Earthquake Timing and Recurrence

We collected four samples of organic material from the Winter Canyon trench for radiocarbon dating. One sample (WCT-RC2) was not analyzed and therefore no date is recorded on plate 1A. WCT-RC1 and RC4 show similar age estimates, and results from WCT-RC1, RC3, and RC4 are in proper chronostratigraphic order.

Formation of paleosol S1 predates the MRE on the Clarkston fault. The soil was buried some time after this event by scarp colluvium which formed the colluvial wedge. Organic-rich sediment collected from the upper horizon contact (UHC) of paleosol S1 beneath the MRE colluvial wedge (WCT-RC1, plate 1A) gave an age estimate of 3,650 +150/-100 cal B.P., which indicates the soil was buried around 3,550 to 3,800 years ago. Organic-rich sediment collected from the middle of the colluvial wedge (WCT-RC3, plate 1A) gave an age estimate of 2,200 +100/-150 cal B.P., which supports our belief that formation of the colluvial wedge was gradual. Thus, we believe a few tens to hundreds of years passed before paleosol S1 was buried at the location of WCT-RC1. Radiocarbon analysis of organic-rich sediment collected from the heel of the colluvial wedge (WCT-RC4; plate 1A) gave an age estimate of 3,800 +/-200 cal B.P. This material would have been shed from the scarp free face very rapidly, possibly immediately after the event. Based on this, our best estimate for timing of the MRE on the Clarkston fault is 3,600 to 4,000 years ago.

Limited data exist regarding timing for the penultimate surface-faulting earthquake (PE) on the Clarkston fault because we only exposed evidence for the MRE in the trench. However, Solomon (1997) noted that the Bonneville shoreline across Short Divide is 9 meters (30-ft) lower near the Clarkston fault than to the south on the Junction Hills fault. Isostasy cannot solely account for the difference, since the gradient of the Bonneville shoreline in this area is about 0.5 meters/kilometer (2.6 ft/mi) and the distance across Short Divide is only 0.6 kilometers (0.4 mi). Furthermore, the Short Divide fault is a south-dipping normal fault and displacement on this fault would produce a higher shoreline elevation (rather than lower) on the Clarkston side. Therefore, most of the difference must be due to movement on the Clarkston fault, Junction Hills fault, or Wasatch fault zone, or to a combination of events on these faults which differentially lowered the shoreline on the hanging wall of the Clarkston fault and/or raised the shoreline on the footwall of the Junction Hills fault (Solomon, 1997). The Collinston segment of the Wasatch fault zone west of Short Divide (figure 1) shows no evidence of surface faulting since Lake Bonneville and a decrease in total displacement northward (Machette and others, 1992). Our paleoseismic data from Roundy Farm (discussed below) indicates only one post-lake event on the Junction Hills fault. Based on this and the displacement we measured from our scarp profiles, and assuming a characteristic earthquake model (Schwartz and Coppersmith, 1984), we believe two or three surface-faulting earthquakes occurred on the Clarkston fault since lake retreat to account for the elevation difference. Assuming one other event at Bonneville shoreline time, the recurrence interval (time between surface-faulting earthquakes) on the Clarkston fault is a maximum of

13,200 years.

Displacement and Slip Rate

We could not directly measure displacement in the Winter Canyon trench. Although unit 2 is traceable across the fault, the upper contact of this unit is visible only in the hanging wall and the lower contact is visible only in the footwall. Ongoing formation of the degraded-scarp free face has also removed the upper portion of unit 2 in the footwall, and no slope colluvium overlies it. However, we observed evidence for the contact between units 1 and 2 (calcium-carbonate coated cobbles and pieces of carbonate matrix) in hand excavations near meter mark 16, which suggests the contact is near the trench floor. Based on this evidence, we estimate unit 1 was displaced at least 3.5 meters (11.5 ft) down to the east by the MRE on the Clarkston fault. Topographic profiles across the fault near the trench site and at the mouth of Raglanite Canyon to the north indicated 3.1 to 3.7 meters (10.2-12.1 ft) of displacement, which is similar to the amount estimated from the trench exposure.

