Earthquake History of the Southern Hayward Fault, San Francisco Bay Area, California

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Element II: Research on Earthquake Occurrence and Effects

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Investigations Undertaken

The purpose of this initial paleoseismic study of the southern Hayward fault is to better constrain the timing of late Holocene surface-rupturing earthquakes along the southern Hayward fault. The first phase of our research involved compilation of existing subsurface information from previous fault studies at several sites along the fault, and analysis of historical observations of the 1868 earthquake. At the Shinn Historic Park in the City of Fremont (Figure 1), we conducted limited exploratory trenching to evaluate stratigraphic and structural relations across a zone that experienced surface deformation during the 1868 earthquake. Ages of stratigraphic units exposed in this shallow trench were estimated on the basis of 18 radiocarbon analyses on charcoal fragments. We also conducted limited exploratory borings at two other sites (UNION Array site and Nakata Nursery site; Figure 1), to determine the presence or absence of adequate stratigraphic relations for assessing past earthquakes.

Results

Shinn Historic Park is on a small topographic high on the western side of the main fault strand (Figure 2). This high is developed on Holocene alluvium deposited by the west-flowing Alameda Creek (presently about 0.8 km northwest of the site), and is bordered by an east-facing scarp that is about 0.5 to 0.6 m high. The near-surface alluvium is part of the Niles alluvial fan, which was deposited during intermittent large floods along Alameda Creek.

Analysis of Previous Trench Data

Woodward-Clyde Consultants (1976) excavated several trenches across the fault within and adjacent to Shinn Historic Park. The trenches documented in this previous study suggest that the site is underlain by bedded silt, clayey silt, silty clay, sandy clay, gravel, and clayey gravel that likely are overbank deposits laid down by Alameda Creek. The trench logs suggest that a 9-m-wide fault zone displaces the fluvial strata and contains several vertical, northwest-striking fault strands. Individual strands show as much as 1 m of vertical displacement of young fluvial deposits, and lower gravel strata adjacent to the fault zone are folded more intensely than the overlying clayey and silty deposits. Woodward-Clyde Consultants (1976) also show several upward fault terminations at distinct lithologic contacts, suggesting the possibility of multiple distinct surface ruptures. The subsurface relations suggested by this previous study led us to believe that the Shinn Historic Park site was likely to yield paleoseismic data on the southern Hayward fault.

Historical Observations at Shinn Historic Park

Historical information suggests that the 1868 earthquake produced surface deformation near Shinn Historic Park. According to Clark (1915, cited in Radbruch [1967]), "Mr. J.C. Shinn reports that during the severe earthquake of 1868 his father's house, standing directly on the fault line, was torn in two and the eastern part dropped about a foot below the western part." This sense of vertical displacement is consistent with the east-facing scarp identifiable on air-photos and in the field at the park (Figure 2). This report also is consistent with historical accounts by H. Tyson, "A crack went thru the old Shinn place," and C. Bonner, "A crack past thru the Shinn and Tyson place" (Lawson, 1908, p. 443). The amount of faulting near Shinn Historic Park during the 1868 earthquake (about 1 ft, or 30 cm), as noted by J.C. Shinn, is similar to that noted in the vicinity by Lawson (1908). According to Lawson (1908), Mr. Decoto noted that a crack near Decoto (about 5 km northwest of Shinn) "opened about 10 to 12 inches at the surface and faulted about as much on the plains side" (p. 443). In the northern part of the Irvington district (about 5 km southeast of Shinn), R.B. Crowell noted, "a crack split the hillside, opening 7 or 8 inches and showing a fault of 8 or 10 inches" (Lawson, 1908, p. 443). We interpret the usage of the term "fault" in these passages to indicate vertical separation of the ground surface, because both note the width of the crack as well as the amount of vertical faulting. Thus, at least three historical accounts suggest that the 1868 earthquake produced about 30 cm of east-down vertical separation along the fault near Shinn Historic Park. Notably, this amount of east-down separation is less than the height of the present-day, 50- to 60-cm-high scarp at the park.

