Investigate Holocene Faulting and Related Earthquake Effects of the Rattlesnake Mountain Portion of the Olympic-Wallowa Lineament

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Investigations Undertaken

We have concentrated our initial research on locating suitable trench sites that minimize problems encountered with previous studies in the area. Our efforts have concentrated on the Rattlesnake Mountain fault and the series of imbricate thrust faults along the continuation of the Rattlesnake Mountain fault in the Snively Basin complex (Figure 1). We identified six sites that were further investigated to insure that our resources are expended on only the best sites.

We completed ground penetrating radar surveys of the five most promising sites and have completed the auger sampling at these locations as well. This completes all the field work we had planned for this phase of the project. We have identified a datable ash horizon at one of these locations and another older ash in a nearby exposure. Several caliche horizons were detected and would provide additional dating opportunities. We are currently using the subsurface stratigraphy determined with the auger data to help with the interpretation of the ground penetrating radar images.

Results

Detailed mapping of the Rattlesnake Mountain fault zone has shown that the fault lies above the highest level of Glacial Lake Lewis that formed when the cataclysmic releases of Pleistocene floodwaters from Glacial Lake Missoula were impounded behind a hydraulic constriction in the Columbia River at Wallula Gap. Slackwater sediments from Lake Lewis form a thick deposit around the central Columbia Basin that obscures fault zones below 1200 feet above mean sea level (MSL). The lower elevations of the Rattlesnake Mountain fault zone are over 2000 feet above MSL but were scoured by the initial floodwaters, removing much of the overlying talus along Rattlesnake Mountain. Subsequent erosion of the mountain and deposition of eolian deposits from prevailing southwest and northwest winds in the past 13,000 years have covered the fault zone with a thin veneer of sediments.

<u>Potential Trench Localities</u>. Six potential trench localities were identified: two are along the main fault zone of Rattlesnake Mountain, two localities are along the upper thrust fault in the Snively Basin complex, and two localities are in the sag ponds that developed in the hanging wall above the upper thrust fault in the Snively Basin complex (Figure 1).

<u>Rattlesnake Mountain fault sites</u>. The two potential trench sites that we identified along Rattlesnake Mountain are shown on Figure 1. The eastern site (a) is near the location where the upper and lower splays of the fault merge into one. An erosional gully has cut through the hanging wall and has exposed part of the fault zone at the base of the gully. A trench can be located along the west wall of the gully exposing the sediments above the fault. The western locality (b) lies where an east-west cross fault intersects the lower trace of the Rattlesnake Mountain fault. A gully has eroded through the basalts of the hanging wall but has not exposed the fault zone. We anticipated the sediment cover to be thicker here than at the first locality. Auger holes and the GPR from the first site led us to abandon the second site as a potential trench site.

<u>Geologic Description of Site a. Rattlesnake Mountain Fault</u>. Site a is located along the north flank of the Rattlesnake Mountain anticline where lava flows of the Columbia River Basalt Group (CRBG) have been thrust northeast over gently northeast dipping CRBG lava flows. At the study site the fault branches westward into upper and lower faults. Rattlesnake Mountain has overridden the anticlinal axis along the upper fault exposing only the steeply northeast dipping lava flows of the north limb of the anticline. At the fault site 6600-year-old ash from Mt Mazama and older sediments, including a caliche of undetermined age, are exposed in a gully and appear to overlie at least a portion of the fault zone. We were able to map out the extent of the ash horizon in the upper 9 feet of the section using the auger data.

