



Photomosaics and Event Evidence from the Frazier Mountain Paleoseismic Site, Trench 1, Cuts 1–4, San Andreas Fault Zone, Southern California (2007–2009)

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Photomosaics and Event Evidence from the Frazier Mountain Paleoseismic Site, Trench 1, Cuts 1–4, San Andreas Fault Zone, Southern California (2007–2009)

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Introduction

The Frazier Mountain paleoseismic site is located at the northwest end of the Mojave section of the San Andreas Fault, in a small, closed depression at the base of Frazier Mountain near Tejon Pass, California (lat 34.8122° N., long 118.9034° W.) (fig. 1). The site was known to contain a good record of earthquakes due to previous excavations by Lindvall and others (2002). This report provides data resulting from four nested excavations, or cuts, along trench 1 (T1) in 2007 and 2009 at the Frazier Mountain site. The four cuts were excavated progressively deeper and wider in an orientation perpendicular to the San Andreas Fault (fig. 2), exposing distal fan and marsh sediments deposited since ca. A.D. 1200 (fig. 3). The results of the trenching show that earthquakes that ruptured the site have repeatedly produced a small depression or sag on the surface, which is subsequently infilled with sand and silt deposits. This report provides high-resolution photomosaics and logs for the T1 cuts, a detailed stratigraphic column for the deposits, and a table summarizing all of the evidence for ground rupturing paleoearthquakes logged in the trenches.

Trenching Methodology

All of the photomosaics presented in this report are from T1. A total of four successive cuts were completed in order to observe older sediments and multiple exposures of the deformation. Each cut is labeled in sequence according to the side of the trench exposed (fig. 2). For example, T1E2 is the second cut on the east side of T1, and T1W2 is the second cut on the west side. The fourth cuts were discontinuous and are further labeled by north or south position (for example, T1E4N is the northern portion of the fourth cut on the east side).

The groundwater elevation at the Frazier Mountain paleoseismic site is high (~0.5 m below the ground surface) which required that walls of the cuts were sloped to remain stable. Once excavated, each cut was scraped smooth to eliminate major irregularities resulting from the excavator bucket, and a string grid was attached to the wall for systematic documentation of the trenches. The vertical strings were spaced 1 m apart, and the horizontal spacing was established by projecting every 0.5 m measured vertically to the sloping trench wall. Because the walls are sloping, the distance between the horizontal grids as measured on the wall is typically 0.6–0.7 m. Gentle curves in the wall produce some irregularity in the grid spacing. Each grid rectangle was photographed and the exposed stratigraphy was logged directly onto a photograph in the field. The photomosaics were created by manually rubber-sheeting individual photographs onto a rectangular grid; line work was added to the grid based on detailed field logs. We surveyed the grid using a combination of methods: cuts 1 and 2 were surveyed with a Trimble GeoXH (post processed accuracy of ~10 cm) and cuts 3 and 4 were surveyed with a Trimble total station

(accuracy of ~5 cm). All surveys were transformed into a common reference frame (WGS84); the cut perimeters are shown in figure 2 and photomosaics in sheets 1–4.

Site Geomorphology and Stratigraphy

The paleoseismic site is located on the north side of Frazier Mountain, where a series of geomorphic surfaces are beveled into the Hungry Valley Formation (fig. 1). Radiocarbon ages (Zhao, 1990) and soil descriptions from these surfaces suggest they are Holocene or older. The San Andreas Fault cuts these surfaces, producing offset drainages and topographic depressions that collect sediments composed of Precambrian gneisses and the Hungry Valley Formation derived from Frazier Mountain (Crowell, 2003). T1 was excavated at the northwest end of a 170- by 70-m-long geomorphic low oriented N. 70° W., parallel to the San Andreas Fault.

The stratigraphic section exposed in T1 shows a general coarsening upward progression from silty clays in unit 50, through alternating sand, silt, and organic-rich layers that compose the bulk of the stratigraphy, into a package of coarse sand to gravel deposits of units 4–6 (fig. 3). Unit thickness ranges from several millimeters to 50 cm, but approximately half of the section has been progressively bioturbated to the extent that only remnant layering is visible. Colored lines on the trench logs (fig. 4, sheets 1–4) highlight key layers that are laterally extensive across the trench, including (1) marker horizons composed of clean, moderately well sorted fine sands (units 6, 12, 23, 25, and 35); (2) a dense, silt layer with carbonate nodules (unit 18); (3) organic-rich layers (units 7, 39, 48–50); and (4) coarse clastic units (units 5, 60). The thickness of each unit is variable across the site due to a combination of deposition into areas of earthquake-produced subsidence and lateral translation of thicker deposits (more proximal to the source fan) to the trench location along major fault strands.

Site Structure

We excavated across the site and identified a main fault zone (fig. 2) that cuts longitudinally through the closed depression and is located 35–40 m south of the scarp that forms the sharp northern boundary of the closed depression. The main fault zone is characterized by a dense array of faults that create down-to-the-north separation and accommodates significant recent deformation. Fault strands in the main fault zone change polarity from steeply north dipping on the east side of T1 to south dipping on the west side of T1 (fig. 4). Excavations across the northern geomorphic scarp revealed faults cutting through the bedrock (Pliocene Hungry Valley Formation), but the faults do not show offset of Holocene units at the location of T1 (fig. 2). Between the geomorphic scarp and the main fault zone, faults are distributed and shift across an 8- to 10-m span from a more southerly concentration of north-dipping faults in T1E3 to predominantly south-dipping faults at the northern end of T1W3 and T1W4 (fig. 4). All of the faults near the northern scarp have down-to-the-south separation. In combination, faulting and folding between the main fault zone and the northern scarp show the area is progressively deepened and folded during earthquakes and then filled by subsequent deposits. The entire section from unit 53 to the modern ground surface, for example, thickens dramatically across the main fault zone from about 1 m thick on the south side to almost 6 m of section several meters away in the center of the syncline.

Event Evidence

Evidence of ground rupturing earthquakes, or events, is documented in multiple observations of faulting, folding, and fissuring that occurred at particular stratigraphic horizons. Appendix 1 contains a list of each observation, the location and a description of each observation, and a quality ranking for each observation. The quality of each observation is based on a scale of 0 to 5; higher values reflect stronger evidence that (1) the deformation was produced by a distinct earthquake and (2) the exact

stratigraphic horizon (and thus age of the deformation) is identifiable. The ranking system was based on the discussion in Scharer and others (2007), which is summarized in table 1.

Table 1. Event quality ranking system.

Quality	Description
0	Fault tip where upper termination not distinct due to unclear stratigraphy
1	Fault tip, minor offset
2	Fault tip, moderate offset
3	Folding and growth strata that has no causative fault and (or) the horizon is difficult to discern due to sedimentation rates
4	Fault tip associated with colluvial wedge or other thickness changes in layers deposited soon after faulting. Broad warping and thickness changes in layer, closely tied to fault that moved to provide accommodation space
5	Fissure, clearly filled with material that postdates inferred event horizon. Folding and growth strata clearly shows the topography was rapidly filled by a single sedimentation event

The event evidence is summarized in figure 5, which presents, by stratigraphic unit, a plot of the range of quality of observations, the sum of quality of evidence, and the total number of event indicators. The plot clearly distinguishes between horizons with multiple lines of evidence, for which an earthquake at that horizon is considered very likely (units 4, 7, 18, 22, 24), horizons at which an earthquake is considered unlikely (unit 34) and all other horizons for which the evidence is likely a product of deformation of the stratigraphic package during subsequent earthquakes. Trenches excavated after 2009 revealed evidence of earthquakes older than unit 34 and are detailed in separate reports.

