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

TO ACCOMPANY MAP MF-2386

LOGS AND DATA FROM TRENCHES ACROSS THE HAYWARD FAULT AT TYSON'S LAGOON (TULE POND), FREMONT, ALAMEDA COUNTY, CALIFORNIA

By

James J. Lienkaemper,[1] Timothy E. Dawson,[1] Stephen F. Personius,[2]
Gordon G. Seitz,[3] Liam M. Reidy,[4] and David P. Schwartz[1]

[1]U.S. Geological Survey, Menlo Park, CA 94025
[2]U.S. Geological Survey, Denver, CO 80225
[3]Lawrence Livermore National Laboratory, Livermore, CA 94551
[4]Department of Geography, University of California, Berkeley, CA 94720

INTRODUCTION

The purpose of this publication is to make available detailed trench logs (sheets 1, 2), radiocarbon dates (table 1) and pollen data (fig. 1) obtained as a result of an intensive subsurface investigation of the Hayward Fault at Tyson's Lagoon (Tule Pond) from August to November 2000 (figs. 1, 2 on sheet 1). The Hayward Fault is recognized to be among the most hazardous in the United States (Working Group on California Earthquake Probabilities, 1999). This document makes available geologic evidence for historical and prehistoric surface-rupturing earthquakes that were recorded at the site. Prehistoric earthquakes deduced from geologic evidence are called paleoearthquakes. Establishing a chronology of paleoearthquakes is of immediate use in resolving the level of hazard posed by the Hayward Fault for producing large earthquakes in the future. Preliminary findings of this investigation have been presented in Lienkaemper and others (2001). A formal report on our conclusions based on these data is in preparation. The investigation at Tyson's Lagoon is ongoing, so these products should not be considered final. Lienkaemper, Dawson, and Personius interpreted the geology and logged the trenches. Seitz and Reidy performed analyses on radiocarbon and pollen samples, respectively. Schwartz led the critical-review field team.

Previous trenching work was done at Tyson's Lagoon (figs. 2, 3 on sheet 1). Lienkaemper (1992) references the location of most of those trenches. The earlier trenching was generally for the evaluation of local fault-rupture hazard, except for the study of Williams (1993), which was a paleoearthquake investigation. An unpublished study by J.N. Alt in 1998 (shown on our site map as trenches 98A and 98B, fig. 3, on sheet 1), also sought evidence of paleoearthquakes. Alt's study and one by Woodward-Clyde and Associates (1970; trenches 70A to 70G, fig. 3) were located south of Walnut Avenue in one of the few areas that still remain undisturbed and were, thus, useful in planning our work in 2000.

METHODOLOGY

TRENCHING

We excavated three trenches: 00A, 00B, and 00C. The site location maps and the log of trench 00A are shown on sheet 1, and logs of trenches 00B and 00C are on sheet 2. As seen on the map of Tyson's Lagoon (fig. 2 on sheet 1), the pond is a classic example of a sag pond (Wallace, 1990), a pull-apart structure caused by a right step in a right-lateral fault.

Data are shown on mosaics of high-resolution color photographs made using a set of techniques and a special device: a camera mounted on a 0.5 m by 1.0 m aluminum frame. The tubular frame can be seen in some places on the photomosaic logs (sheets 1, 2). Digital images from these photos were rectified to the field grid, string lines visible on the logs. Distance (y-axis) of all three trenches is measured from an arbitrary line parallel to the fault, hence the starting point of each trench is some arbitrary non-zero value.

The most useful paleoearthquake information was developed from the youngest materials and structures exposed in trench 00A (sheet 1). Trenches 00B and 00C lack the thick young section found in trench 00A. They are not inconsistent with the results from trench 00A nor can they be used to corroborate them, but we have

included logs from trenches 00B and 00C (sheet 2). To save on expense, users may chose to print only sheet 1 without loss of the principal results. The remainder of this text refers primarily to our observations in trench 00A, unless stated otherwise.