<u>Snively Basin Complex.</u> Two potential trench sites were located along the upper splay of the Rattlesnake Mountain thrust fault in the Snively Basin complex (Figure 1). The lower elevation splays of the fault are all covered by thick deposits of talus and/or alluvial fan deposits making them poor candidates for trench studies. In addition, geologic studies indicate that the most recent movement occurred on the upper splay of the fault. The western site (c) is located near *Rattlesnake Creek*. Rattlesnake Creek has eroded through the hanging wall of the fault zone and provided a steep east wall to the gully that could provide exposure of the fault zone by excavating along the gully wall. This would reduce the amount of overburden that would be required to be excavated yet allow a deep cut into the fault zone. The eastern site (d) is at *upper Snively spring* where a gully has eroded through the hanging wall of the fault zone. This site appears to have more overburden that site (c) but is attractive for trench studies because it lies directly below the sag ponds that developed in the hanging wall of the fault.

<u>Geologic Descriptions of Site c, *Rattlesnake Creek*, and Site d, *Upper Snively Springs*</u>. Sites c and d are located along the upper most thrust fault of the Rattlesnake Mountain fault zone in the Snively Basin area. Mapping indicates that there is at least 4 km of shortening across the entire fault zone in this area. Three million year

old sediments have been overturned along the lower thrust fault but, based on field mapping, the upper most thrust fault has most recent movement. The uppermost thrust fault is marked by a north-thrusted anticline of basalt overlying nearly flat CRBG lava flows. A colluvial wedge of basalt and loess overlies the fault zone. The Pringle Falls E ash, 150,000 years old, was found a few hundred feet north of the two sites but was not encountered in a series of auger holes from the sites.

<u>Sag Ponds.</u> An extensive series of sag ponds developed in the hanging wall above the upper splay of the Rattlesnake Mountain fault. We have selected two localities (Figure 1, E) with sufficient sediment fill that have a very good potential for preserving datable material.

<u>Geologic Description of Site e, Sag Ponds.</u> A series of extensional grabens developed along the crest of the anticline overlying the upper Rattlesnake Mountain fault (Sites c and d in Snively Basin). These grabens can be traced discontinuously along the entire crest of the anticline in Snively Basin and form sag ponds up to 70 m wide and several 100 m long. A series of auger holes up to 9 feet deep in the sag ponds encountered layers of loess and several soil horizons.

<u>Ground Penetrating Radar Data.</u> We established a subcontract with Central Washington University to obtain the support of Dr. Brian Whiting, who used CWU-owned field equipment and processing facilities to obtain and process Ground Penetrating Radar (GPR) images of five sites for excavating and exposing sediments across the Rattlesnake Mountain Fault. Three potential trench (Rattlesnake and two in Snively Basin) areas described above were imaged across the fault, and two profiles were run across two graben-like sag ponds in the upper extensional areas of the hanging wall. For the cross-fault imaging at Rattlesnake Mountain, we ran two parallel lines with length of 190 m, one in the base of the gulley and the second above the wall of the gully, approximately 10 m higher position. At the western Snively Basin site (termed *Rattlesnake Creek Site*), we ran a single profile down an even slope for approximately 190 m. At the eastern Snively Basin site (termed *Upper Snively Springs*) we ran a profile along the west margin of the shallow gully for 170 m and a nearly parallel, but crossing, profile directly from above the eastern wall of the gully to the base of the slope. The GPR images for the fault-crossing profiles are shown in Figure 2. For the sag pond imaging, we conducted two parallel lines across the short axis of the grabens, approximately 70 to 80 m in length, and these images are shown in Figure 3.

We tested both 50 and 100 MHz antennae at several locations and concluded that the 50 MHz data were superior. There were interfering effects due to buried metallic objects and overhead power lines at the Rattlesnake Mountain location, these effects were noted in the field and logged. At other sites, we were able to remove most such problems (like downed fence wire, etc) but there are still some artifacts in the data that need to be considered during the interpretation. In general, the GPR data shows consistent reflections and changes in character for about the first 150 nanoseconds (ns) of data. Assuming a velocity of 0.07 m per ns,

this two-way time indicates that we were able to obtain reflected energy from depths as great as 5 m.

<u>Graduate Student Assistance.</u> Ms. Michelle Valenta, a graduate student at Washington State University, joined our team as a research assistant. Ms. Valenta has been assisting us in the Seismic Monitoring Program and will support us through the duration of this study.

