)	$^{230}Th/^{238}U$ (±2σ)	$^{230}Th/^{232}Th$ (±2σ)	Detritus-corrected values[c] initial $^{234}U/^{238}U$ activity (±2σ)	$^{230}Th/U$ age (ka, ±2σ)	Sample descriptions and comments
SPU1a	15.0, 3.1	2b	0.04	1.50	0.88	1.39 ± 0.03	1.35 ± 0.06	6.98 ± 0.46	1.92 ± 0.13	244 +74/-50	Dense lens of brown calcite within inner rind on gravel clast; evidence of uranium loss
SPU1c	15.0, 3.1	2b	0.06	2.55	1.08	1.38 ± 0.01	0.86 ± 0.01	6.18 ± 0.10	1.56 ± 0.03	92 ± 7	Dense lens of brown calcite in rind adjacent to surface of gravel clast
SPU2d	-45.2, 7.1	up1c (2b)	0.08	2.18	1.12	1.27 ± 0.01	1.39 ± 0.01	8.26 ± 0.12	Undefined	Excess ^{230}Th	Dense lens of brown calcite within thick rind on gravel clast; evidence of uranium loss
SPU3c	117.6, -3.3	lp1 (2b)	0.03	1.90	1.37	1.42 ± 0.01	0.79 ± 0.01	3.33 ± 0.04	1.63 ± 0.07	70 ± 11	Thin layer of brown, porous carbonate in rind adjacent to surface of gravel clast

[a]All uranium and thorium isotope data were obtained with mass spectrometry by James B. Paces at the U.S. Geological Survey, Denver, Colorado; uncertainties for uranium and thorium concentrations are not listed but are typically less than five percent (95-percent confidence limit) of the reported value.
[b]Measured activity ratios have been corrected for the addition of spike solutions, mass discrimination, and procedural blank subtraction.
[c]Measured activity ratios corrected for a secular equilibrium detrital component assumed to have a Th/U ratio of 4 ($^{232}Th/^{238}U$=1.276 ± 50%; $^{234}U/^{238}U$=1.0 ± 10%, $^{230}Th/^{238}U$=1.0 ± 25%). Ages and initial $^{234}U/^{238}U$ activity are calculated from detrital-corrected activity ratios using conventional dating equations (Appendix A of Ivanovich and Harmon, 1992) as formulated in ISOPLOT (Ludwig, 1991).

