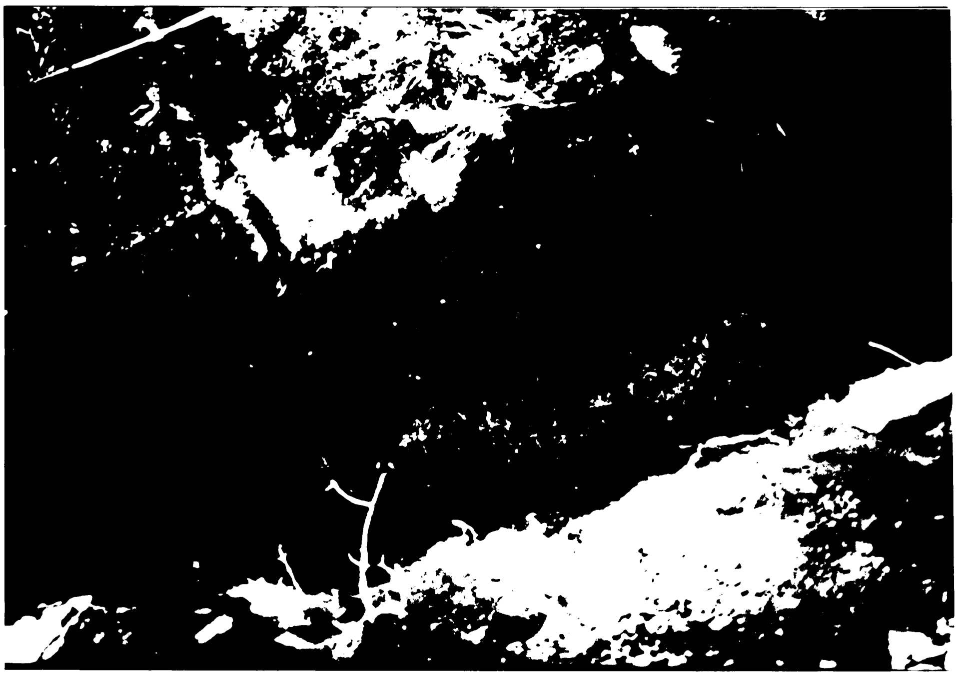

Figure 11. South view of fault zone exposed in the Deep Canyon trench, Wellsville fault.

loess deposited after the lake retreat (unit 6, plate 1C), similar to the stratigraphic sequence found in the Winter Canyon trench (plate 1A). However, unit 6 is only evident in the hanging wall. A 2-meter- (7-ft-) deep test pit west of the trench above the fault scarp also did not expose unit 6, and thus the loess was either only deposited along the base of the fault scarp at this site or it has been eroded from the top and front of the scarp. A soil A horizon formed on top of units 5 and 6 (paleosol S1, plate 1C). All these units were displaced down to the east by the MRE across the main fault and a smaller subsidiary fault (near meter station 3, plate 1C); the MRE also displaced a wedge of units 4b through 6 up to the west along a small thrust fault in the fault zone (meter mark 7, plate 1C). A colluvial wedge roughly 1.2 meters (3.9 ft) thick formed on top of unit 6 and paleosol S1 following the MRE (unit 7). Unit 7 is overlain by slope colluvium (unit 8) on which the modern soil (soil S2) is forming (plate 1C).

Earthquake Timing and Recurrence

We collected five samples of organic material from the Deep Canyon trench for radiocarbon dating. Radiocarbon analysis of degraded charcoal taken from the base of unit 2 (DCT-RC1, plate 1C) gave an age estimate of 21,530 +/- 160 yr B.P. Organic-rich sediment collected from the lower horizon contact (LHC) of paleosol S1 (DCT-RC2, plate 1C) gave an age estimate of 5,250 +100/-250 cal B.P.; material from the UHC of paleosol S1 (DCT-RC3, plate 1C) gave an age estimate of 4,500 +100/-150 cal B.P. Organic-rich sediment collected from the center of the colluvial wedge unit 7 (DCT-RC4, plate 1C) above DCT-RC3 gave an age estimate of 3,200 +100/-150 cal B.P.; material collected from the LHC of soil S2 (DCT-RC5, plate 1C) above DCT-RC4 gave an age estimate of 1,700 +/-150 cal B.P. All these samples appear to be in a proper chronostratigraphic sequence.