<u>Publications.</u> There were no publications that resulted from this work during the reporting period. Related work on the currently estimated slip rates in the Yakima Fold belts was presented at the Workshop on Seismic Hazard Mapping for the Pacific Northwest, March 30-31, 2000, sponsored by the U.S. Geological Survey. Digitized fault traces, dips, and the slip rates and maximum magnitude estimates were provided to Dr. Art Frankel earlier this year.

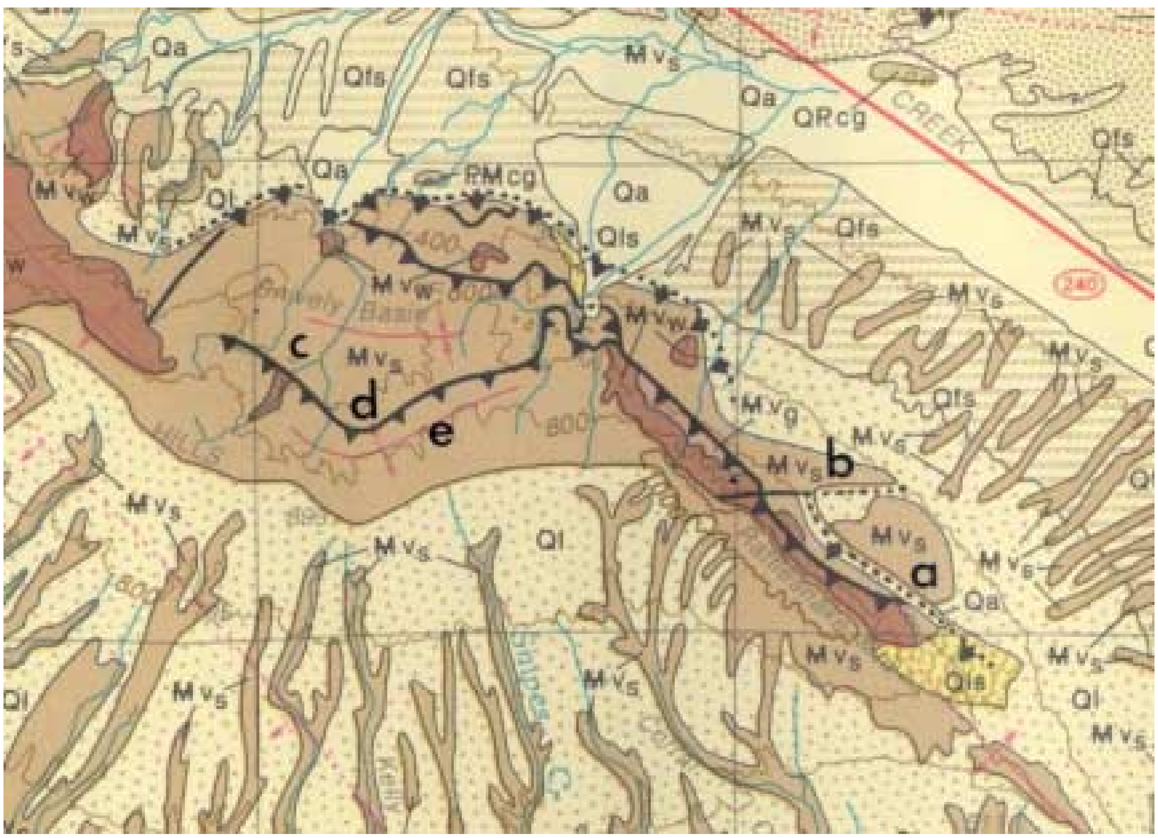


Figure 1. Geologic map of the Rattlesnake Mountain-Snively Basin Area in south-central Washington. Letters show he location of investigation areas discussed in the text. Fine lines in the figure are township/range lines 6 miles apart.