Table 2. Magnetic susceptibility data from Hubbell Spring trench

Trench unit	Location (x,y)	Measurements[a] 1st	2nd	3rd	4th	5th	6th	Average	Std dev.[b]	Unit description
1	14.0, 1.7	3.25	3.47	3.63	3.53	4.17	3.24	3.55	0.34	Upper Santa Fe Group--well sorted sand
1	31.3, 0	5.38	4.13	4.63	5.14	4.54	4.52	4.72	0.46	Upper Santa Fe Group--well sorted sand
2a	29.5, 1.6	0.39	0.55	0.58	0.37	0.54	0.59	0.50	0.10	calcic soil in fan gravel, near fault
up1a	-44.5, 6.1	0.66	0.59	0.56	0.52	0.51	0.53	0.56	0.06	bedded fan gravel, upper pit; trench unit 2b
up1c	-44.5, 7.3	0.31	0.18	0.26	0.25	0.25	0.39	0.27	0.07	calcic soil in fan gravel, upper pit; trench unit 2b
2b	9.2, 3.7	0.48	0.33	0.56	0.46	0.45	0.50	0.46	0.08	calcic soil in fan gravel
2b	10.8, 2.3	1.01	1.16	0.93	1.12	0.86	1.18	1.04	0.13	fan gravel
2b	23.7, 2.2	1.01	0.92	0.77	0.94	0.81	0.88	0.89	0.09	calcic soil in fan gravel
2b	33.5, 0.4	0.28	0.42	0.42	0.51	0.28	0.46	0.40	0.10	calcic soil in fan gravel, near fault
2b	37.5, 0.1	0.51	0.45	0.52	0.71	0.53	0.42	0.52	0.10	calcic soil in fan gravel
3	24.2, 2.7	0.90	0.95	1.33	0.76	1.06	0.76	0.96	0.21	first eolian/colluvial sand; coarser than units 4, 5, 7
3	29.8, 2.1	0.93	0.91	0.87	0.80	0.90	0.83	0.87	0.05	first eolian/colluvial sand; coarser than units 4, 5, 7
4	33.5, 1.5	0.68	0.97	1.11	0.97	1.11	1.04	0.98	0.16	second eolian/colluvial sand
4	39.5, 0.6	1.00	0.99	0.83	1.05	1.09	1.21	1.03	0.13	second eolian/colluvial sand
4	43.0, 0	0.82	0.93	0.92	1.00	0.97	1.10	0.96	0.09	second eolian/colluvial sand
4	53.5, -0.6	1.13	1.18	1.41	1.05	1.17	1.08	1.17	0.13	second eolian/colluvial sand, in hanging wall
5	33.3, 2.2	1.52	1.67	1.20	1.39	1.31	1.33	1.40	0.17	third eolian/colluvial sand
5	37.6, 1.4	1.55	1.44	1.57	1.62	1.36	1.55	1.52	0.10	third eolian/colluvial sand
5	43.4, 0.8	1.46	1.78	1.67	1.40	1.73	1.65	1.62	0.15	third eolian/colluvial sand
5	53.5, 0.1	1.69	1.49	1.68	1.53	1.42	1.70	1.59	0.12	third eolian/colluvial sand, hanging wall
6	46.0, 0.3	1.45	1.23	1.14	1.52	1.73	1.38	1.41	0.21	burrowed eolian/colluvial sand
7	46.0, 1.0	2.00	1.92	1.58	1.92	1.78	1.59	1.80	0.18	fourth eolian/colluvial sand
k	46.5, -0.3	1.34	1.34	1.72	1.43	1.37	1.48	1.45	0.14	burrowed eolian/colluvial sand
lp1	117.8, -3.5	0.80	0.64	0.69	0.44	0.76	0.76	0.68	0.13	calcic soil in fan gravel, lower pit; trench unit 2b
lp2	119.6, -2.9	1.32	1.48	1.42	1.32	1.59	1.46	1.43	0.10	eolian/colluvial sand, lower pit; mixed units 4 and 5?
lp4	118.6, -1.9	1.30	0.93	1.49	1.27	1.66	1.69	1.39	0.29	Btk soil in alluvial/eolian sand, lower pit
lp5	118.6, -1.6	1.16	1.01	1.15	1.19	1.43	1.01	1.16	0.15	alluvial/eolian sand, lower pit

[a]Measurements are dimensionless (SI) units, times 10^{-3}, made in situ with a commercially available hand-held susceptibility meter; they roughly correlate with quantity of magnetite contained in the sediment.
[b]± 1σ.

Table 3. Thermoluminescence (TL) and infrared stimulated luminescence (IRSL) ages from Hubbell Spring trench