These historical accounts suggested that the site would provide an opportunity to expose evidence of the 1868 surface rupture. On this basis, we anticipated encountering strata containing Gold Rush-era artifacts, which could help interpret the occurrence of pre-1868 ruptures with confidence. Our approach was to attempt to expose pre-1868 strata that were displaced by the 1868 rupture and, hopefully, that were undisplaced by earlier ruptures. In this way, the intent of our trenching was to determine the timing of at least the penultimate earthquake on the fault.

Trench Stratigraphy

An exploratory trench across the 0.5-m-high fault scarp at Shinn Historic Park showed the presence of several very subtle near-vertical faults and fractures along the creeping strand of the Hayward fault, and a series of poorly bedded, fining-upward fluvial sand strata derived from the nearby Alameda Creek (Figure 3). The five lowermost strata exposed are well-sorted sandy silt, clayey silt, and sandy clay deposits. As a whole, there is little lithologic variability between these deposits, although the fining-upward character of each deposit makes the basal contacts discernible. Units 2, 3, and 4 are slightly thicker in the northeastern part of the trench than in the southwestern part. On the basis of the fine-grained nature and fining-upward character of the deposits, we interpret that each of the five fluvial deposits (units 1 through 5) exposed in the trench were deposited as a result of intermittent overbank sedimentation. Eighteen radiometric dates suggest that the lowermost strata are as much as about 1,900 years old and that the uppermost stratum (unit 5) is less than about 350 years old. The uppermost deposit exposed in the trench (unit 6, Figure 3) is a cultural deposit placed on the site as an artificial fill. The abrupt basal contact of the fill is undeformed, and may provide evidence against the occurrence of vertical creep at the site.

Trench Structure

The trench exposed a few very subtle faults within a zone approximately 5 m wide. This zone includes faults that exhibit less than a few cm of vertical separation, as well as fractures with no discernible displacement (Figure 3). The most prominent structural feature in the trench is an east-facing, 5-m-wide monocline developed in the sandy fluvial strata. Strata outside of the monocline (southwest of station 9 m and northeast of station 4 m) have basal contacts that dip less than 1 to 2 degrees northeast. Within the monocline, the basal contacts dip more steeply. The base of unit 2 dips about 15 degrees northeast, and the base of unit 3 dips about 10 to 15 degrees northeast. Notably, the overall dips of younger units across the monocline are progressively shallower upsection. For example, the dip of unit 4 is about 9 degrees and the dip of unit 5 is about 4 degrees, over the 5-m-wide monocline between stations 4 m and 9 m (Figure 3). Notably, there is progressively less vertical separation of younger deposits exposed in the trench, with the differences in vertical separation between adjacent strata ranging from 25 to 35 cm (Figure 3). For example, the lowermost exposed stratum (unit 1) has slightly more than 1 m of total vertical separation, whereas the uppermost native stratum (unit 5) has only about 0.3 m of separation.

The vertical separations exposed in the trench do not appear to be a product of vertical creep, although nearby cultural features show the presence of lateral fault creep at a rate of 5 to 6 mm/yr. There is no evidence that vertical creep is an active process in the site vicinity. Specifically, there is no vertical deformation of railroad tracks 100 m northwest of Shinn Historic Park, suggesting that most (if not all) of the creep involves right-lateral movement and little or no vertical movement. In addition, the base of historic fill exposed in the trench shows no vertical displacement across the monocline. Lastly, sandy beds in the basal parts of the fluvial deposits parallel the monoclinal fold, suggesting that the trench relations are a result of folding rather than stratigraphic onlap onto a surficial fold scarp.

Number and Timing of Possible Earthquakes

We interpret that the progressive deformation of the originally flat-lying fluvial beds exposed in the trench at Shinn Historic Park is evidence for a series of surface-deforming earthquakes. Each of these possible events appears to have produced roughly 30 cm (± 20 cm) of vertical separation at the site. This separation is consistent with historical accounts of the 1868 earthquake at the Shinn site, which indicate that the eastern side of the fault dropped about 30 cm. Thus, our preliminary interpretation is that there was a minimum of four surface deformational events at the site since about AD 540, including the documented historical deformation produced in AD 1868. Based on the eighteen radiocarbon age estimates, the trench exposure yielded the following possible times for late Holocene surface deformations: between AD 540 and AD 780, between AD 680 and AD 890, between AD 680 to AD 1868, and in AD 1868.

