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PALEOSEISMOLOGY OF THE NEPHI SEGMENT OF THE WASATCH FAULT ZONE, JUAB COUNTY, UTAH—PRELIMINARY RESULTS FROM TWO LARGE EXPLORATORY TRENCHES AT WILLOW CREEK

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INTRODUCTION

The Nephi segment is one of the most prominent, yet least understood parts of the Wasatch fault zone (WFZ) in Utah (fig. 1) (see Machette and others, 1992a, 1992b). Initial studies of this segment of the WFZ by Woodward-Clyde geologists (Hanson and others, 1981, 1982; Schwartz and others, 1983, 1984) reported evidence for multiple Holocene surface ruptures at North Creek with only broad bounds of the timing of each event. Machette (USGS) mapped the surficial geology along the segment in 1983–84 (see Harty and others, 1997), and Michael Jackson (Jackson, 1991) trenched the southern part of the segment at Red Creek and reconfirmed evidence of three Holocene earthquakes. However, Jackson's results did little to refine the original, now two-decade-old chronology. With designation of the Mt. Nebo Wilderness area, the possibility of further trenching on the segment seemed problematic. However, the Utah Geological Survey (UGS) recently re-evaluated the segment's paleoseismic record for seismic hazards (Lund, 2005), and DuRoss and Bruhn (2005) estimated new slip rates based on the scarp's morphology. As a result, the UGS identified the Nephi segment as Utahs' highest priority for further paleoseismic research (Lund, 2005), and the hunt was on for a new trenching site.

Key questions about the paleoseismic history of the Nephi segment focused on:

(1) Time of the most recent surface-rupturing earthquake (P1) was known to be younger than 750–1,110 yr from charcoal in a faulted debris flow, but was considered to be considerably younger (300–400 yr old) based on the fault scarp's youthful morphology;

(2) The penultimate (P2) earthquake was either >1,650 or >3,640 yr based on conflicting radiocarbon dates from charcoal and organics in the buried A horizon on fault-scarp colluvium deposited after P2;

(3) An earlier (P3) earthquake was inferred from a fluvial terrace inset into the uplifted block at North Creek; and

(4) The entire faulting history at North Creek was known to be <4,000±400 yr (or <4,580 yr) based on two ages from charcoal in fan-head deposits adjacent to the trench (Bucknam, 1978). (All above ages are based on uncorrected radiocarbon dates; that is, in 14C yr B.P.).

The purpose of this report is to publish detailed stratigraphic, structural, and chronologic data required to interpret the paleoseismic history of the Willow Creek site. Such interpretations, which require discussing the entire Nephi segment and its relation to the WFZ, will be made in subsequent publications with reference to this report .

WILLOW CREEK TRENCH SITE

In 2004, we identified a small parcel of U.S. Forest Service land at the mouth of Willow Creek (about 5 km west of Mona, Utah) that was excluded from the Mount Nebo Wilderness area owing to previously established egress to the forest. At the Willow Creek site, which is near the middle of the southern strand of the Nephi segment (see index map, fig. 2), the WFZ has vertically displaced alluvial-fan deposits >6–7 m, forming large, steep, multiple-event scarps (see fig. 4). Both DuRoss and Bruhn (2005) and Machette (field notes, 1984) had surveyed topographic profiles in the area. In May 2005, we dug two 4- to 5-m-deep backhoe trenches at the Willow Creek site, identified three colluvial wedges in each trench, and collected samples of charcoal and A-horizon organic material for AMS (acceleration mass spectrometry) radiocarbon dating, and sampled fine-grained eolian and colluvial sediment for luminescence dating (table 1). The new radiocarbon dates (table 2) have been calendar corrected using Calib v. 5.0.2 (http://radiocarbon.pa.qub.ac.uk/calib/). These AMS dates are from charcoal and herbaceous materials (twigs) that were separated by Kathy Puseman of Paleo Research Institute, Golden, Colo.

The trenches yielded a stratigraphic assemblage composed of moderately coarse grained fluvial and debris-flow deposits and discrete colluvial wedges associated with three faulting events (P1, P2, and P3). About one-half of the net vertical displacement is accommodated by monoclinal tilting of fan deposits on the hanging-wall block, possibly related to massive ductile landslide deposits that are present beneath Willow Canyon. The top of these landslide deposits are exposed as small islands surrounded by Holocene alluvium of the Willow Creek fan, west of our study area.