Sample number	Location (x,y)	Trench unit	Unit description	Dating method[a]	Temperature data[b] (°C)	Equivalent dose[c] (grays)	Dose rate[d] (grays/ka)	Comments	Age[e] (ka)
modern	N/A	N/A	modern eolian sand from coppice dune on scarp, depth 30 cm	TL-tb, pb	250-430	N/A	3.68 ± 0.06	ave. of 3 ages (2.7, 2.95, 2.25 ka); indicates only minor inherited TL signal	2.6 ± 0.4
				IRSL	160/6 hrs	1.07 ± 1.28	3.68 ± 0.06	indicates complete bleaching in all grains	0.3 ± 0.7
HSF2	41.4, 0.4	4	second eolian/colluvial deposit, upper part	TL-tb	380-410	210.84 ± 4.41	3.68 ± 0.05		57.3 ± 2.9
				IRSL	140/8 hrs	198.99 ± 3.08	3.68 ± 0.05		54.1 ± 2.3
				IRSL	124/62 hrs	162.37 ± 2.24	3.68 ± 0.05	probably too young; large residual errors	44.1 ± 1.7
HSF3	41.8, 1.0	5	third eolian/colluvial deposit	TL-tb	200-380	N/A	3.79 ± 0.05	ave. of two ages (27, 28.5 ka)	28.1 ± 1.3
				IRSL	160/6 hrs	107.58 ± 4.48	3.79 ± 0.05		28.4 ± 2.5
HSF4	46.3, 0.5	7	fourth eolian/colluvial deposit	TL-tb	210-390	N/A	4.04 ± 0.06	ave. of two ages (10.5, 13.6 ka)	11.6 ± 0.5
				IRSL	160/6 hrs	51.03 ± 0.86	4.04 ± 0.06		12.6 ± 0.6
HSF5	45.6, 0.6	7	fourth eolian/colluvial deposit	TL-tb	200-420	N/A	4.04 ± 0.06	ave. of two ages (10.2, 14.1 ka)	12.3 ± 0.5
				IRSL	160/6 hrs	54.32 ± 0.82	4.04 ± 0.06		13.45 ± 0.6
HSF6	118.3, -2.2	lp4	eolian sand, lower pit	TL-tb	290-450	N/A	4.14 ± 0.06	ave. of three ages (13.1, 10.1, 10.7 ka);	11.0 ± 0.3
				IRSL	140/8 hrs	37.52 ± 0.38	4.14 ± 0.06	TL and IRSL ages suggest unit may be	9.1 ± 0.3
				IRSL	124/62 hrs	41.45 ± 0.42	4.14 ± 0.06	slightly younger than unit 7	10.0 ± 0.4
HSF7	118.3, -3.0	lp2	eolian/colluvial deposit, lower pit	TL-tb	320-390	165.11 ± 7.41	4.14 ± 0.06	probably too old; mixed sample or inherited TL?	39.9 ± 1.1
				TL-tb	370-460	179.80 ± 6.69	4.14 ± 0.06	probably too old; mixed sample or inherited TL?	43.4 ± 3.5
				TL-tb	350-440	117.40 ± 1.41	4.14 ± 0.06		28.4 ± 1.1
				IRSL	140/7 hrs	97.33 ± 0.65	4.14 ± 0.06	probably too young; preheat too intense?	23.5 ± 0.7
				IRSL	124/62 hrs	118.60 ± 3.99	4.14 ± 0.06		28.65 ± 2.1
HSF8	45.6, 0.1	6	burrowed eolian/colluvial deposit	TL-tb	230-400	N/A	3.59 ± 0.07	ave. of three ages (19.6, 17.6, 14.7 ka)	15.9 ± 0.9
				IRSL	140/7 hrs	57.03 ± 1.21	3.59 ± 0.07		15.9 ± 0.9
HSF9	40.7, 0.2	4	second eolian/colluvial deposit	TL-tb, pb	280-400	N/A	3.68 ± 0.05	ave. of four ages (52.5, 55.1, 56.7, 60.9 ka)	56.6 ± 3.0
				IRSL	160/6 hrs	169.42 ± 2.96	3.68 ± 0.05	probably too young; large residual errors	46.0 ± 2.1
				IRSL	160/6 hrs	138.14 ± 7.27	3.68 ± 0.05	probably too young; large residual errors	37.5 ± 4.1
HSF10	52.5, -0.2	5	third eolian/colluvial deposit	TL-tb, pb	200-430	N/A	3.89 ± 0.06	ave. of five ages (19.5, 21.6, 30.1, 34.8, 36.0 ka)	31.9 ± 2.2
				IRSL	160/6 hrs	113.95 ± 5.41	3.89 ± 0.06		29.3 ± 2.9
HSF11	52.9,-1.1	4	second eolian/colluvial deposit	TL-tb	270-410	156.71 ± 6.14	3.74 ± 0.05	probably too young; analyzed after IRSL	41.9 ± 3.5
				TL-tb	370-440	258.10 ± 19.59	3.74 ± 0.05	probably too old; mixed sample or inherited TL?	69.0 ± 10.7
				IRSL	160/6 hrs	135.13 ± 4.99	3.74 ± 0.05	probably too young; near saturation	36.1 ± 2.9

[a]TL thermoluminescence, tb total bleach, pb partial bleach; IRSL infrared stimulated luminescence.
[b]Values for TL are plateau temperatures; values for IRSL are preheat temperatures and durations.
[c]All figures quoted to ± 1σ; N/A not applicable; no equivalent dose listed for averaged samples.
[d]Dose rate measured by high-resolution gamma spectrometry on ~600-gram bulk samples at field moisture (<10%); error is ± 1σ.
[e]All ages in thousands of years, quoted to ± 2σ; averaged ages are error-weighted.