The log of trench 00A shows a graben structure that has subsided at at a rate of nearly 3 mm/yr. The rate of sedimentation approximately equalled the rate of subsidence. We assigned unit numbers to most of the stratigraphic units, from u20 at the base of the trench to u550, the most recent artificial fill. These unit numbers are used to correlate the radiocarbon samples between trench walls (table 1). The graben-filling units are generally fine grained deposits, with varying amounts of silt and clay, and some sand, particularly near the main fault trace. The main fault trace is located between meters 5 and 7. West of the main fault trace are older sand and gravel alluvial deposits of the Niles alluvial cone (California Department of Water Resources, 1967) predating the inception of subsidence at Tyson's Lagoon. We have dated pond units near the base of trench 00A as old as 4,000 years, but do not know the age of inception of the pond. Hence, these deposits precede the most recent 2,000 years of earthquake rupture history, which is the focus of this investigation.

Color is used to highlight some key stratigraphic units on the logs. The lowest of these we call orange silty clay (OSC) and the other four (C1, C2, C3, C4) are organic clay-rich horizons that may represent periods of relatively longer stability. Each of these clay layers is overlain by a horizon that is much siltier (S1, S2, S3, S4.) The upper two silt units are much sandier than the lower two. These silt and sand units may have been deposited as colluvium from the older alluvial materials west of the fault.

Earthquakes cause a disruption of the ground surface along the trace of the causative fault. The original ground surface prior to deformation can be shown on a trench log as an event horizon. Event horizons are shown as green dashed lines labeled: E1, E2, E3, E4, EX? and EY. Three distinctive units of blocky scarp colluvium (BSC1, BSC2, BSC3) demonstrate the occurrence of sudden, major deformation events at the ground surface near the main fault trace.

RADIOCARBON DATING

Laboratory radiocarbon ages of samples from trenches 00A and 00B are given in tables 1 and 2, respectively. Samples from trench 00C were not dated, but are described in table 3. Units in trench 00C, described in table 4, correlate well with units found in trench 00B where radiocarbon ages are available.

POLLEN ANALYSIS

A continuous sample was taken from the south wall of trench 00A near meter 8. Standard pollen extraction and preparation procedures were followed (Faegri and Iversen, 1975). Samples were sieved with a 125 µm mesh filter to remove large debris and then processed with the following treatments: hydrochloric acid, potassium hydroxide, hydrofluoric acid, isopropynol wash, nitric acid, glacial acetic acid, and acetolysis. The residues were stained with safranin, dehydrated with tertiary butyl alcohol, suspended in silicone oil, and mounted on microscope slides.

Slides were scanned on a Zeiss light microscope at 100x magnification for non-native *Erodium cicutarium* (red stem filaree) pollen. *Erodium cicutarium* is a weedy plant species not indigenous to North America that has been introduced into the Fremont area in historic times (Mensing and Byrne, 1998). It provides a useful chronological marker for the geologic record.

Erodium first appears in the record at 120 cm depth (fig. 4). The first appearance of *Erodium* pollen helps constrain the date of the E2 paleoearthquake event. *Erodium* probably arrived in the Fremont area during the early Spanish period and possibly even earlier. The date for the arrival of *Erodium* locally probably dates to A.D. 1800± 20 years.

ACKNOWLEDGMENTS

This project funded by U.S. Geological Survey, National Earthquake Hazards Reduction Program #7460-09712. Special thanks go to John Rogers of the Alameda County Public Works Agency for permitting access to the site and J.N. Alt for sharing his unpublished information. Reviews by T.E. Fumal and H.D. Stenner and editing by Theresa Iki improved the clarity of the map and text.

REFERENCES CITED

California Department of Water Resources, 1967, Evaluation of ground water resources: South Bay (Appendix A: Geology), California Department of Water Resources Bulletin, p. 153.

Faegri, R.I., and Iversen, J.D., 1975, Textbook of pollen analysis (3d ed.): New York, Hafner Press, 295 p.

