Logs and Data from Trenches Across the Hayward Fault at Tyson's Lagoon (Tule Pond), Fremont, Alameda County, California, 2001-2003

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INTRODUCTION

The purpose of this publication is to make available detailed trench logs (sheets 1 through 8), radiocarbon dates (table 1) and brief stratigraphic unit descriptions (Appendix 1) obtained as a result of an intensive subsurface investigation of the Hayward Fault at Tyson's Lagoon (Tule Pond) from 2001 through 2003 (figs. 1, 2 and 3 on sheet 2). Preliminary findings of this investigation based on fieldwork done in 2000 have been published as Lienkaemper and others (data archive, 2002a; report, 2002b). 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 preserved at the site. Establishing a chronology of prehistoric or paleoearthquakes is of immediate use in resolving the level of hazard posed by the Hayward Fault for producing large earthquakes in the future. A second 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, Williams, Dawson and Personius interpreted the geology and logged the trenches. Seitz and Heller performed analyses on the radiocarbon samples. Schwartz led the critical-review field team.

Previous trenching work was done at Tyson's Lagoon (figs. 2, 3 on sheet 2). 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 An unpublished study by J.N. Alt in 1998 (shown on our site map as trenches 98A and 98B, fig. 3, on sheet 1), also sought evidence of paleoearthquakes.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. Unpublished field investigations at this site by P. L. Williams in 1992 have been incorporated in this report. His trench W2 is presented herein as sheet 8 (see fig. 3 sheet 2 for location). William's 1992 trench W1 was re-excavated by us in 2002 and is shown as trench 02E (sheet 4).

Version 2.0 corrects stratigraphic correlations across the pond based on continuous trenching across the entire pond in 2005 (Lienkaemper and others, 2005). Logs of trenches within the pond and across the eastern fault trace have been corrected (sheets 1, 3, 4, 6, 7 and 8.) Logs of trenches O2A (sheet 2) and 03A (sheet 5) required no revision in unit correlation.

Version 3.0 delineates two paleoearthquake horizons between unit u100 and u80. Formerly only one horizon had been shown on most logs. Hence, all paleoearthquake event horizons have been renumbered below unit u100 to reflect this correction to the earthquake sequence.

METHODOLOGY

TRENCHING

As seen on the map, Tyson's Lagoon (fig. 2 on sheet 1) is a classic example of a sag pond (*e.g.*, Wallace, 1990), a pull-apart structure caused by a right step in a right-lateral fault. We excavated one trench in 2001, 01A (sheet 1); five trenches in 2002, 02A (sheet 2), 02B, C, D (sheet 3) and 02E (sheet 4); and two trenches in 2003, 03A (sheet 5) and 03B (sheet 6). The site location maps showing the locations of these trenches is on sheet 2 (fig. 3).

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 0.7 m by 1.2 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 main fault trace, hence the starting point of each trench is some arbitrary non-zero value.

Our previous report focused on evidence of the four youngest earthquakes, which occurred during the past 500 years. In this phase of the investigation, the most useful paleoearthquake information was developed from 500-1700 yr BP materials and structures best exposed in trench 02A (sheet 2). Because these logs are the most important to the study, we have placed the index maps on this sheet. To save on expense, users may chose to print only sheet 2 for some of the most critical results. Sheets 4, 6 and 8 also contain critical information about some paleoearthquakes not shown directly on other logs. See the stratigraphic cross-section (sheet 7) for best overview of the entire stratigraphic section in the pond and the age relationship between earthquake data found on the eastern trace to the paleoearthquakes on the western trace. Sheet 1 (log of 01A) and sheet 3 (logs of pits 02A, B, C) are the least critical to readers seeking an overview of the earthquake evidence, although they both contain stratigraphic and radiocarbon information essential to the investigation.