WILLOW CREEK NORTH TRENCH (WCN)

The Willow Creek north trench site (WCN) is about 150 m north of the Willow Creek (U.S. Forest Service) road, and north of an east-west jog in the U.S. Forest Service boundary fence (see fig. 5). This trench crossed a 8.7-m-high scarp (profile m83-36, figs. 4 and 5) on colluvium and fan alluvium deposited on the north margin of the valley of Willow Creek. The alluvial package exposed in the WCN trench comprises alternating fluvial, debris-flow, and loess deposits (fig. 6, table 3), all parallel bedded but slightly finer

grained than the fan-head alluvium in the Willow Creek South trench (WCS). Although deposits on both sides of the fault appeared correlative, dating shows that the hanging-wall deposits are substantially younger that those on the footwall. We mapped three discrete colluvial wedges, each related to a major surface-faulting earthquake. As with the south trench, tilting accommodated about one-half of the net vertical tectonic throw.

WILLOW CREEK SOUTH TRENCH (WCS)

The Willow Creek south trench (WCS) is about 55 m north of the Willow Creek (U.S. Forest Service) road (fig. 5) and crossed a 6.3- to 6.9-m-high scarp (profiles m83-33, m83-34, and m83-35; figs. 4 and 5) on fan-head alluvium of Willow Creek. We suspected that the alluvium is middle Holocene in age, based on a 4,580 14C yr B.P. date from charcoal (Bucknam, 1978) collected from alluvial deposits at North Creek, 6 km to the north (fig. 2). The alluvial package exposed in the WCS trench comprises alternating fluvial, debris-flow, and loess deposits, all parallel bedded and largely conformable (fig. 7, table 4). The trench exposed correlative deposits on both sides of the fault, as demonstrated by dating. Not finding correlative deposits is a common problem in paleoseismic investigations, often resulting in minimum estimates of fault displacement and incomplete paleoseismic records. We mapped three discrete colluvial wedges, each related to a major surface-faulting earthquake. The oldest wedge (Cw3) is the smallest, but fills a large fissure along the main fault. This suggests the event P3 may have caused both broad tilting in the footwall block and brittle faulting. We mapped some minor synthetic faults, but no antithetic faults or grabens were found in the trench. As a result, about one-half of the net vertical tectonic throw in WCS is related to tilting rather than brittle faulting.

RELATIVE TIMING OF EVENTS

Currently, our conclusions about the absolute timing of surface faulting events at Willow Creek are limited. The luminescence age estimates (table 1) and radiocarbon dates (table 2) provide broad timing constraints. Two dates from the WCS trench tightly bracket the most recent faulting event (P1) at between 270 and 315 calendar yr ago (see results of radiocarbon dating, table 2). Event P2 is probably older than 1,227±54 calendar yr since this is the age of organic material collected from the A horizon of the soil formed on the P2 colluvium (unit Cw2 in the WCN trench, fig. 7). The oldest recorded event (P3) in the Willow Creek trenches must be much older than P2 (>1,227 calendar yr), but younger than faulted deposits in the footwall, which are dated at about 2,500 to 3,150 calendar yr (dates generalized from tables 1 and 2).

Combining our new dates with those previously published for the North Creek and Red Canyon sites, our analyses suggest new and interesting interpretations. Our preliminary interpretations of the timing of major surface-faulting events at Willow Creek are as follows:

P1—probably about 300 yr ago,
P2—probably about 1,230 yr ago, and
P3—less than 2,320 yr ago.

These times are much younger than those from the North Creek and Red Canyon sites and will have to be reconciled in light of our new data. In addition, new studies at the Santaquin site (fig. 2) should reveal timing for the northern strand for the Nephi segment of the WFZ.

Figure 1. Major Quaternary faults in northern Utah. Red box shows location of Nephi segment of Wasatch fault zone (fig. 2). Faults from Black and others (2003); shaded-relief digitial elevation model (DEM) created by Chris DuRoss (UGS, November 2006). Abbreviations: WFZ, Wasatch fault zone; WVFZ, West Valley fault zone; SLC, Salt Lake City.

Figure 2. Index map for the Nephi segment showing location of paleoseismic trench sites (marked by asterisks). Map and shaded-relief digitial elevation model (DEM) created by Chris DuRoss (UGS, November 2006).

Figure 3. Index map of the Willow Creek site showing fault scarp, trenches, and other cultural and geographic features.

Figure 4. Scarp profiles from the Willow Creek site, Nephi segment of the Wasatch fault zone. Only the fault-scarp portion of the profiles are shown. Profile locations are shown on figures 3 and 5.

Figure 5. Detailed topographic map of the Willow Creek site showing trenches, profile locations and other features.

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