Lawson, A.C., 1908, The earthquake of 1868, *in* Lawson, A.C., ed., The California earthquake of April 18, 1906: Report of the State Earthquake Investigation Commission (Volume I): Carnegie Institution of Washington Publication 87, p. 434-448.

Lienkaemper, J.J., 1992, Map of recently active traces of the Hayward Fault, Alameda and Contra Costa counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF– 2196, 13 p. (1 sheet).

Lienkaemper, J.J., Dawson, T.E., Personius, S.F., Seitz, G.G., Reidy, L.M., and Schwartz, D.P., 2001, Evidence for timing of paleoearthquakes on the southern Hayward Fault at Tyson's Lagoon (Tule Pond), northern California (abs.): Seismological Research Letters, v. 72, no. 2, p. 226.

Mensing, Scott, and Byrne, Roger, 1998, Pre-mission invasion of *Erodium cicutarium* in California: Journal of Biogeography, v. 25, p. 757-762.

Wallace, R.E., 1990, Geomorphic expression, *in* Wallace, R.E., ed., The San Andreas Fault System, California: U.S. Geological Survey Professional Paper 1515, p. 14-58.

Williams, P.L., 1993, Geologic record of southern Hayward Fault earthquakes: California Division of Mines and Geology Special Publication, v. 113, p. 171-179.

Woodward-Clyde and Associates, 1970, Fremont Meadows active fault investigation and evaluation, Fremont, California [on file at California Division of Mines and Geology, San Francisco, California; file no. AP-744].

Working Group on California Earthquake Probabilities, 1999, Earthquake probabilities in the San Francisco Bay Region: 2000-2030——A Summary of findings: U.S. Geological Survey Open-File Report 99-517, 55 p. [http://geopubs.wr.usgs.gov/open-file/of99-517/].