We assigned unit numbers to most of the stratigraphic units, from u05 (east trace) and u10 (west trace) at the lowest level exposed in the trenches to u550, the most recent artificial fill. These unit numbers are used to correlate the radiocarbon samples between trench walls (table 1). Letters (A through Z) were assigned to units near the east trace by Williams in 1992 and these are used along with the number designated units where correlations are clear. The pond deposits are generally fine-grained with varying amounts of silt and clay, and some sand, particularly near the main fault trace. The main (western) fault trace is located near meter 5 (sheets 1, 2 and 5). 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 deposits near the base of trenches as old as 2000 years BP, but do not yet know the age of inception of the pond. Color is used to highlight some key stratigraphic units on the logs, which are described in Appendix 1.

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 a paleoearthquake horizon. Paleoearthquake (event) horizons are shown as green dashed lines labeled E1 through E11. The six most recent events (E1-E6) correspond to events E1, E2, E3, E4, EX? and EY, respectively as shown in Lienkaemper and others (2002a).

RADIOCARBON DATING

Along with laboratory radiocarbon ages of the samples from the 2001-2003 USGS trenches (table 1), we also include those from William's 1992 trenches W1 (02E herein) and W2).

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Appendix 1. Stratigraphic Unit descriptions

Unit u10, a bluish gray to blue clay is the lowest pond deposit observed in our trenches. It may actually comprise different units that have been subjected to continuous saturation. Near the main fault trace blue clay underlies u15, but in the pond it may be derived by the reduction of younger units. Blue crystals of unknown origin and mineralogy can be seen by 20X hand lens in the freshly exposed blue clay. Unit u15 (V), is light brown organic silty clay, darker near the east trace, which becomes progressively more altered with depth to shades of light gray, developing a mottled appearance suggesting the organic materials are being lost by some chemical process, and at greater depth begins a transition toward blue clay. Unit u20 (STU) is very fine yellowish sandy silt, relatively low in organics except for a nearly continuous charcoal-rich burn layer in the upper 10-20 cm. Unit u31 (QR) is brown clay silt, more organic rich near the top; in the east unit Q is composed of distinct bands of clay and silt. A key marker unit, u41 (P), the lower shelly layer, is observed in all trenches at the site is in the east a cross-bedded fine sand which to the west has increasing amounts organics, silt, gastropod shells and bioturbation. Unit u45 (JKLMNO) is gray brown clayey silt with shells, but many fewer gastropods than in u41 and shells of freshwater clams are also found. The shells in u45 diminish and disappear approaching the main fault on the west. On the east side of the pond u45 is composed of sandier units (J, L, N) and clayier units (K, M, N, O), which gradually merge westward.

Unit u50 (I) is charcoal-rich, organic-rich clayey silt, which thins westward and was not recognized from meter 15-34 but reappears near the west trace. Unit u61 (H) is charcoal-rich alluvial sand with stones at its base. Unit u63 (G) is a thick layer of sandy silt, apparently mostly a single flood deposit. U63 is capped by u70, a series of brown clayey silts that in some exposures appear as distinct bands of varying shades of brown and elsewhere seem more massive. Unit u80, orange silty clay (osc), is a burn layer which in most locations is conspicuous, but in some places is indistinguishable minor band near the top of u70, lying within 5 cm of its top. Overlying the orange silty clay are gray silty clays, units u90 and u95, identical except that u95 contains several fine charcoal stringers, the lowest of which forms the base of the unit. Strata above this are described in Lienkaemper and others (2002b).