Material suggestive of the contact between units 1 and 2 in the hanging wall may also be part of an older colluvial wedge derived from unit 1. However, because no stratigraphic sequence below unit 2 was exposed in the hanging wall, we are uncertain whether an older wedge exists between units 1 and 2. McCalpin (1991) indicates symmetric scarp degradation models predict the maximum thickness of scarp-derived colluvium is one-half the height of the free face from which it was shed. The MRE colluvial wedge in the Winter Canyon trench has a maximum thickness of 1.3 meters (4.3 ft). This suggests the MRE scarp should have been at least 2.6 meters (8.5 ft) high, which is slightly lower than the estimated displacement. However, wedges deposited on sloping surfaces (such as the Winter Canyon site) have lower maximum thicknesses than those on horizontal or nearly horizontal surfaces (Ostenaa, 1984; McCalpin, 1991). Therefore, we believe the displacement is probably the result of only one surface-faulting earthquake. A multiple-event scarp with the measured displacement at the Winter Canyon site should show multiple, thinner colluvial wedges.

Because evidence for only one event was exposed at Winter Canyon, we were unable to determine a long-term slip rate for the Clarkston fault. For this, the difference in shoreline elevations across Short Divide provides the best information. Based on this difference and the shoreline age, Solomon (1997) determined a maximum slip rate of 0.54 millimeters/year (0.021 in/yr) for the Clarkston fault since latest Pleistocene time (9 meters [30 ft] of displacement in the past 16,800 years). This rate is higher than for the northern segment of the East Cache fault zone of 0.25 to 0.50 millimeters/year (0.010-0.020 in/yr) since the early Pleistocene (table 2; McCalpin, 1994), and is the highest of any of the faults in the West Cache fault zone. Machette and others (1992) indicate scarps and steep topography on the eastern side of the Malad Range suggest the northern part (Clarkston fault) of the West Cache fault zone is the most active.

Junction Hills Fault

Geology

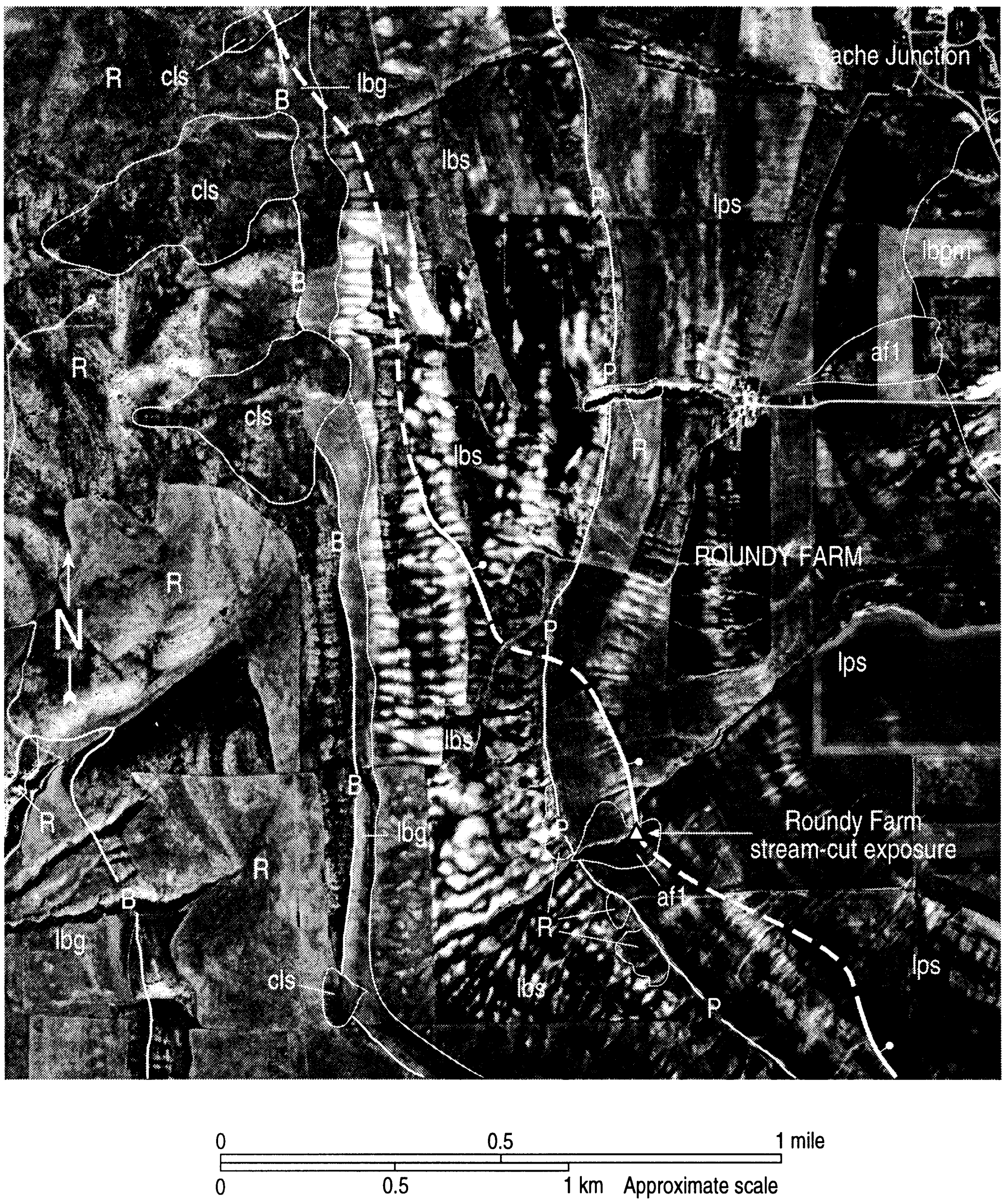
The Junction Hills fault is 25 kilometers (16 mi) long and consists of a single discontinuous east-dipping fault trace locally buried by landslide debris and fan alluvium. East of Short Divide, at its north end, the fault displaces Tertiary sedimentary rock, but to the south the fault exits bedrock and displaces deposits of Pleistocene Lake Bonneville (Solomon, 1997). The fault parallels the Bonneville shoreline to the south of Cutler Reservoir, where it diverges and once again enters bedrock (Solomon, 1997).