Non-technical Summary

Understanding the timing of large paleoearthquakes on the Hayward fault is critical for assessing seismic hazards and calculating probabilities of large earthquakes in the populated San Francisco Bay area. In this study, we are collecting information on the timing and recurrence of past earthquakes along the southern Hayward fault through exploratory trenching at one or two selected sites. At one site in Fremont, preliminary data suggest the occurrence of four surface deformational events at the site since about AD 540, including the earthquake in AD 1868. An improved understanding of the earthquake cycle on the southern Hayward fault is critical for providing input to probability estimates for future earthquake occurrence, and thus for developing adequate risk mitigation in the San Francisco Bay area.

Reports Published

Because this project is in progress, there have been no publications generated yet.

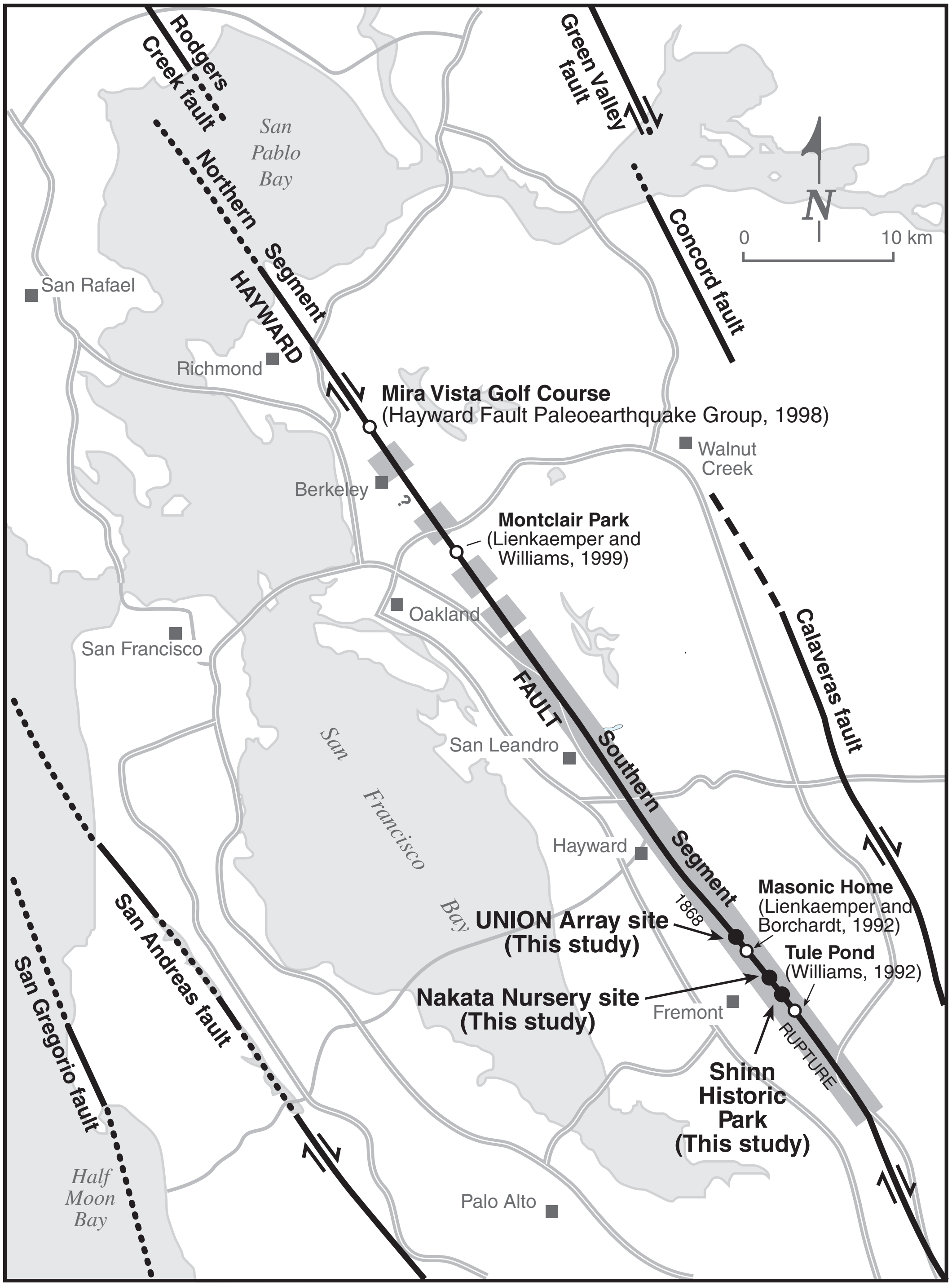

Figure 1. Regional fault map of the Hayward fault showing recent research sites (open circles), the 1868 rupture (shaded), the trench site at Shinn Historic Park, and coring sites at UNION Array and Nakata Nursery.