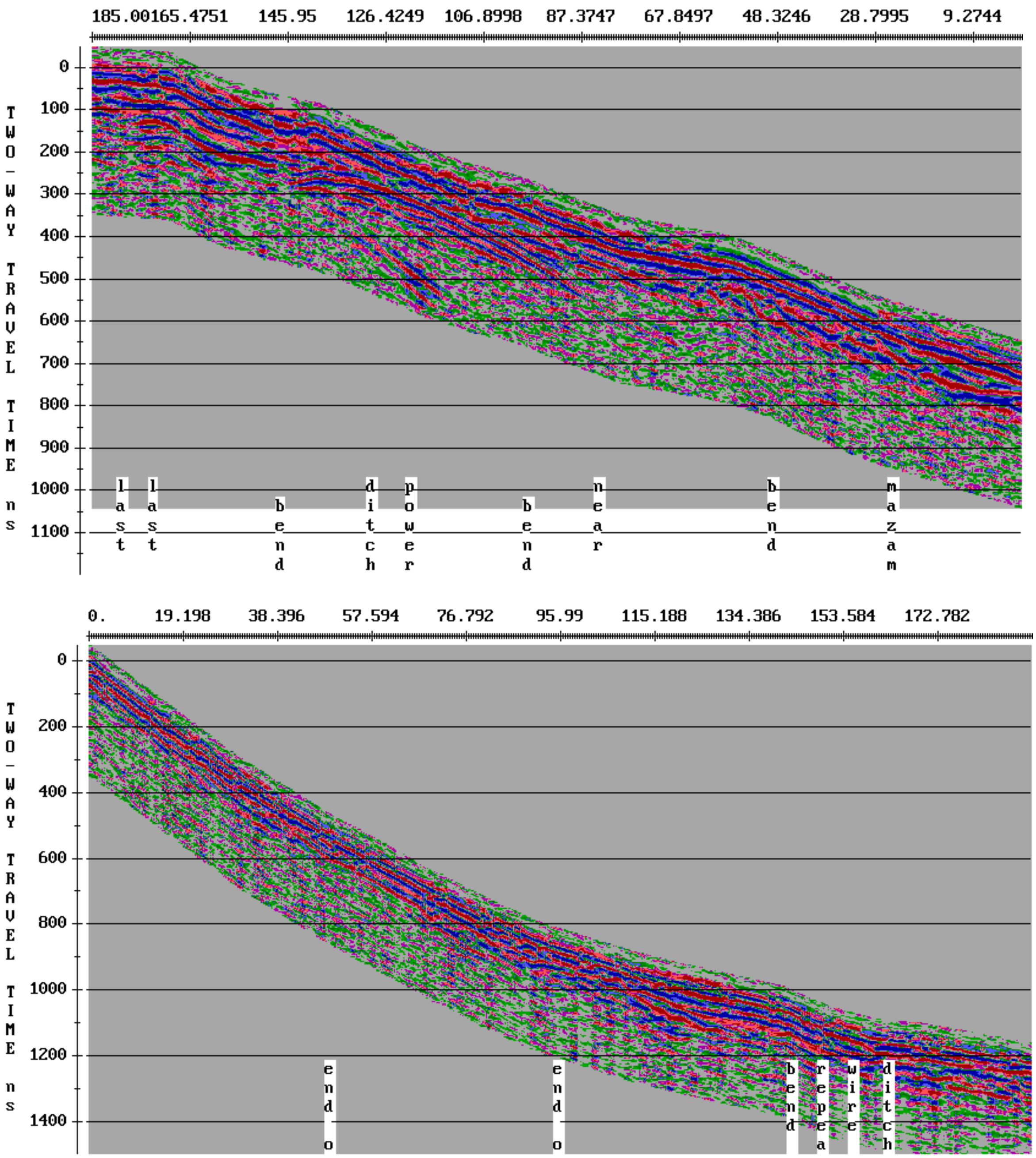
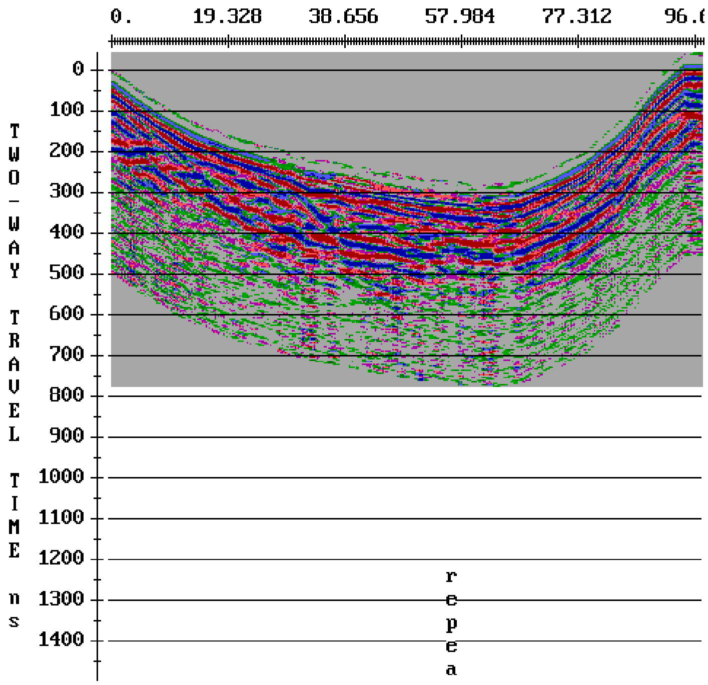