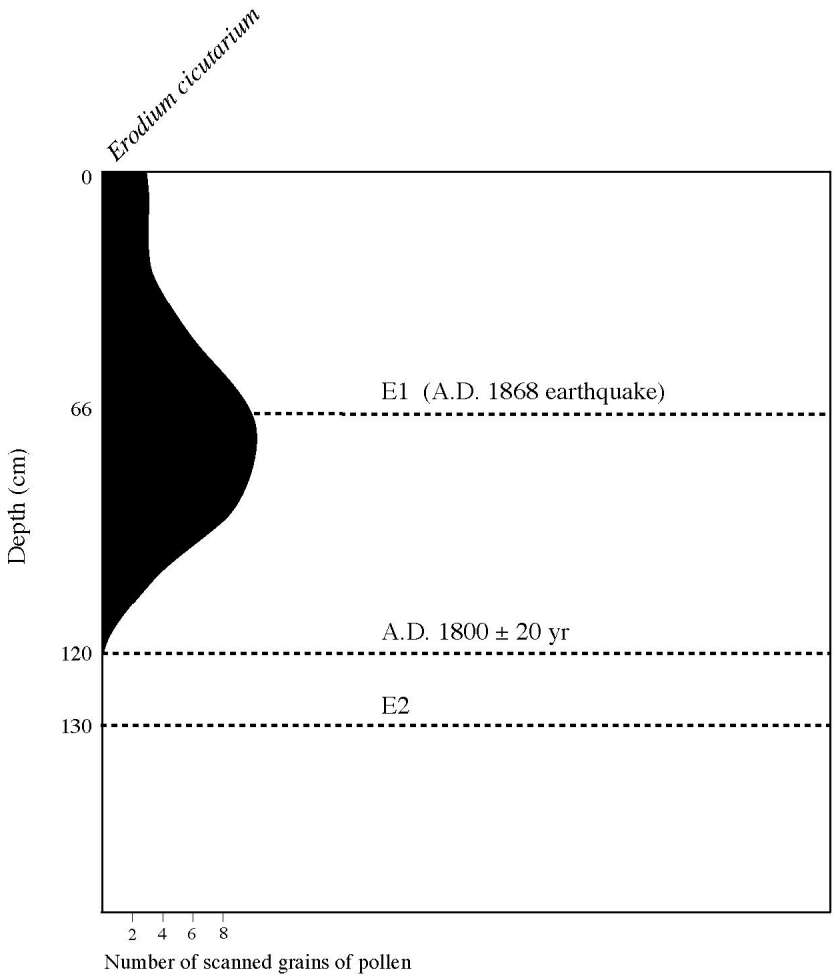

Figure 4. Graph showing first appearance of *Erodium cicutarium*, and paleoearthquake events E1 and E2 at Tyson's Lagoon. Pollen sample from south wall of Trench 00A.

Table 1. *Radiocarbon ages of samples from Trench 00A*

Sample no. (00A#)	^{14}C age (yr)	Sample type[1]	Key strati-graphic units[2]	Unit no. (u#)	Wall	Location (y. coord.) (m)	Lab no.
1	550±40	c	C1	100	S	10-11	68696
1	680±50	h	C1	100	S	10-11	69161
2	250±40	f	S1	140	S	8.5-9	68487
2	350±40	fa	S1	140	S	8.5-9	69162
3	3670±90	c	–	30	N	12-13.5	68697
4	3640±120	c	–	40	S	12.5-13.5	68698
4	2840±40	s	–	40	S	12.5-13.5	68699
4	2600±110	h	–	40	S	12.5-13.5	69163
5	2760±50	c	–	40	S	11-12	68700
5	1980±40	h	–	40	S	11-12	69235
6	610±50	c	S1	140	S	8.5-9	69164
7	960±40	c	C2	200	S	8.5-9	69165
8	270±50	c	S3	350	S	8-9	69166
9	210±40	c	S4	450	S	8.5-9	69167
10	1050±50	c	C2	200	S	7-8	69168
11	400±40	f	S1	135	N	7-8.5	69722
12	690±40	f	C2	200	N	10-11	69723
14	210±40	f	C2	200	N	7-8.5	69724
15	180±40	c	S3	350	N	7-8.5	69904
15	210±60	h	S3	350	N	7-8.5	69726
17	1470±40	c	C1	100	N	8.5-10	69905
18	1420±70	c	C2	200	N	6-7	69789
18	230±40	h	C2	200	N	6-7	69727
19	2430±40	s	S1	135	N	7-8.5	69906
20	990±50	c	S1	130	N	7-8.5	69790
20	2800±40	s	S1	130	N	7-8.5	69907
20	680±50	h	S1	130	N	7-8.5	69728
21	1460±60	c	C2	200	S	6.5-7	69791
21	1720±40	f	C2	200	S	6.5-7	69730

Table 1. *Radiocarbon ages of samples from Trench 00A (continued)*

Sample no. (00A#)	^{14}C age (yr)	Sample type[1]	Key strati-graphic units[2]	Unit no. (u#)	Wall	Location (y. coord.) (m)	Lab no.
22	1140±50	c	C2	200	S	6.5-7	69792
23	3840±40	s	C3	300	S	8-9	69908
24	1330±50	c	OSC	80	N	12-13.5	69793
24	1120±40	h	OSC	80	N	12-13.5	69729
26	2240±50	s	–	40	S	13.5-14	69909
27	2350±50	s	–	40	S	13.5-14	69910
30	290±50	p	S1	135	N	9-11	76313
30	330±50	h	S1	135	N	9-11	76169
31	850±40	c	C1	100	S	9.5-10	72241
32	1090±40	c	–	90	S	9.5-10	72242
33	510±50	c	C1	100	S	9.5-10	72243
39	1080±50	c	OSC	80	S	6-6.5	72244
40	290±40	f	S1	135	N	9-11	76162
44	300±110	c	S1	135	N	9-11	76314
53	1110±40	c	OSC	80	S	12.5-13.5	72245
60	2010±30	c	S1	135	N	9-11	76315
60	160±50	f	S1	135	N	9-11	76316
60	350±50	f , h	S1	135	N	9-11	76170
69	890±40	c	C1	110	S	8.5-9	72246
71	730±50	seeds	C1	100	S	8-9	72247
76	1350±60	c	–	60	S	11-12	72248
77	1140±40	c	OSC	80	S	12.5-13.5	72249