Table 5. Unit descriptions from Hubbell Spring trench

Trench unit	Location (x,y)	Matrix grain Size	Percent gravel	Largest clast (mm)	Sorting	Dry color	Dry consistence[a]	Wet consistence[a]	Soil development[b]	Genesis	Comments[c]
1	30.7, 0.3	sand (m-c)	2-5	10	well	10YR 7/1	so	so, po	none	fluvial	crude, thin (1-2 mm) bedded; sand composition: qtz>>fld>lithics; contains blocks of Bk-II to Bk-III soil; upper Santa Fe Group
1	12.7, 2.1	sand (m-c)	1-5	20	well	10YR 7/1	so	so, po	none	fluvial	minor crude, thin (1-2 mm) bedded, otherwise massive; sand composition: qtz>>fld>lithics; contains blocks of Bk-III soil
2a	28.9, 1.1	sand (f-c)	60-80	200	mod.	10YR 7/3	so	ss, ps	Bk-II	alluvial	gravel transport directions 250-290°; deposited in channels cut in units 1 and 2b
2a	32.2, 0.25	sand (f-c)	60-80	100	mod.	10YR8/2	so	ss, ps	Bk-II	alluvial	gravel transport directions 280-295°; deposited in channels cut in units 1 and 2b
2b	39.4, -0.25	sand (m-c)	40-70	30	mod.-well	10YR 8/1	vh	ss, ps	K-III+	alluvial	nonbedded
2b	27.2, 1.3	sand (f-c)	25-50	80	mod	10YR 7/4	vh	ss, ps	Bk-III	alluvial	nonbedded; abundant filled cicada burrows
2c	38.5, 0.15	sand (f)	30-60	80	poor	10YR 6/6	h	ss, ps	Btk-II	alluvial	eroded Btk in upper part of unit 2
3	27.5, 2.3	sand (f-c)	5	90	mod.	10YR 8/2	vh	ss, ps	Bk-III	eolian/colluvial	coarser than other eolian/colluvial deposits; stone lines in footwall
4	41.0, 0.5	sand (f)	2-5	15	well	10YR 7/8	sh	ss, ps	Bk-III	eolian/colluvial	pervasive fracturing increases near western fault zone
4	52.7, -1.0	sand (f)	3	20	well	10YR 7/4	h	ss, ps	Bk-II	eolian/colluvial	eolian/colluvial deposit from second event in hanging wall
5	42.0, 1.1	sand (f-m)	3	15	well	5YR 6/6	h	ss, p	Btk-II	eolian/colluvial	some slope-parallel pebble alignment; abundant slope-parallel and vertical carbonate-filled fractures and veins; no carbonate in matrix; third eolian/colluvial deposit
5	52.5, 0.1	sand (f-m)	2-3	40	mod.	7.5YR 6/6	sh	ss, ps	Btk-II	eolian/colluvial	crude slope-parallel bedding; abundant slope-parallel and near-vertical carbonate-filled fractures and veins; third eolian/colluvial deposit
6	46.0, 0.2	sand (f-m)	2-5	25	mod.	10YR 7/4	h	ss, ps	Btk-II	eolian/colluvial, burrowed	more gravelly than unit 7, pebbles have near-vertical orientations; probably burrowed mixture of trench units 4 and 5
7	45.7, 0.8	sand (f)	2	10	well	7.5YR 7/4	vh	ss, ps	Bk-II+	eolian/colluvial	abundant filled cicada burrows, fourth eolian/colluvial deposit; unfaulted
8	11.9, 3.8	sand (f-c)	10	40	poor	10YR 7/3	h	ss, ps	Bk-II+	burrowed colluvium	nonbedded; probably older burrow fill
8	7.7, 4.3	sand (f-c)	10	100	poor	10YR 8/2	sh	ss, ps	Btk-II	burrowed colluvium	nonbedded; probably older burrow fill
9	50.7, 1.4	sand (f-m)	2-10	20	poor	10YR 6/6	so	s, p	Bw	colluvium	nonbedded; post-faulting slope wash
9	24.3, 3.3	sand (f-c)	5-10	20	poor	10YR 7/3	so	ss, ps	Bw	colluvium	nonbedded; post-faulting slope wash
k	49.0, 0.2	sand (f-c)	10	50	mod.	10YR 6/8	so	ss, ps	--	burrowed colluvium	nonbedded; rodent-burrowed; mixed sand and minor gravel of units 2, 3, 4, 5, 6, 7, 8, and 9