Figure 2. Examples of GPR images for Rattlesnake Mountain profile above gully (top), and of the western Snively Basin profile at Rattlesnake Creek (bottom). On the upper figure, the broad hyperobolae at late times are caused by overhead wires. In both images, there are dipping horizons and changes in reflection character detected.



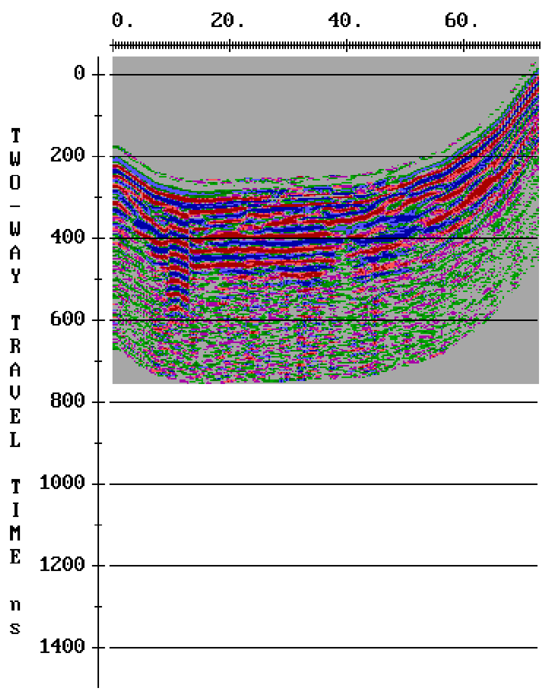


Figure 3. GPR images across two of the sag ponds. The effect of the shallowing depth to basalt beneath the sediments in the graben can be seen on either end of these profiles.

Non-Technical Summary

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The Olympic-Wallowa Lineament is a 500-km alignment of folds and faults stretching from northeast Oregon across Washington to the Puget Sound area. This feature passes close by the US Department of Energy's Hanford Nuclear Site, the Tri-Cities of central Washington, and several major dams on the Columbia River. Detailed geologic studies have identified areas of potentially young fault activity not previously recognized is this area, suggesting a potentially higher seismic hazard than previously recognized. Key local experts are performing detailed shallow geologic and geophysical investigations along the faults, to select sites for excavating and dating the fault movement history.