[1] c, charcoal; h, humic acids extracted from charcoal; f, fungus; fa, fungus treated with acid only, p, treated plant fibers; s, shell

[2] —, indicates sample from unit not designated as key unit

Table 2. *Radiocarbon ages of samples from Trench 00B*

Sample no. (00B#)	^{14}C age (yr)	Sample type[1]	Unit no.	Wall	Location (y. coord.) (m)	Lab no.
1	2250±40	c	8	S	11-11.5	68701
1	2350±50	h	8	S	11-11.5	69682
2	1150±50	c	13	S	9.5-10	68702
2	1340±50	h	13	S	9.5-10	69683
3	420±70	h	16	S	10-10.5	69725
4	1580±40	c	12a	S	12.5-13	69169
5	1290±40	c	13	S	12-12.5	69170
6	1570±40	c	10	S	10-10.5	69171
7	420±50	c	16	S	10.5-11	69172
8	1290±40	c	13	S	10-10.5	69173

[1] c, charcoal; h, humic acids extracted from charcoal

Table 3. *Radiocarbon samples, Trench 00C*

Sample No.	Location[a] x/y (m), wall	Unit No.	Notes
R00C-1	8.2,14.7 N	18	Small fragment of oxidized charcoal?
R00C-2	8.9, 13.9 S	6	Several charcoal fragments
R00C-3	9.1, 14.2 S	6	Several charcoal fragments
R00C-4	9.5, 14.0 S	12	Several charcoal fragments
R00C-5	9.65, 13.4 S	12	Several charcoal fragments
R00C-6	9.65, 13.1 S	12	Several charcoal fragments
R00C-7	9.85, 13.0 S	11	Several charcoal fragments
R00C-8	10.45, 12.65 S	10	Several charcoal fragments
R00C-9	10.55, 12.65 N	9	Shells (mostly gastropods) and large charcoal fragments near top of shelly layer
R00C-10	10.5-10.7, 12.65 N	9	Bulk fossil and charcoal sample from shelly layer, 5 cm x 20 cm sample
R00C-11	9.5, 14.45 N	14	Large bone fragment
R00C-12	11.6, 13.5 S	13	Small bone fragment
R00C-13	11.7, 13.75 S	15	Charcoal fragments and shells (mostly gastropods); crack fill of unit 15 in top of unit 14
R00C-14	11.5, 13.85 S	15	Charcoal and shells (mostly gastropods); above ash layer
R00C-15	12.7, 13.65 S	14	Charcoal in bedded part of unit
R00C-16	12.75, 13.55 S	13	Fine charcoal in thin burn layer in interbedded silts
R00C-17	12.85, 13.9 S	15	Large charcoal fragment
R00C-18	12.6, 13.8 S	15	Bulk fossil and charcoal sample
R00C-19	12.4, 14.1 S	16	Small charcoal fragment
R00C-20	13.35, 13.7 S	15	Small charcoal fragments in middle of ashy layer; roots nearby

[a]location correction: to align measurements from string grid to surveyed trench site datum, subtract 40 cm from horizontal (x) value