Acknowledgments

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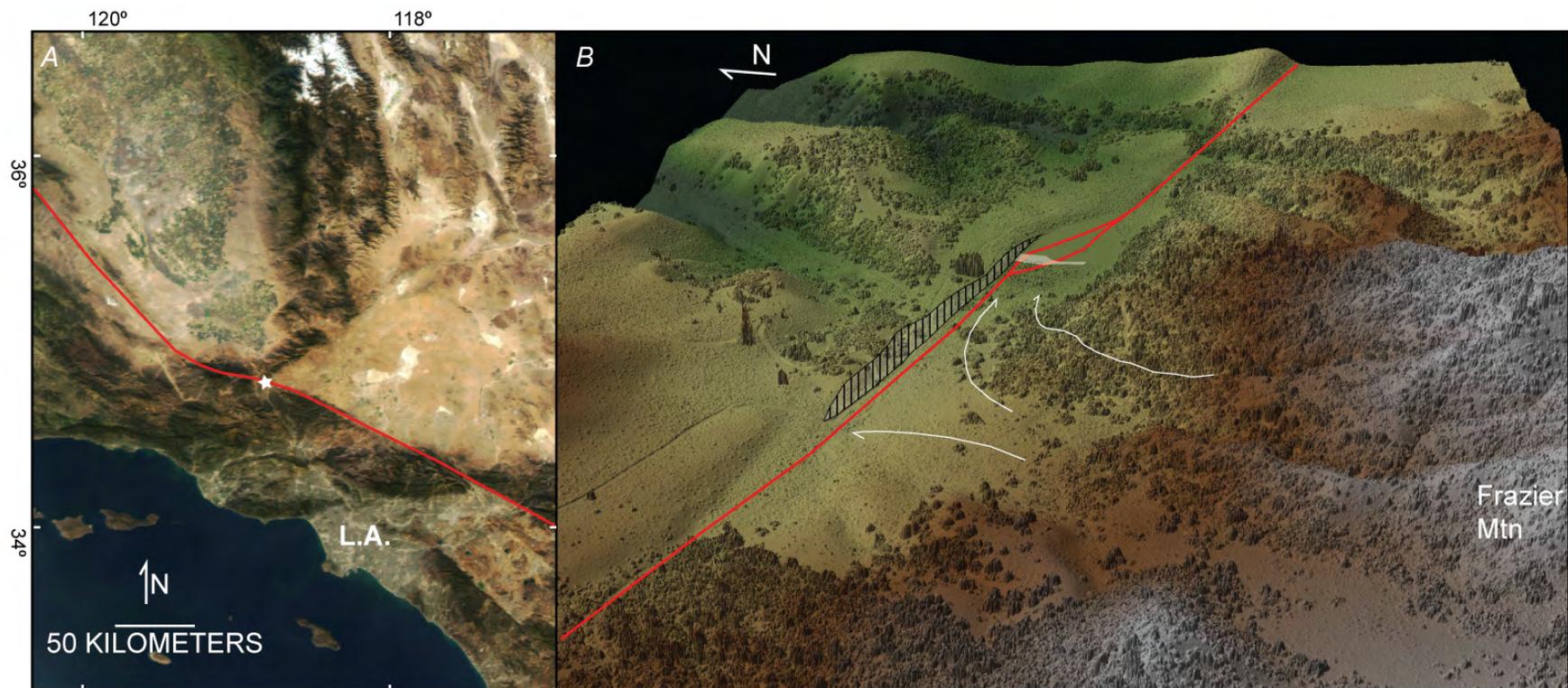


Figure 1. Location and setting of Frazier Mountain paleoseismic site. *A*, Star shows location of site (lat 34.8122° N., long 118.9034° W.) along the San Andreas Fault (red line) relative to Los Angeles (L.A.) in southern California. Satellite image from the National Aeronautics and Space Administration accessed through U.S. Department of Agriculture Forest Service Remote Sensing Applications Center. *B*, Perspective view of Frazier Mountain site constructed from B4 Lidar dataset (Bevis and others, 2005; <http://dx.doi.org/10.5069/G97P8W9T>). View is toward east, and scale is variable, but image shows ~1 km of the fault (red line) and elevations from 1,350 to 1,210 m. Drainage northward off Frazier Mountain is currently diverted into the site by a south-facing ridge (striped pattern) that blocks connection to channels draining the surface. White arrows show general drainage pattern across fan; white shading shows the location of T1.