Surficial evidence of the Junction Hills fault is poorly preserved. Solomon (1997) indicates the only conclusive evidence of late Quaternary displacement on the Junction Hills fault is found near Roundy Farm about 2 kilometers (1 mi) southwest of Cache Junction. Surficial geology in the vicinity of Roundy Farm consists of deposits related to the Bonneville and Provo stages of Lake Bonneville, and local deposits of alluvium and colluvium (figure 8). Three short (460- to 610-meter- [1,509-2,001-ft] long) east-facing normal fault scarps displace the lake deposits at this site. Two of the scarps are below the Provo shoreline, the third is between the Bonneville and Provo shorelines (figure 8). The fault is exposed in a natural stream cut at the southern end of the central scarp. At this exposure, Oviatt (1986) reported 2.4 meters (7.9 ft) of displacement in the basal transgressive gravel of Lake Bonneville and evidence for additional pre-Bonneville surface-faulting earthquakes. Solomon (1997) indicates finding no fault exposures at the other two scarps, but he assumes they are also of tectonic origin.

Sequence of Deposition and Faulting in the Roundy Farm Stream Cut

The Roundy Farm stream cut is at the southern end of the central scarp mapped by Solomon (1997). The stream cut crosses the fault obliquely, yielding a low apparent fault dip in exposures. The site is also on the edge of a plowed field, and little surface expression of the scarp remains. The stream cut exposes a single main fault trace (figure 9), an antithetic fault trace bounding a 4.3-meter- (14.1-ft-) wide graben, and evidence for two surface-faulting earthquakes.

The oldest unit in the stream-cut exposure is a pre-Lake Bonneville alluvial-fan deposit (unit 1, plate 1B) comprised of clay and grusified cobbles, possibly highly weathered bedrock of the Tertiary Salt Lake Formation. Unit 1 is truncated by a degraded-scarp free face from the penultimate surface-faulting earthquake (PE) on the Junction Hills fault, but we observed no evidence of a colluvial wedge from the PE and believe it is likely buried beneath material sloughing off the stream-cut wall. The PE free face is mantled by a pre-Lake Bonneville alluvial-fan deposit comprised of silty sand with gravel forming crudely bedded channels (unit 2, plate 1B). Unit 2 is thin in the footwall, but thickens eastward in the hanging wall and extends well away from the fault zone, and it contains at least one interbedded paleosol A horizon east of the exposure. No soil was evident on top of unit 2; the upper portion of this unit may have been



DESCRIPTION OF MAP UNITS AND SYMBOLS

af1	Fan alluvium, unit 1 (upper Holocene)
cls	Landslide deposits (Holocene to middle Pleistocene)
lps	Provo regressive sand and silt (uppermost Pleistocene)
lbpm	Undivided Lake Bonneville deposits (upper Pleistocene)
lbg	Bonneville transgressive gravel and sand (upper Pleistocene)
lbs	Bonneville transgressive sand and silt (upper Pleistocene)
R	Bedrock, undivided

(fault symbol)	Normal fault, bar and ball on downthrown side, dashed where approximately located.
(line)	Contact
—B—	Highest shoreline of the Bonneville level
—P—	Highest shoreline of the Provo level
△	Steam-cut exposure

Figure 8. Air-photo geologic map of the Roundy Farm stream cut vicinity (modified from Solomon, 1997).