Table 4. *Unit descriptions, Trench 00C*

Unit No.	Location[a] x/y (m)	Matrix grain size	Percent gravel (mm)	Largest clast	Sorting	Dry color	Dry[b] consistence	Wet[c] consistence	Soi development	Genesis	Notes
1	6.5, 14.8 S	sand f-c	40-50	100	poor	10YR 6/1	so	so, po	none	alluvial gravel	Non-oxidized color; sandy pebble and occ. cobble gravel; clasts loc. derived sed. liths.; crudely bedded to nonbedded; Niles Canyon fan deposit
1						7.5YR 5/8					Oxidized color; groundwater oxidation and manganese staining common
2	5.0, 15.5 S	sand f-c	<1	35	well	10YR 6/1	sh	ss, ps	none	alluvial sand	Occ. pebbles; graded bedding fines upward, from pebbly coarse sand at base to fine sand at top
3	5.0, 15.6 S	silty sand, vf-f	<1	30	v. well	10YR 6/3	h	ss, ps	none	alluvial silty sand	Has 1-5 cm thick intermittent pebble gravel bed at base of unit
4	5.0, 15.7 S	sand f-c	40-50	100	poor	10YR 6/1	so	so, po	none	alluvial gravel	Similar to unit 1
5	2.5, 16.5 S	sand m-c	<1	20	v. well	10YR 6/2	sh	so, po	none	alluvial sand	No bedding apparent
6	7.7, 14.0 S	clay	<1	40	well	10YR 4/2	vh	vs, vp	none	pond mud in shear zone	Pebbly, sandy pond clay, probably highly sheared; strong groundwater oxidation
6						10R 4/4					Oxidized color; many medium mottles
7	8.7, 14.0 N	silt	<1	40	v. well	10YR7/2	vh	s, p	none	pond mud	No bedding apparent
7						2.5YR 4/8					Oxidized color; common groundwater oxidation; many fine mottles
8	9.5, 12.7 S	clay	<1	40	v. well	10YR 4/1	vh	vs, vp	none	organic pond mud	Tiny fragments of charcoal throughout; no bedding apparent; incr. oxid. near faults at 8.5-9 m
8						10R 4/4					Oxidized color; groundwater oxidation; few fine mottles
9	10.5, 12.6 N	clay to sand f-c	0	--	mod.	10YR 3/6	sh	vs, vp	none	mixed organic pond sediment	Mixed clay to sand, organic rich; shell-rich, both intact gastropods and shell frags
10	9.8, 12.9 S	clay	<1	10	v. well	10YR 5/1	vh	vs, vp	none	pond mud	Wispy, 1-3 mm organic beds at top, otherwise no apparent bedding; more mottled than unit 8
10						2.5YR 4/4					Oxidized color; common fine mottles
10	9.35, 12.95 S	silt to sand vf	0	--	v. well	10YR 6/4	sh	s, p	none	pond mud	Silt interbeds in unit 10; bedding very disrupted and only preserved near faults at m 8.75-9.5 in both walls
11	12.0, 12.8 S	silt	0	--	v. well	10YR 5/4	sh	s, p	none	pond mud	Wispy, 1-3 mm organic beds at top, bottom, and middle of unit; discontinuous flame structures at top of unit
11						10YR 6/6					Oxidized color; more oxidation near fault zone at m 8.75-11

Table 4. *Unit descriptions, Trench 00C* (continued)