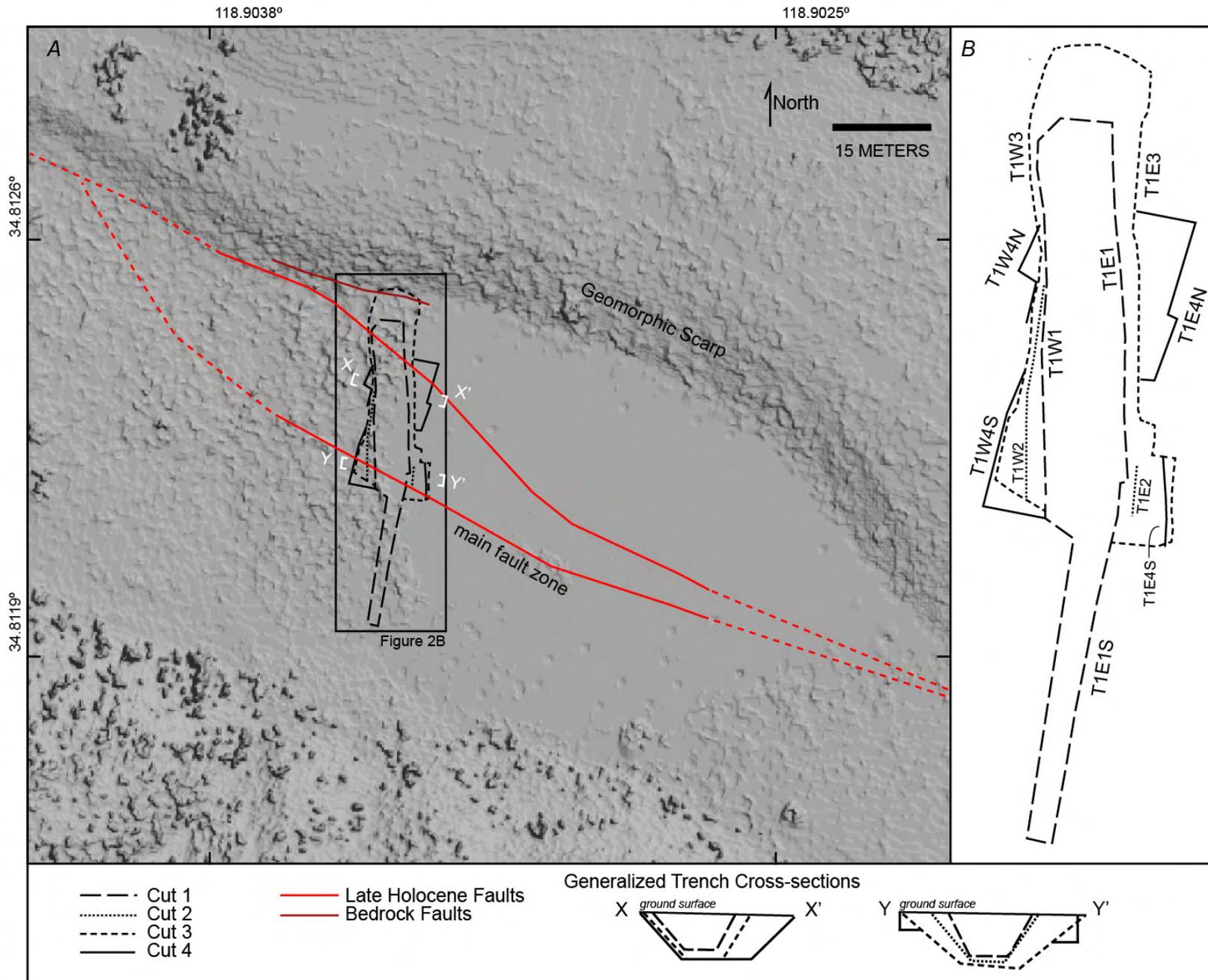


Figure 2. Trench 1 (T1) excavations within the geomorphic depression at Frazier Mountain paleoseismic site. *A*, Base map of B4 lidar (Bevis and others, 2005) shows gentle fan grading into relatively flat terrain; water when the lidar survey was collected produces the smooth surface east of trench. Solid red lines outline area of extensive faulting in trench 1, dashed red lines based on topography; excavations conducted after 2009 provide the location of the main faulting outside of T1. Generalized trench cross-sections shows nested geometry of cuts at locations X–X' and Y–Y'. Progressive excavation of deeper and wider trenches along T1 allowed observation of greater lateral extent of surface deformation and changes in fault orientations (fig. 4). *B*, Diagram of T1 cuts as labeled in pamphlet and sheets 1–4.

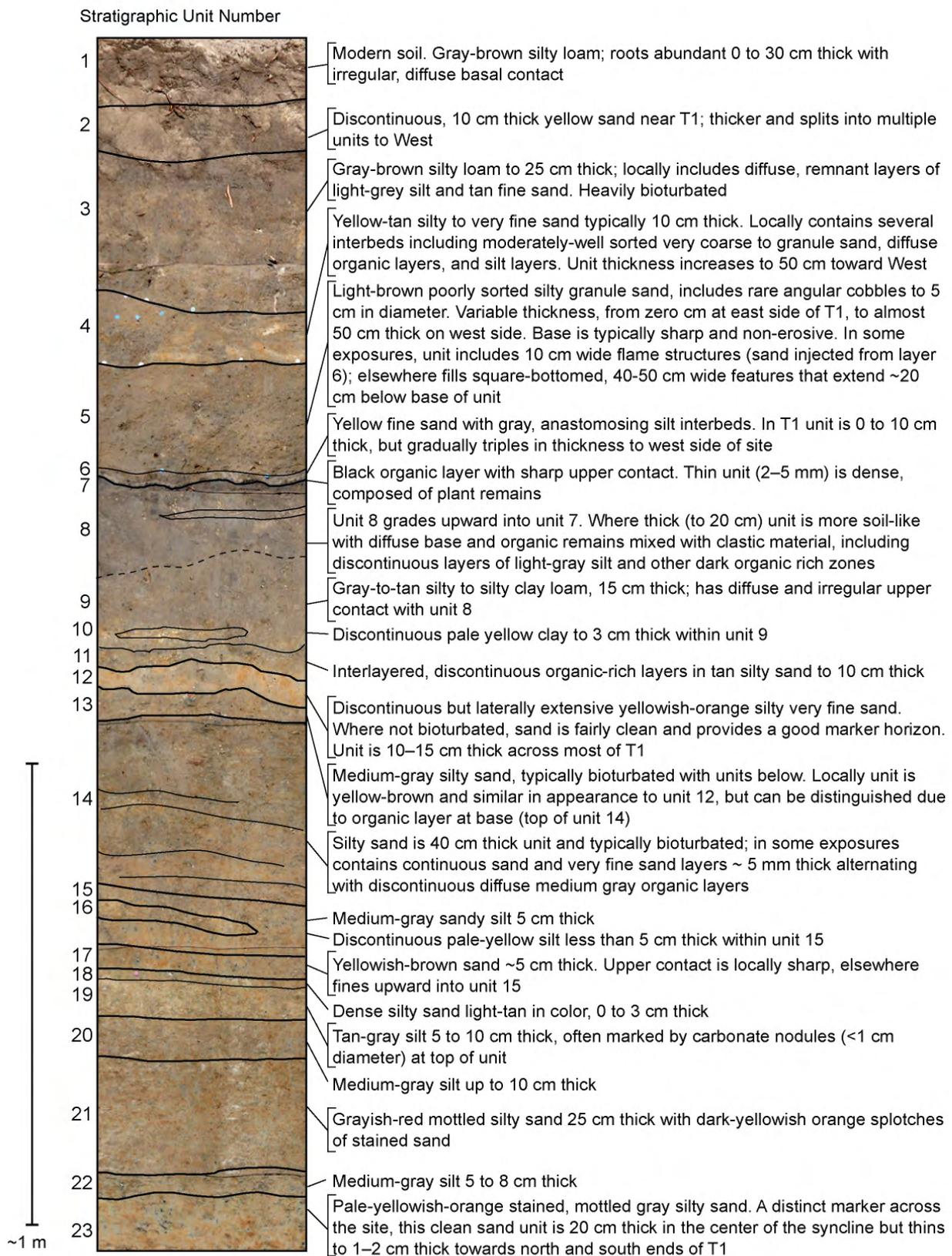


Figure 3. Stratigraphic column and unit descriptions of sediments exposed in trench 1 (T1) at Frazier Mountain paleoseismic site. Stratigraphic numbers correlate with numbers on maps (sheets 1–4).