Formation of paleosol S1 predates the MRE on the Wellsville fault. The soil was buried sometime after this event by scarp colluvium which formed unit 7. Based on the age of the UHC contact of paleosol S1, the soil was buried around 4,350 to 4,600 years ago. However, this age comes from beneath the distal portion of the colluvial wedge; we were unable to sample the wedge heel or paleosol UHC at the main fault (due to possible contamination from animal burrowing). Thus, as in the Winter Canyon trench on the Clarkston fault, time passed between the MRE and soil burial. The age difference between DCT-RC3 and RC4 suggests the rate of scarp formation at Deep Canyon was similar to that at Winter Canyon. At Winter Canyon, about 50 to 200 years passed between the MRE on the Clarkston fault and soil burial by scarp colluvium. Based on this, we believe the MRE on the Wellsville fault likely occurred between 4,400 to 4,800 years ago.

Units 1 through 3 in the Deep Canyon trench are alluvial-fan sediments comprised of debris flows and debris floods. These units predate the PE on the Wellsville fault. We found small pieces of degraded detrital charcoal along the base of unit 2 which yielded an age of 21,500 ± 160 yr B.P. Although this age is too old to calibrate directly, the method we use elsewhere for correlating Lake Bonneville ages (radiocarbon age times 1.16) yields an approximate age of 25,000 years. This age is a maximum limiting age for the PE on the Wellsville fault. The PE predates deposition of unit 6 (plate 1C), which consists of windblown silt and fine sand (loess). Loess was commonly deposited in valley basins throughout the Basin and Range around 15,100 years ago (13,000 yr B.P.) after dessication of pluvial lakes in the region and retreat of glaciers and soil ice (Kleber, 1994; Donald R. Currey, verbal communication, 1998). Based on this, we believe the PE likely occurred sometime between 15,100 and 25,000 years ago. This suggests a minimum of 10,300 and a maximum of 20,600 years passed between the PE and MRE on the Wellsville fault.

Displacement and Slip Rate

No correlative stratigraphy is in the Deep Canyon trench to indicate displacement from the PE on the Wellsville fault. However, unit 5 is traceable across the fault and can indicate displacement from the MRE (unit 5 postdates the PE). Linear projection of the basal contact of this unit across the fault zone shows 1.9 meters (6.2 ft) of displacement down to the east from the MRE. Topographic profiling of the scarp at the trench site shows 6.6 meters (21.7 ft) of displacement from multiple surface-faulting earthquakes. A compound scarp often contains multiple breaks in slope, each of which originated in separate rupture events; a histogram of slope angle versus total distance (Haller, 1988) can often point out subtle inflections (gradient changes) in a compound scarp (McCalpin, 1996). A histogram of the profile at the trench site shows three gradient changes that we believe represent three past surface-faulting earthquakes (figure 12). Average displacement per event would therefore be 2.2 meters (7.2 ft), which is similar to the displacement measured in the trench from the MRE.

Assuming two surface-faulting earthquakes on the Wellsville fault in the past 15,100 to 25,000 years and a total displacement of 4.4 meters (14.4 ft), the slip rate for the Wellsville fault would be 0.18-0.29 millimeters/year (0.007-0.011 in/yr). This rate is near the post-Bonneville slip rate for the central segment of the East Cache fault zone of 0.28 millimeters/year (0.011 in/yr), but is higher than the average slip rate for the southern segment of the East Cache fault zone of 0.01 to 0.07 millimeters/year (0.0004-0.0026 in/yr) since the early Pleistocene (table 2; McCalpin, 1994). South of Deep Canyon, the fault displaces an alluvial fan similar to those estimated by McCalpin (1989) to be 100,000 to 200,000 years old. Topographic profiling of this scarp showed 13.2 meters (43.3 ft) of displacement. Based on this displacement and the estimated age for the faulted alluvial-fan deposits, the maximum long-term slip rate for the Wellsville fault since middle Pleistocene time is 0.13 millimeters/year (0.005 in/yr).

Fault Segmentation and Comparison

Paleoseismic data obtained from our investigations suggest that the Clarkston, Junction Hills, and Wellsville faults rupture independently and can be considered separate segments of the West Cache fault zone. Timing for the MRE on all three faults differs, which suggests that each fault generated a separate earthquake. However, because of the limited age span of our paleoseismic data, we are uncertain if the faults always rupture independently (such as in the MRE). Slip rates also differ between the faults, with the Clarkston fault having the highest rate and the Junction Hills fault the lowest.