Unit no.	Location[a] x/y (m)	Matrix grain size	Percent gravel	Largest clast (mm)	Sorting	Dry color	Dry[b] consistence	Wet[c] consistence	Soil development	Genesis	Notes
12	10.0, 13.3 S	clay	<1	100	mod.	10YR 4/2	vh	vs, vp	none	pond mud	No bedding apparent; lots of small charcoal frags in lower part; numerous pebbles and cobbles floating in clay matrix, more abundant near base of unit near fault zone at m 9-10.5 (may form intermittent stone line near base)
						10YR 3/6					Oxidized color; common fine to many large mottles, lots of oxidized root casts
13	12.6, 13.5 S	silt and clay	<1	5	v. well	10YR 7/1	vh	s, p	none	Interbedded pond muds	Color and consistence of silts; interbedded, discontin. 5-20 cm thick beds of silt and clay; several 3-5 mm discontin. burn layers of both fine black charcoal and oxidized charcoal; contains one discontin., 5 cm x 10 cm white burned ash bed, oxidized to orange color
13						10YR 4/1	vh	vs, vp			Color and consistence of clays
13						10R 3/4					Color of oxidized burn layer
14	12.0, 13.7 S	clay	<1	60	well	10YR 4/1	vh	vs, vp	none	organic pond mud	Contains minor discontin., 5-15 mm thick, <20 cm long silt beds, otherwise no apparent bedding; small fragments of charcoal throughout; contains one large bone fragment near top of unit in north wall
15	12.8, 13.9 S	silt and minor clay	<1	20	mod.	10YR 5/1	h	s, p	A horizon	mixed pond and colluvial/soil sediment	One prominent burn ash layer, 10-150 mm thick, near base of unit; contains gastropod shell fragments, bone fragments, and abundant small charcoal fragments; presence of sand and pebbles suggests colluvial input; no bedding apparent, lots of bioturbation from insects and rodents? Soil A horizon developed throughout unit, with very fine to fine, moderate granular structure.
16	11.5, 14.1 S	silt	<1	20	poor	10YR 5/2	vh	s, p	none	liquefied? pond silt and fluvial sand	Color and consistence of silts; complexly interbedded thin silt and sand beds, in chevron folds, flame structures, vertical and draped bedding; pebbly at base; very irregular boundary with overlying unit 17; may contain a few small blocks of underlying unit 14 near base; basal contact with unit 14 dips more steeply than underlying bedding, suggesting units 16 and 17 are filling a channel cut into unit 14
16		sand f-c				10YR 5/4	sh	so, po			Color and consistence of sand
17	10.7, 14.4 S	sand f-c	<1	10	well	10YR 5/6	sh	so, po	none	liquefied? fluvial sand	Has complex bedding (flame structures and folding) similar to unit 16
18	10.0, 14.6 S	silt and sand f-c	1-20	70	v. poor	10YR 6/4	vh	s, p	none	colluvium	No bedding apparent; unit coarsens near main fault zone, reflecting colluvial input of fluvial gravel from western fault block; no soil development may reflect truncation of upper surface during emplacement of artificial fill unit 21; may be correlative with units 19 and 20 in north wall.

Table 4. *Unit descriptions, Trench 00C* (continued)

Unit no.	Location[a] x/y (m)	Matrix grain size	Percent gravel	Largest clast (mm)	Sorting	Dry color	Dry[b] consistence	Wet[c] consistence	Soil development	Genesis	Notes
19	5.2, 15.5 N	silty sand vf-f		1	poor	10YR 7/3	vh	s, p	none	colluvium	Texture and geometry indicate unit is colluvium shed from erosion of unit 3; may be correlative with unit 18
20	4.5, 15.8 N	sand f-c	40-50	120	v. poor	10YR 5/1	so	so, po	none	colluvium	Texture and geometry indicate unit is colluvium shed from erosion of unit s 4 and 5; may be correlative with unit 18
21	9.5, 15 S	silt and sand f-c	1-20	120	v. poor	10YR 5/2	vh	s, p	none	artificial fill	Contains abundant manmade objects (rusted steel cans, blocks of asphalt, etc)

[a] location correction: to align measurements from string grid to surveyed trench site datum, subtract 40 cm from horizontal (x) value

[b] dry consistence: so--soft, sh--slightly hard, h--hard; vh--very hard

[c] wet consistence: no--nonsticky, ss--slightly sticky, s--sticky; vs--very sticky no--nonplastic, sp--slightly plastic, p--plastic, vp--very plastic

README FILE

readme.txt

pamphlet.pdf	PDF of pamphlet
sheet1.pdf	PDF of sheet one: 29" x 43.5" (Logs of trench 00A, location map and site map)
sheet2.pdf	PDF of sheet two: 30.5" x 42" (Logs of trenches 00B and 00C)

PDFs were generated using Adobe Distiller 5.0. These documents are compatible with Adobe Acrobat 4.0 and versions higher.
Fonts are embedded; there are no thumbnails or previews.

For questions related to files enclosed in these data packages, contact Jim Lienkaemper at 650-329-5642 or jlienk@usgs.gov