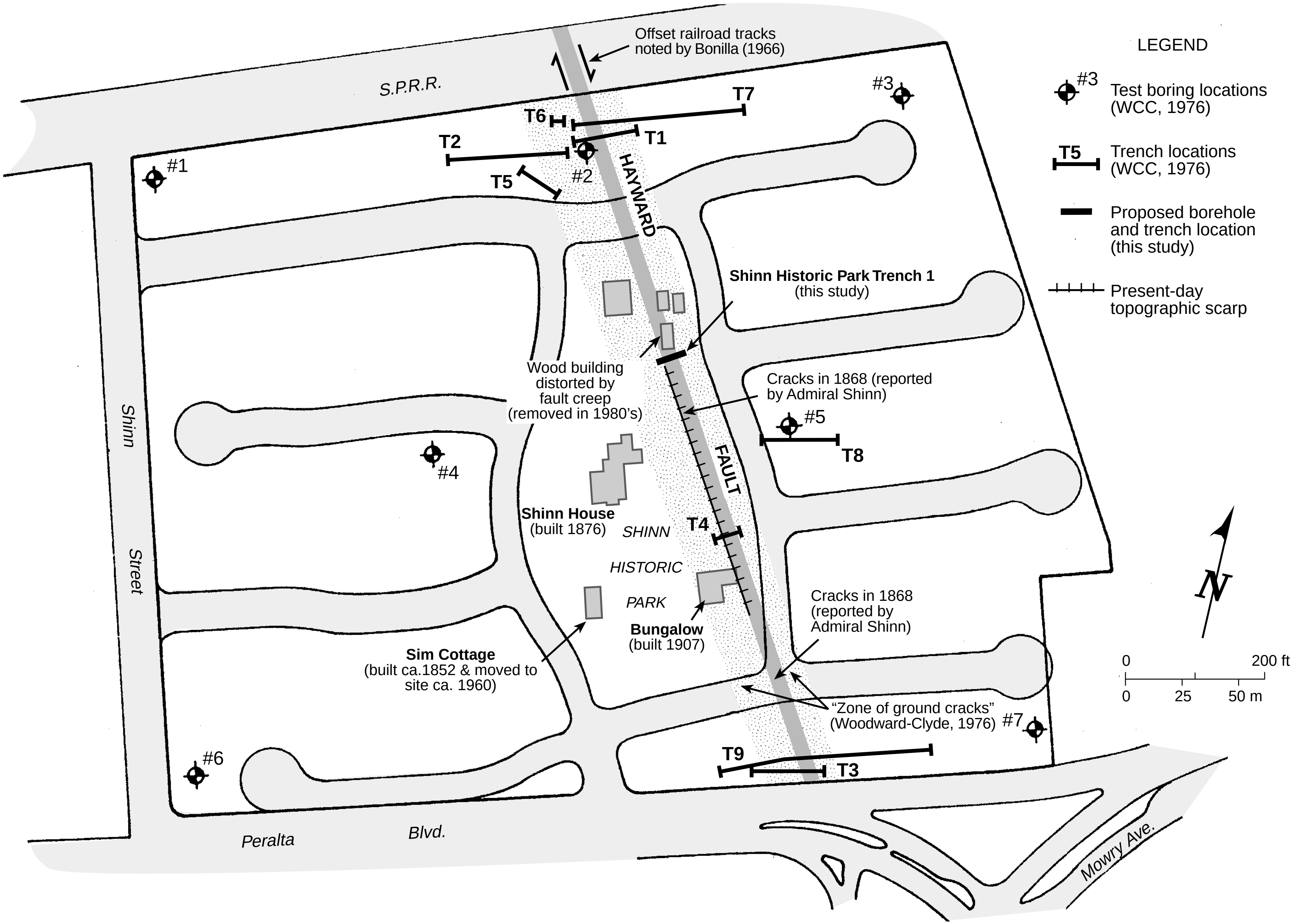

Figure 2. Map showing the location of the Hayward fault, exploratory trenches, boreholes and historic buildings at the Shinn Historic Park (after