The Short Divide fault marks the boundary between the Clarkston and Junction Hills faults, and Solomon (1997) believes the Clarkston fault is a seismically independent structural segment of the West Cache fault zone based on the elevation difference of the Bonneville shoreline across Short Divide. The relationship between the Junction Hills and Wellsville faults is less clear. The south end of the Junction Hills fault is poorly expressed at the surface. Solomon (1997) maps a concealed trace of the Junction Hills fault trending south out into the valley and dying out. The Wellsville fault begins farther west near the range front, about 3 kilometers (2 mi) north of the southern end of the Junction Hills fault. The overlap between the Junction Hills and Wellsville faults is the segment boundary. This boundary may not be persistent; surface faulting from a large-magnitude earthquake on one fault may step over and propagate onto the adjacent fault. However, the MREs on the Junction Hills and Wellsville faults show no evidence of cross-boundary propagation either at the surface or in the fault exposures.

Table 2 shows a possible correlation between earthquake timing and slip rates for the Wellsville fault and the central segment of the East Cache fault zone. The MRE and PE on both faults have similar ages, and their slip rates since late Pleistocene time are also similar. The earthquake timing similarity suggests a large earthquake on one of the faults may have triggered a

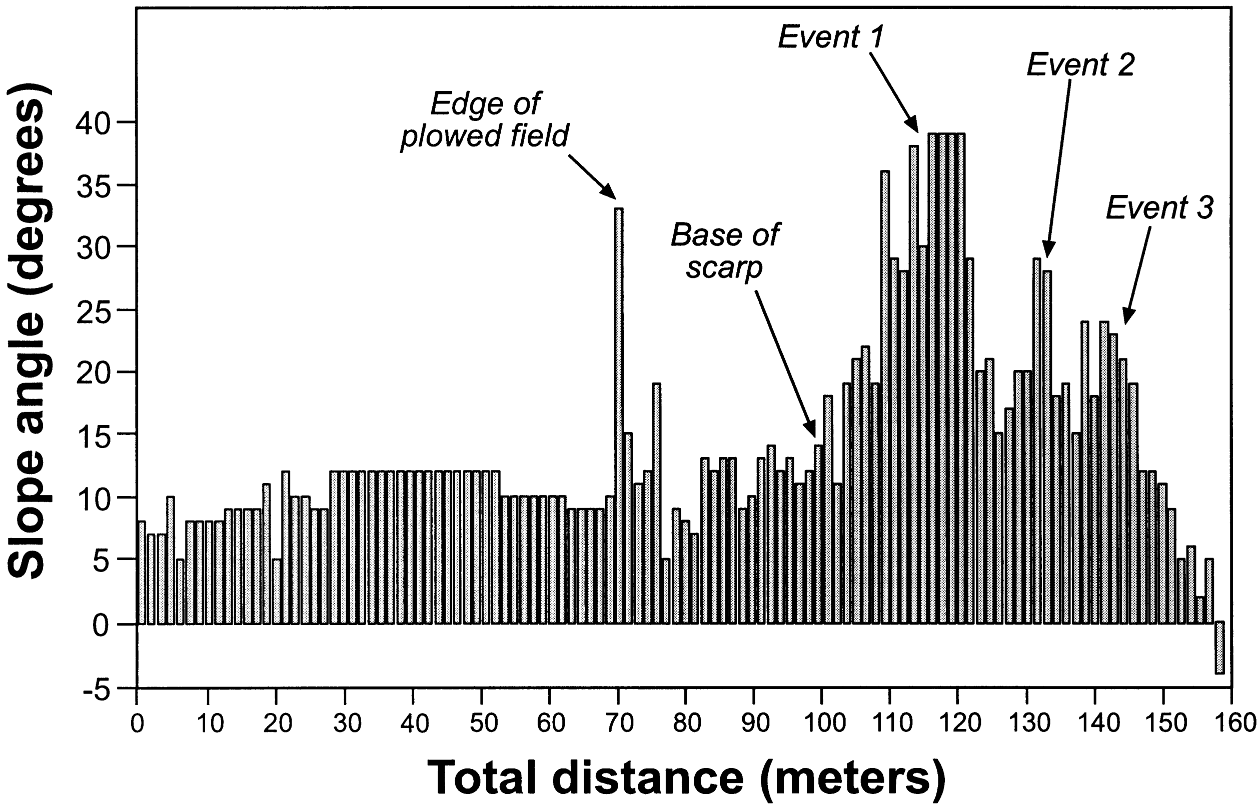

Figure 12. Histogram of slope angle versus total distance for scarp profile 1, Deep Canyon, Wellsville fault. The scarp shows three gradient changes (spikes) possibly representing three surface-faulting earthquakes.