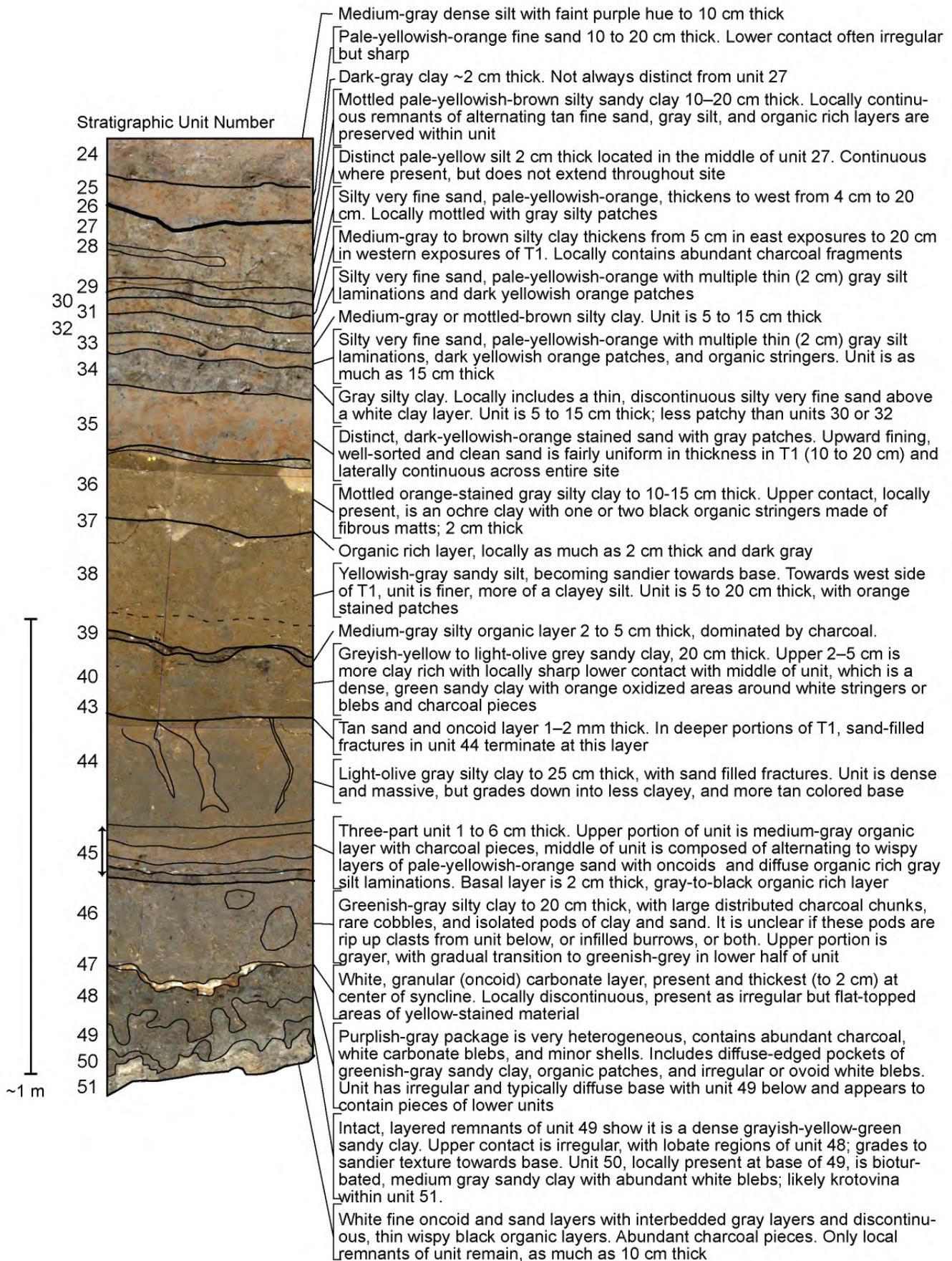


Figure 3 (continued)

Stratigraphic Unit Number

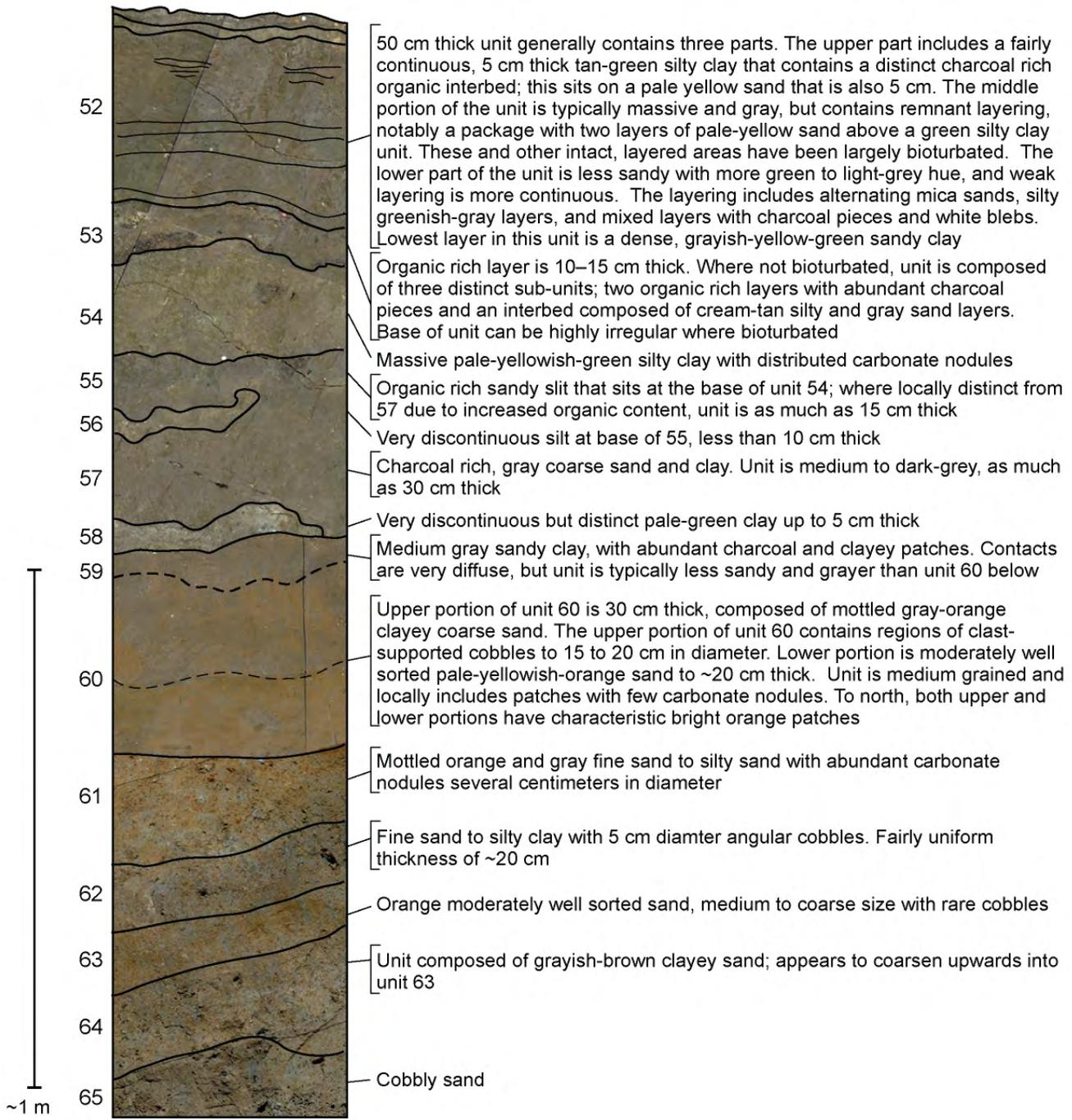


Figure 3 (continued)