Woodward-Clyde Consultants, 1976).

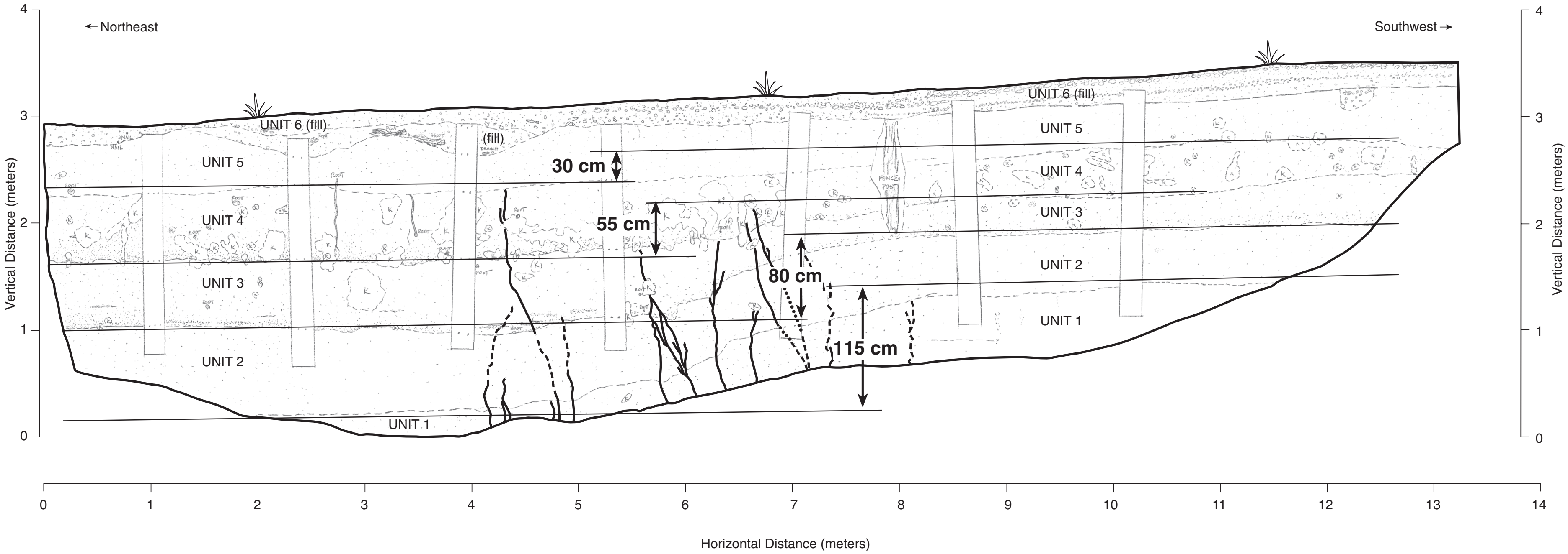

Figure 3. Simplified log of Trench 1, showing vertical separation of units 2 through 5. See Figure 3 for explanation.