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Table 1

Radiocarbon ages from charcoal samples

Sample no[1]	^{14}C age (yr) BP, corrected[2]	Unit no.	Location wall	Location (m)	$d^{13}C$[3]	Lab no.[4]
W1-5	1540 ± 30	u50(i)	s	2	-26.42	OS-9102
W1-5a	2780 ± 45	u50(i)	s	2	-26.17	OS-4513
W1-12	2090 ± 30	u45(o)	s	2	-25.63	OS-5140
W1-20	3390 ± 110	u45(j)	s	3	-23.88	OS-9091
W1-32	1910 ± 35	u50(i)	s	4	-26.66	OS-4507
W1-39	1940 ± 35	u45(o)	s	4	-24.41	OS-4506
W1-47	1910 ± 50	u31(r)	s	5	-24.65	OS-4508
W1-58	2520 ± 30	u20(tu)	s	7	-26.83	OS-7543
W1-99	4130 ± 70	u15(v)	s	10	-26.06	OS-9101
W1-100	4120 ± 70	u15(v)	s	10	-25.82	OS-7541
W1-109	2940 ± 55	u20(tu)	s	10	-25.41	OS-7925
W1-113	2690 ± 45	u50(i)	s	1	-25.16	OS-5313
W1-141	6360 ± 140	u05(x)	s	11	-23.33	OS-9096
W1-143	7570 ± 95	u05(x)	n	12	-24.73	OS-9099
W1-154	>Modern	u41(p)	s	2	-25.69	OS-7551
W1-178	2150 ± 25	u45(o)	n	7	-26.1	OS-7542
W1-180	1560 ± 40	u50(i)	n	7	-26.63	OS-7547
W1-183	1760 ± 30	u20(u)	n	8	-24.54	OS-7545
W2-9	3140 ± 45	u41(p)	s	10	-25.66	OS-4514
W2-18	2530 ± 55	u70(d)	s	0	-25.76	OS-4515
W2-22	1310 ± 30	u63(e)	s	2	-25.96	OS-4509
W2-25	3120 ± 75	u70(d)	n	0	-25.62	OS-4516
W2-29	1780 ± 30	u31(q)	s	1	-26.8	OS-4510
W2-30	1910 ± 30	u31(q)	s	1	-26.58	OS-9090
W2-31	2000 ± 30	u31(q)	s	1	-25.87	OS-4511
W2-34	1430 ± 40	u41(p)	n	5	-25.18	OS-4512
W2-58	1810 ± 30	u41(p)	n	2	-25.89	OS-5138
W2-61	1700 ± 40	u63(e)	s	3	-23.85	OS-5139
W2-71	3550 ± 65	u31(q)	s	3	-25.62	OS-5141
W2-71a	3110 ± 50	u31(q)	s	3	-26.52	OS-7535
W2-83	2660 ± 85	u31(r)	s	1	-27.62	OS-9095
01A-02	1510 ± 50	u61	s	8	-24.7	79168
01A-03	1260 ± 40	u61	s	9	-25.9	79169
01A-04	1270 ± 40	u61	s	9	-26.8	79170
01A-05	1300 ± 40	u61	s	9	-26.3	79171
01A-06	1330 ± 40	u61	s	8	-25.9	79172
01A-07	1320 ± 30	u61	s	5	-23.4	79173
01A-08	1350 ± 40	u61	s	5	-28.4	79174
01A-09	1290 ± 40	u61	s	5	-24.7	79175
01A-10	1290 ± 40	u61	n	10	-25.8	79176
03A-1	1970 ± 40	u20	s	8	-25	100715
03A-1a	2740 ± 70	u20	s	8	-26	101210
03A-2	2355 ± 30	u20	s	8	-25.91	100716
03A-2a	2310 ± 35	u20	s	8	-25.23	101211
03A-3	2645 ± 40	u20	s	8	-25	100717
03A-4	3135 ± 35	u20	s	7	-25.89	100718
03A-5	2895 ± 40	u20	s	6	-25	100719
03A-6	2175 ± 45	u31c	s	8	-25	100720
03A-7	1860 ± 35	u31b	s	8	-25.15	100721
03A-8	1970 ± 35	u31b	s	8	-26	100722
03A-9	1965 ± 30	u31b	s	8	-25.23	100723
03A-10	2070 ± 30	u31b	s	9	-25.51	100724
03A-11	3410 ± 45	u31a	s	9	-26.61	100725
03B-1	1610 ± 35	u50(i)	s	2	-25.99	100726

[1]Sample number includes trench designation before the hyphen

[2]Ages corrected for $d^{13}C$ (Stuiver and Pollach, 1977)

[3] $d^{13}C$ value without decimal are estimated with ±2 (Stuiver and Pollach, 1977)

[4] AMS analyses on early trenches(W1, W2) by National Ocean Sciences AMS Facility (NOAMS), Woods Hole, MA; later ones by Center for Accelerator Mass Spectrometry (CAMS), Lawrence Livermore National Laboratory,