NORTH

SOUTH

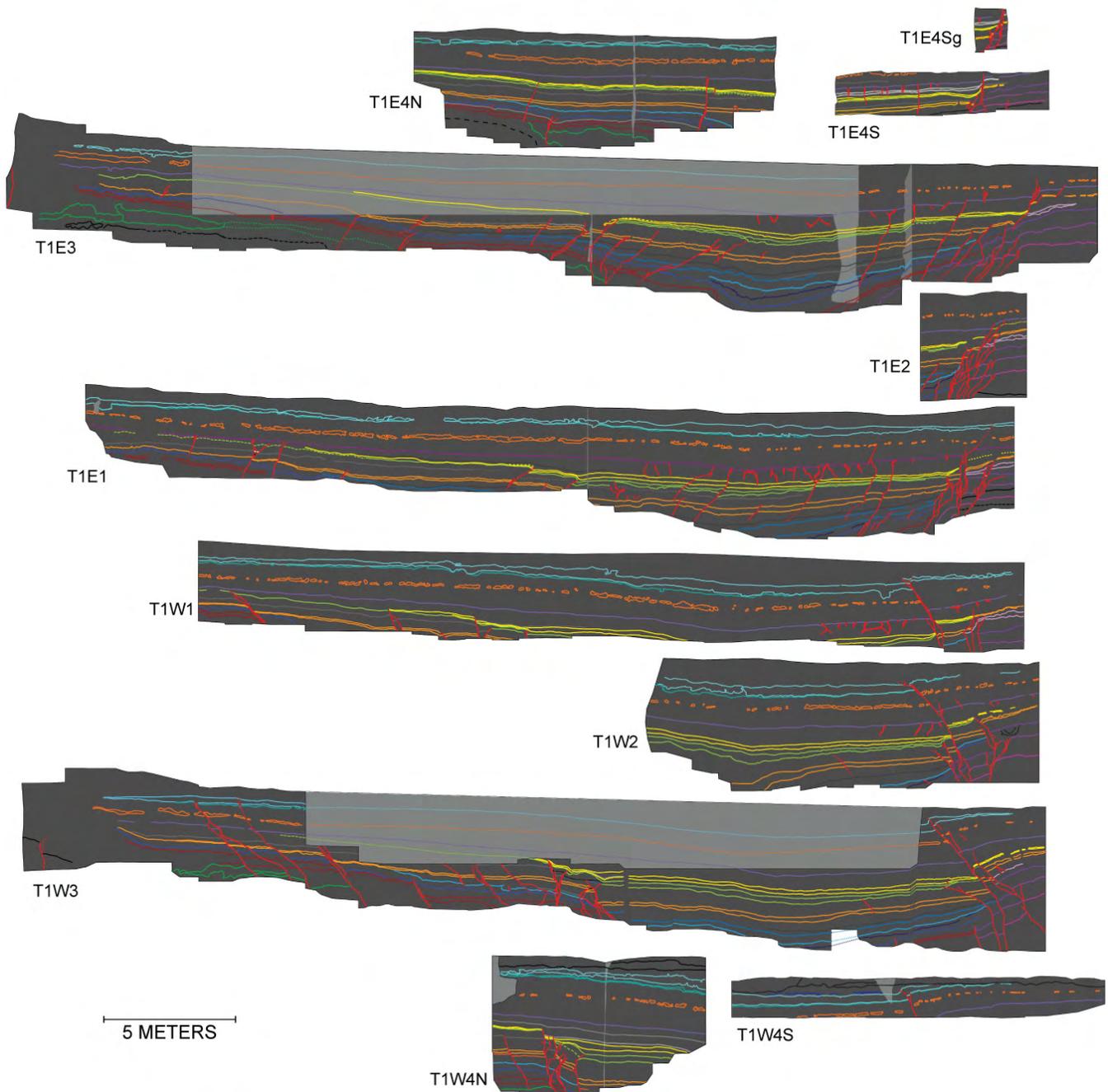


Figure 4. Composite of simplified trench 1 (T1) logs at Frazier Mountain paleoseismic site. Logs from top to bottom show exposures from east to west; layout of cuts is shown in figure 2b. The logs are roughly aligned along the zone of most active faulting (main fault zone in fig. 2), which trends N. 60° W. This zone is on the south side of the trenches and reverses polarity across the site, from north-dipping, normal separation on the east side to south-dipping, reverse separation on the west. Except for T1W4S and T1E4S (which are vertical), exposures are shown as viewed on the trench wall and have 10–40 percent vertical exaggeration. Upper light gray areas in T1W3 and T1E3 merged into cut 1 and thus were not mapped separately; the contacts were projected from T1W1 and T1E1, respectively.

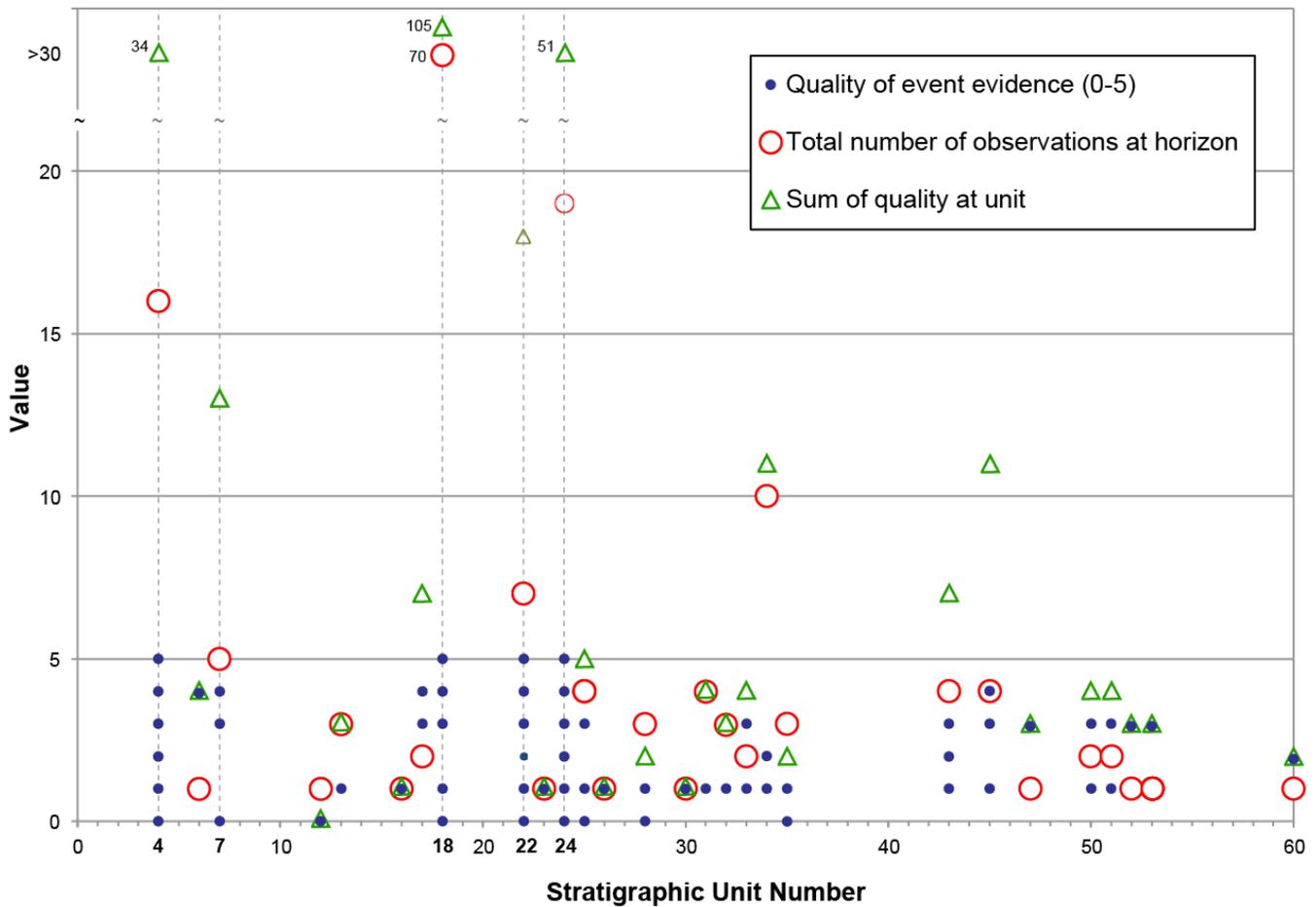


Figure 5. Plot showing event quality of trench 1 (T1), cuts 1–4 for each stratigraphic unit. Values are from Appendix 1 and show the range of event quality, total number of event observations, and the sum of the quality for each unit. Note break in scale above 20; values >30 are noted next to symbol. Horizons with dashed vertical lines (units 4, 7, 18, 22, 24) are considered very likely to be earthquakes; they have both a large number and a high sum of quality of evidence. An earthquake at approximately the time of unit 34 is considered unlikely, because none of the individual event evidences was strong. Evidence for earthquakes older than unit 39 was exposed in trenches excavated after 2009 and will be the focus of future studies.

Appendix 1

Table A1. Location and quality of event evidence from the Frazier Mountain paleoseismic site, trench 1, cuts 1-4, San Andreas Fault, southern California (2007-2009). See Event Evidence section and table 1 for discussion of event quality, and figure 5 for a plot of the event quality organized by stratigraphic unit.