up1a	-44.2, 6.1	sand (f-c)	50-70	70	mod.	10YR 6/4	so	so, po	Bk-I	alluvial	well bedded in parallel beds 3-10 cm thick, apparent dips of 3-5° E; coarse sand mostly lithic grains; gravels locally derived limestone and metamorphic rocks from Manzano Mountains to east
up1b	-44.7, 6.5	sand (f-c)	30-50	70	poor	10YR 7/2	so	ss, ps	Bk-I	alluvial	poorly bedded to massive; buried soil?
up1c	-44.7, 7.1	sand (f-c)	50-70	250	mod.	10YR 8/1	vh	ss, ps	K-III+	alluvial	nonbedded, rodent burrowed in part
lp1	118.0, -3.5	sand (f-c)	40-50	80	mod.	10YR 8/4	vh	ss, ps	Btk-III	alluvial	probably top of fan alluvium (trench unit 2b)
lp2	118.1, -3.1	sand (f-c)	5-10	50	poor	10YR 8/2	vh	ss, ps	Bk-III	eolian/colluvial	nonbedded; may be burrowed mixture of trench units 4 and 5
lp3	118.0, -2.3	sand (f-c)	20-40	20	mod.	10YR 8/3	sh	ss, ps	Bk-II	alluvial	nonbedded; probably deposited as alluvium from fan to north and/or south of trench site
lp4	118.2, -2.0	sand (f-m)	1	40	well	7.5YR 6/4	vh	s, p	Btk-I+	eolian, colluvial? alluvial?	massive; strong, medium prismatic soil structure and many thick clay films present
lp5	118.2, -1.7	sand (f-c)	15-30	15	mod.	10YR 7/4	so	ss, ps	Bw	alluvial/eolian	coarsens downward; probably from fan to north and/or south of trench site
lp6	120.5, -1.4	sand (f)	1-5	15	well	10YR 6/4	so	s, p	Bw	eolian/alluvial	similar to lp5 but finer grained; alluvium from fans to north and/or south of trench site
ec1	52.85, -3.0	sand (f-m)	10	30	poor	10YR 7/6	vh	ss, ps	Bk-II	alluvial	auger sample from eastern core; v. difficult drilling; block of unit 2b in burrow fill?
ec2	52.85, -2.0	sand (f-m)	15	30	poor	10YR 7/6	h	ss, ps	Bk-I+	alluvial	auger sample from eastern core; difficult drilling; probably eroded top of unit 2b
wc1	53.8, -2.3	sand (f-c)	30-60	80	mod.	10YR 8/3	vh	ss, ps	Bk-III	alluvial	auger sample from western core; probably intact unit 2b

[a]consistence: so--soft, sh--slightly hard, h--hard, vh--very hard, so--nonsticky, ss--slightly sticky, s--sticky, po--nonplastic, ps--slightly plastic, p--plastic.
[b]maximum soil development in unit, Roman numerals are stages of calcium carbonate morphology; nomenclature from Birkeland (1999).
[c]qtz--quartz; fld--feldspar.

Log and data from a trench across the Hubbell Spring fault zone, Bernalillo County, New Mexico

By

Stephen F. Personius,[1] Martha C. Eppes,[2] Shannon A. Mahan,[1] David W. Love,[3] David K. Mitchell,[2] and Anne Murphy[2]

2000

Author affiliations:
[1]U.S. Geological Survey, Denver, CO 80225
[2]Dept. of Earth & Planetary Sciences, University of New Mexico, Albuquerque, NM 87131
[3]New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801

Manuscript approved for publication October 19, 2000
Minor revisions dated May 25, 2001
Any use of trade names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey
This map was produced on request, directly from digital files, on an electronic plotter
For sale by the U.S. Geological Survey Information Services
Box 25286, Federal Center, Denver, CO 80225
This map is also available as a PDF at http://geology.cr.usgs.gov