[Abbreviations: ang unc, angular unconformity; fiss, fissure; ft, upward termination of fault tip; gs, growth strata; MRE, most recent earthquake; mult, multiple locations; unc, unconformity]

Likely unit of event horizon	Trench cut label	Map sheet no.	Meter on cut	Event evidence type	Lowest affected unit	Highest affected unit	Quality of event evidence	No. of observations	Sum of quality	Description and interpretation of event evidence
4	T1W3	4	33	ft	4	3	5	1	5	Fault offsets base of unit 4; upper contact not clearly offset; unit thins to south
4	T1W4S	4	6	ft	4	3	5	1	5	Clear faulting of unit 4 and lower, capped by unit 3
4	T1W2	3	34	ft	4	3	4	2	8	Clear offset and reverse separation of gravel unit 5 and base of unit 4; geometry and upper tip of fault not as clear due to bioturbation
4	T1W1	3	35	ft	4	3	3	2	6	Upper event horizon poorly expressed, but thickness change of units 4 and 5 indicate lateral slip significant
4	T1W3	4	7	fiss	4	3	3	1	3	Faults cut unit 6 and appear to extend through unit 5. Quality lower because fissure material is not clearly distinct from surrounding layers, but some changes include gravel (unit 5) displaced into unit 8 below and possible offset of upper contact (unit 3) noted in field
4	T1W4N	4	1-8	gs	5	3	3	1	3	Unit 4 is 1.5x thicker to south
4	T1W1	3	13-35	gs	4	3	2	1	2	Stratigraphy is poor due to bioturbation, but unit 3 thicker at center, and top is ~50 cm lower
4	T1E1	2	35	ft	5	4	1	1	1	Contacts above fault tip are bioturbated; could extend higher

Likely unit of event horizon	Trench cut label	Map sheet no.	Meter on cut	Event evidence type	Lowest affected unit	Highest affected unit	Quality of event evidence	No. of observations	Sum of quality	Description and interpretation of event evidence
4	T1E4S	1	5	ft	18	0	1	1	1	Event horizon in modern soil likely due to MRE. Highest continuous unit shows ~20 cm of apparent vertical separation across fault, which increases in lower units
4	T1E3	1	39	ft	9	1	0	1	0	Although upper termination is unclear, changes in thickness in lower units indicates substantial movement on the fault. Probably equivalent to MRE
4	T1E3	1	39	ft	18	12	0	1	0	Likely accommodation fault associated with motion during MRE
4	T1E3	1	40	ft	17	12	0	1	0	Likely accommodation fault associated with motion during MRE
4	T1W3	4	33	ft	5	5	0	1	0	Accommodation fault associated with large offset; tip is within gravel unit
4	T1E4Sg 2	1	5	ft	18	0	0	1	0	Event horizon in modern soil, likely due to MRE. Highest continuous unit shows ~20 cm of apparent vertical separation across fault, which increases in lower units due to progressive increase in dip; unclear if other events on this trace
6	T1W3	4	5	fiss	6	5	4	1	4	Small fissure cuts sand (unit 6) below gravel (unit 5), and gravel fills fissure. Suggests that earthquake occurred before gravel deposited. Although offset is minor, feature clearly associated with fault below. Quality rank lowered due to coarseness of unit 5, which might obscure upper horizon. Lower sand within unit 6 shows thickness changes, suggesting lateral slip, while upper sand does not
7	T1W1	3	6-35	gs	8	5	4	1	4	Gravel unit and sand and organic units below thicken by 2.8x and 1.7X, respectively, in center of trench. Base of sand unit is 1.5 m lower in center than at north end of trench (~50 cm due to MRE). Modern pond has <50 cm relief along same length. Units below are folded similarly

Likely unit of event horizon	Trench cut label	Map sheet no.	Meter on cut	Event evidence type	Lowest affected unit	Highest affected unit	Quality of event evidence	No. of observations	Sum of quality	Description and interpretation of event evidence
7	T1E1	2	mult	gs	8	3	3	1	3	Sand (unit 6) and gravel layer (unit 5) is two to three times thicker in center of fold. Base of unit 6 is ~1 m lower in center than edges. No causal faults apparent, but units below are uniform in thickness across the same span. Unit above (3) is modulated by modern soil but shows same general pattern. If base of unit 6 is event horizon, the depression continued to fill through the MRE
7	T1W4N	4	1–8	gs	7	4	3	1	3	Units 5 and 6 thicken by 3x
7	T1W2	3	27–34	gs	7	5	3	1	3	Unit 6 thins towards main fault zone; thickness changes in unit 6 appear to be product of scour from unit 5, but overall package shows doubling of thickness
7	T1W4S	4	0–9	gs	7	5	3	1	3	Units 5 and 6 are 2.5x thicker towards center of fold; base of unit 6 is ~30 cm lower in center of fold (when offset due to MRE removed)
12	T1W3	4	36	ft	12	12	0	1	0	Minor vertical separation (2 cm) appears to be accommodation fault associated with MRE
13	T1E1	2	34	ft	14	13	1	1	1	Contacts above fault tip are bioturbated; could extend higher
13	T1W2	3	36	ft	14	13	1	2	2	Tiny offset; upper termination not clear
16	T1E3	1	37	ft	16	14	1	1	1	Fault with 5-cm offset cuts unit 17 but does not terminate in fissure. Does not appear to extend higher. Could be evidence that fissures associated with unit 18 opened when unit 17 was already deposited
17	T1E4N	1	11	fiss	17	16	4	1	4	Fissure filled with sand unit 17 continues into fault with ~10-cm vertical separation. Nice example of fault with vertical separation and fissure at this horizon

Likely unit of event horizon	Trench cut label	Map sheet no.	Meter on cut	Event evidence type	Lowest affected unit	Highest affected unit	Quality of event evidence	No. of observations	Sum of quality	Description and interpretation of event evidence
17	T1E2	1	3	ft	18	12	3	1	3	About 20 cm of vertical separation and thicker units on N side of fault. Likely due to movement during deposition of unit 17; vertical separation due to translation of thicker section from NW. Event quality moderate because thickness changes could also occur during MRE, which is poorly expressed on E side in cuts 1, 2, and 3
18	T1E1	2	mult	fiss	19	17	5	5	25	Fissures that are connected to faults below show minor vertical separation and are filled with sand from unit 17.
18	T1E1	2	mult	gs	19	13	4	1	4	Base of unit 18 is 50 cm lower at center of fold; unit is 20 cm thicker in center for a maximum thickness of 66 cm. Folding can be attributed to several faults across fold and the central fault zone. Unit 12 shows no thickness changes, suggesting all deformation was filled during deposition of units 18–13
18	T1E3	1	34	fiss	19	17	4	1	4	Small fissure filled with unit 17 and connected to fault below
18	T1E3	1	35	fiss	19	17	4	1	4	Small fissure filled with unit 17 and connected to fault below
18	T1E4S	1	3	fiss	18	17	4	1	4	Small fissure connected to fault with ~5 cm of vertical separation in units 18 and older
18	T1E1	2	34	ft	19	17	3	1	3	Base of unit 18 drops 22 cm across main fault zone and is 50% thicker, indicating lateral motion or thickness changes could be product from later motion during MRE
18	T1W1	3	9-33	gs	18	12	3	1	3	Thickness changes (1.8x) between units 18 and 12 for maximum thickness of 0.7 m; total relief of base is 1.7 m. Note this is only on N side of fold
18	T1E1	2	mult	fiss	19	17	1	12	12	Fissures that are not connected to faults below
18	T1E1	2	mult	ft	19	17	1	3	3	Very minor separation
18	T1E2	1	4	fiss	19	17	1	1	1	Sand unit 17 fills narrow fissure with no fault below
18	T1E3	1	mult	ft	19	17	1	6	6	Sand unit 17 fills narrow fissure with no fault below

Likely unit of event horizon	Trench cut label	Map sheet no.	Meter on cut	Event evidence type	Lowest affected unit	Highest affected unit	Quality of event evidence	No. of observations	Sum of quality	Description and interpretation of event evidence
18	T1W1	3	32-39	fiss	19	17	1	18	18	Fissures filled with sand but not connected to faults below
18	T1W1	3	36	ft	19	17	1	1	1	Simple fault
18	T1W2	3	34-39	fiss	19	17	1	9	9	Fissures filled with sand but not connected to faults below
18	T1E4S	1	mult	fiss	18	17	1	7	7	Fissures not connected to faulting below
18	T1E4Sg 2	1	5	fiss	18	17	1	1	1	Fissures not connected to faulting below
18	T1W3	4	35	ft	18	18	0	1	0	Fault tip is dashed between units 23 and 18 because offset is minor (<1 cm). Could be product of reactivated faulting from older event that creates several centimeters vertical separation of sand unit 23
22	T1W4N	4	1-2	ft	22	21	5	1	5	Three vertical faults with 20 cm of vertical separation in lower half of unit 21 and older units. Upper portion of unit 21 is not faulted and appears to thicken across fold to the south
22	T1E1	2	18	ft	23	21	4	1	4	Reverse separation across fault. In footwall, layer 23 (sand) and silt above (unit 22) are clearly faulted and base of unit 21 appears to thicken; in hanging wall, top of unit 23 and unit 22 are difficult to identify. Fault could extend to unit 18, but unlikely based on 60% thickness increase across fault in units 22-20
22	T1W1	3	19	ft	22	22	4	1	4	Fault offsets unit 23; unit 22 thickens over fault; base is cut
22	T1E3	1	23	fiss	24	21	2	1	2	Fault clearly cuts through units 25 and 24; unit 23 thins toward the fault and is down-dropped between subsidiary faults. Earthquake could have occurred soon after unit 23 was deposited, but units above 23 are massive, making upper horizon uncertain

Likely unit of event horizon	Trench cut label	Map sheet no.	Meter on cut	Event evidence type	Lowest affected unit	Highest affected unit	Quality of event evidence	No. of observations	Sum of quality	Description and interpretation of event evidence
22	T1W2	3	37	ft	25	22	2	1	2	Thickness changes of units 34–27 indicate fault postdates these units; unit 25 thins across fault and neither unit 25 or 24 is present on south side of fault. Base of sand unit 23 is locally discontinuous and shows subtle fold to north of fault; but likely unit is continuous and base represents upper event horizon. Field notes suggest sand unit 23 drapes a scarp that would have occurred when unit 24 was at surface; low score reflects this uncertainty
22	T1E4N	1	4	ft	23	18	1	1	1	Fault with small (<5 cm) vertical separation cuts units 23 and lower. Upper termination unclear due to massive stratigraphy at this location
22	T1W3	4	19	ft	23	21	0	1	0	Unit 23 is faulted; termination shown by photos in T1W1 indicate upper unit is 21. Not given high quality here since the upper termination not actually documented in this exposure
23	T1E3	1	39	ft	24	23	1	1	1	Sand unit 23 offset along fault; could be accommodation fault associated with later earthquake
24	T1E1	2	19	ft, gs	25	23	5	1	5	Reverse separation clearly places sand unit 25 above silt unit 24 across fault. Suggests earthquake occurred during unit 24 and was subsequently buried by sand unit 23. Unit 23 is consistently thicker to south and provides all thickness changes between 23 and 18. Suggest earthquake during unit 24; scarp later filled by sand 23
24	T1W4N	4	2–3	ft/unc	25	23	5	2	10	Two faults that offset base of unit 25. In upthrown block, unit 25 is thinned and has diffuse contact with unit 24, which is much thicker on downthrown block to south. Interpret that earthquake early during deposition of unit 24 followed by erosion of upper block accounts for thinner section

Likely unit of event horizon	Trench cut label	Map sheet no.	Meter on cut	Event evidence type	Lowest affected unit	Highest affected unit	Quality of event evidence	No. of observations	Sum of quality	Description and interpretation of event evidence
24	T1W3	4	21	colluvial wedge	25	24	5	1	5	Silt (unit 24) deposited on and thickens across reworked section of unit 25. Suggests earthquake occurred after unit 25 deposited
24	T1W2	3	36	colluvial wedge	25	24	5	1	5	Fault cuts base of sand unit 25 and is capped by silt unit 24. Unit 24 sits on reworked material, likely colluvial wedge deposited on same horizon as 25
24	T1W1	3	21	ft	24	23	4	1	4	Top of sand (unit 25) and base of grey silt (unit 24) are clearly faulted against each other; top of unit 24 is not faulted, and unit 23 thickens across the feature. Interpret that earthquake occurred during unit 24 but scarp smoothed before unit 23 deposited
24	T1E2	1	2	colluvial wedge	25	24	4	1	4	Lump of massive sand sits at same level as base of unit 25; lower contact of this sand is shown with dashed gray line. Deposit could result from colluvial wedge when unit 25 was at surface, or early in deposition of unit 24. Interpret that thinning of units 24 and 23 over feature is depositional, possibly folded during later event
24	T1E4S	1	5	ft/unc	24	23	3	1	3	Offset along two faults that terminate within unit 24, capped by locally present thin clay that sits just below sand unit 23. Unit 23 is draped across fault, thickening into sag, suggesting it filled the displacement but only in part, as this sand is not present south of main fault
24	T1E4Sg 2	1	5	ft/unc	24	23	3	1	3	Fault with vertical separation of units below 24 terminates within unit 24; sand unit 23 disrupted and thinned above. Event within unit 24 likely
24	T1W1	3	19	ft	25	24	3	1	3	Fault cuts upward to base of unit 25. Unclear character of sand unit 25 in this area lowers quality

Likely unit of event horizon	Trench cut label	Map sheet no.	Meter on cut	Event evidence type	Lowest affected unit	Highest affected unit	Quality of event evidence	No. of observations	Sum of quality	Description and interpretation of event evidence
24	T1E1	2	33	ft, gs	25	24	2	1	2	Silt (unit 24) and sand (unit 23) thin and tilt up dramatically to south of fault tip. Units 24 and 23 could be sheared but appear to be intact and drape this edge. Fault cuts base of unit 24, so it was likely at ground surface during time of earthquake. Thinning and tilting of units above could result from shear during subsequent earthquake
24	T1W3	4	19	ft	25	23	2	1	2	Thick, convex-up deposit of sand (unit 25) in meters 19–20 is covered by unit 24, which thins across the deposit. Suggests event was at top of unit 25 or early in deposition of 24. However, base of unit 24 is cut and 2x thicker across fault, covered by unit 23. No thickness changes of unit 23 above this fault. Fault may have been reactivated during event during deposition of unit 22. Lower quality rank due to this uncertainty
24	T1W2	3	26–36	gs	25	24	2	1	2	Thickness changes (3.9x) of sand unit 25 for maximum thickness of 35 cm; total relief of base is 0.6 m (similar to modern topography, therefore lowered event quality). Unit above (24) shows no significant thickness changes
24	T1W4N	4	0	ft	27	24	1	1	1	Small vertical separation on fault that terminates in massive unit
24	T1W3	4	34	ft	25	24	1	1	1	Small fault cuts base of sand unit 25 and could be continuous with fault that creates colluvial wedge elsewhere at level of unit 25. Mottled silt and sand units 28–26 thicken above a fault with reverse separation, suggesting colluvial wedge that causes reworking and local thickening of units 28–26. The fault trace is not visible through the wedge, but sand unit 25 is clean and thickens across older units. Fault cuts unit 25, suggesting event at top of 25 or base of 24

Likely unit of event horizon	Trench cut label	Map sheet no.	Meter on cut	Event evidence type	Lowest affected unit	Highest affected unit	Quality of event evidence	No. of observations	Sum of quality	Description and interpretation of event evidence
24	T1W3	4	35	fiss	23	23	1	1	1	Small (2 x 4 cm) fissure shape with overlying sand unit 23 inside could be from bioturbation or tension crack associated with low-amplitude folding of silt unit below. If so, event could have occurred when unit 24 was at the surface or just after 23 was deposited. Ranked low because feature is small and not connected to faulting below
24	T1W1	3	10	ft	27	21	0	2	0	Units too attenuated to determine exact event horizon
24	T1W1	3	16	ft	26	22	0	1	0	Units too attenuated to determine exact event horizon
25	T1E1	2	20	fiss/ft	27	24	3	1	3	Odd-shaped feature is likely edge of fissure or fault at high angle to trench. Contact between units 26 and 25 is offset across fault, suggesting a change in ground surface that was capped by unit 25 or subsequently smoothed out if unit 25 was in place during the event. Feature could be burrow, because no continuous fault below, but rare feature. Rare at this horizon, the contact between units 25–24 does not appear affected
25	T1E3	1	28	ft	28	25	1	1	1	Fault may extend to base of unit 25 and relate to thickening of sand unit 25
25	T1W2	3	35	ft	28	25	1	1	1	Tiny fault cuts units below sand unit 25 and has reverse separation of ~10 cm, but separation not continuous to unit 25
25	T1E3	1	7	ft	29	17	0	1	0	Clear deformation, but stratigraphy is too compressed at this end to differentiate exact event horizon
26	T1W2	3	32	ft	28	26	1	1	1	Upper termination not clear
28	T1E3	1	25	ft	28	27	1	1	1	Simple fault
28	T1E3	1	27	ft	28	27	1	1	1	Simple fault
28	T1E3	1	27	ft	28	23	0	1	0	Likely associated with fault to north that terminates higher
30	T1E1	2	10	ft	33	29	1	1	1	Difficult to determine upper event horizon with confidence

Likely unit of event horizon	Trench cut label	Map sheet no.	Meter on cut	Event evidence type	Lowest affected unit	Highest affected unit	Quality of event evidence	No. of observations	Sum of quality	Description and interpretation of event evidence
31	T1E1	2	21	fiss	32	31	1	3	3	Sand fills these small narrow fissures; lack of faults below and tiny offsets lower quality
31	T1E3	1	29	ft	31	28	1	1	1	Simple fault
32	T1E1	2	26	ft	33	32	1	1	1	Separation reduces significantly upsection; difficult to determine upper event horizon
32	T1W4N	4	2	ft	33	29	1	2	2	Complex faulting shows downdrop of unit 33; proximity to later, more substantial faulting makes interpretation of this difficult. Could be accommodation faulting during unit 24 earthquake
33	T1E3	1	38	ft	34	32	3	1	3	Upper termination is sharp and thickness changes indicate moderate lateral slip. Possibly accommodation feature for subsequent events
33	T1E4N	1	12	ft	34	32	1	1	1	Two poorly expressed faults at bottom of trench; as mapped, the center block is lifted and contains unit 35
34	T1W2	3	29–36	gs	34	26	2	1	2	Minor thickness changes of units 34–26, but some of this is product of change in slope of trench wall (for example meter 29).
34	T1E2	1	4	ft	35	18	1	1	1	Minor vertical offset, offset could extend into younger units and not be separate event
34	T1E1	2	18	ft	34	34	1	1	1	Minor but sharp offset on fault; poor stratigraphy above makes upward termination uncertain
34	T1E2	1	1	ft	35	34	1	1	1	Simple fault
34	T1E3	1	24	ft	35	35	1	2	2	Two fault tips end within sand unit 35. Upward reduction in slip suggests fault tip may not reach event horizon in this exposure
34	T1E3	1	37	ft	35	34	1	1	1	Amount of separation not consistent downfault
34	T1E3	1	19	fiss	36	35	1	1	1	Fissure-type feature has sharp edges and is filled with clean sand (unit 35), thus does not look like burrow. No fault below; possibly just the edge of the feature is exposed
34	T1W3	4	36	ft	35	35	1	2	2	Minor faults offset base of sand unit 35

Likely unit of event horizon	Trench cut label	Map sheet no.	Meter on cut	Event evidence type	Lowest affected unit	Highest affected unit	Quality of event evidence	No. of observations	Sum of quality	Description and interpretation of event evidence
35	T1W2	3	29–36	gs	35	35	1	1	1	Most of thickness change of unit 35 here is artifact of bulge in trench wall; thickness changes are better observed in exposures where wall is more planar
35	T1E1	2	25–34	gs	36	32	1	1	1	Minor thickness increase in units 35 through 33, but likely attributable to lateral motion on younger faults; total vertical offset on faults is roughly equivalent to total thickness changes on main fault
35	T1E1	2	35	ft	37	34	0	1	0	Attenuated units above make upper termination uncertain
43	T1E3	1	mult	gs	43	39	3	1	3	Slight thickness change and additional layers between meters 26 and 31
43	T1E2	1	2	ft	45	43	2	1	2	Fault cuts unit 45 and lower units and may extent to unit 43
43	T1E1	2	31	ft	44	43	1	1	1	Fault possibly extends through overlying units to 36; contacts above unit 43 are not sharp
43	T1E1	2	32	ft	44	43	1	1	1	Contacts above fault tip are not sharp; could extend higher
45	T1E3	1	26–33	gs	45	43	4	1	4	Package 1.5x thicker within fold; possible causal fault at meter 25
45	T1E4N	1	3–12	ang unc	45	35	3	1	3	Units pinch out between units 45 and 35. Neither units 35 nor 51-45 show significant thickness changes across this section
45	T1E1	2	25–33	gs	45	39	3	1	3	Sand silty sand package is 50% thicker in middle of fold; small faults in meters 32 and 33 could be causal
45	T1W3	4	33–22	gs	45	43	1	1	1	Organic silty clay units thicken in center of trench. Thickness changes (1.8x) of layers 45–44 for maximum thickness of 32 cm; total relief of base is 1.1 m. No causal fault evident in this exposure
47	T1E3	1	25–33	gs	47	45	3	1	3	Package is 2.5x thicker in center of fold
50	T1W3	4	35	ft	53	50	3	1	3	Juxtaposes (~2,000-year-old) units south of fault against younger pond units, suggesting significant lateral slip

Likely unit of event horizon	Trench cut label	Map sheet no.	Meter on cut	Event evidence type	Lowest affected unit	Highest affected unit	Quality of event evidence	No. of observations	Sum of quality	Description and interpretation of event evidence
50	T1E4N	1	5	fiss	50	45	1	1	1	Fissure filled with dark organic rich unit 49; bioturbation makes upper limit unclear
51	T1E3	1	26–33	gs	51	47	3	1	3	Package is 3.6x thicker in center of fold
51	T1E3	1	16	ft	51	39	1	1	1	Small fault with reverse separation. Layers on south side are thicker and could represent an event horizon, but section is compressed here, creating uncertainty on exact event horizon. Could also step up to fault above
52	T1E3	1	25	colluvial wedge	52	51	3	1	3	A 20-cm-thick irregular deposit between lowest third of unit 52 and base of unit 51 is wedge-shaped and thicker on south side of fault. Fault extends higher, but does not account for the deposit and is interpreted to be result of later event
53	T1E3	1	31–36	gs	53	51	3	1	3	Package is 2.6x thicker in fold
60	T1E4N	1	4–9	ang unc	60	54	2	1	2	Sharp unconformity with strongly folded units 60 and underlying units pinches out against base of attenuated package of units 5–59