Paleoseismic Investigation of Earthquake Hazard and Long-Term Movement History of the Hurricane Fault, Southwestern Utah and Northwestern Arizona
Final Technical Report

William R. Lund, Philip A. Pearthree, Lee Amoroso, Michael J. Hozik[4], and Stanley C. Hatfield

Principal Investigator, Utah Geological Survey
SUU Box 9053, Cedar City, UT 84720
(435) 865-8126, lund@suu.edu

Co-Principal Investigator, Arizona Geological Survey
416 W. Congress Street, Tucson, AZ 85701
(520) 770-3500, Pearthree_Phil@pop.state.az.us

Arizona State University
Box 871404, Tempe, AZ 85287-1404
(480) 965-4053, lamoroso@asu.edu

The Richard Stockton College of New Jersey
P.O. Box 195, Pomona, NJ 08240-0195
(609) 652-4277, hozikm@loki.stockton.edu

Southwestern Illinois College
2500 Carlyle Ave., Belleville, IL 62221
(618) 235-2700, ext. 5159, stan.hatfield@southwestern.cc.il.us

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TECHNICAL ABSTRACT

The Utah Geological Survey (UGS) and Arizona Geological Survey (AZGS) are cooperators on a study of the Hurricane fault in southwestern Utah and northwestern Arizona. The Hurricane fault is one of the longest and most active of several large, late Cenozoic, west-dipping normal faults within the structural and seismic transition between the Colorado Plateau and Basin and Range physiographic provinces. Assessing the seismic hazard of the Hurricane fault is important because southwestern Utah is experiencing a now decades-long construction and population boom. The UGS investigated the paleoseismicity and long-term slip history of the northern portion of the fault (proposed Ash Creek and Anderson Junction segments) in Utah. The AZGS studied the proposed Shivwitz segment to better understand the geologic controls of earthquake rupture on the Hurricane fault in Arizona.

Utah

Approximately 80 kilometers of the Hurricane fault trend north-south through southwestern Utah. Displaced Quaternary basalt flows (hundreds of meters) and alluvial and colluvial deposits (meter to tens of meters) indicate a moderate rate of Quaternary fault activity. The UGS proposed to excavate trenches across fault scarps formed on unconsolidated deposits to characterize the size, timing, and rate of late Quaternary faulting, and to calculate long-term slip rates from displaced basalt flows.

There are six fault scarps on unconsolidated deposits on the Utah portion of the fault. The preferred UGS trench site at Coyote Gulch is on private property and was unavailable for study. Trenching at Shurtz Creek, the best alternative site, encountered large boulders that prevented exposing the fault zone. The remaining sites had similar geologic constraints or access problems, so the UGS refocused on dating geologically young alluvium that overlies the fault at three locations on the Ash Creek segment. The alluvium at the two northern sites (Middleton and Bauer) is not faulted, while the sediments at the southern site (Coyote Gulch) are displaced. Radiocarbon ages from detrital charcoal recovered from the alluvium at the Bauer and Coyote Gulch sites, were 330-525 cal B.P. and 1,055-1,260 cal B.P., respectively. Charcoal from a paleosol at the Middleton site gave an age of 1,530-1,710 cal B.P. The difference in ages of the alluvium at Coyote Gulch and Middleton sites, and the fact that the sediments at Coyote Gulch are faulted and those at Middleton are not, show that the most recent surface-faulting earthquake (MRE) at Coyote Gulch did not extend north to the Middleton site, indicating the likely presence of a seismogenic boundary between the two sites. The most likely location for a boundary is at a right bend in the fault north of Coyote Gulch. The new northern fault segment is named the Cedar City segment and is approximately 20 kilometers long. The redefined Ash Creek segment is about 33 kilometers long. Based on those lengths and on limited displacement-per-event data, the Cedar City segment can produce a M 6.6 earthquake and the Ash Creek segment can produce a M 6.9-7.1 event.

The Hurricane fault displaces Quaternary basalt flows at several locations in Utah.

Determining long-term slip rates for the fault using the displaced flows required correlating the flows across the fault using trace-element geochemistry and new geologic mapping, dating correlative flows using $^{40}Ar/^{39}Ar$ dating techniques, and evaluating near-fault deformation using a combination of paleomagnetic vector analysis and geologic mapping.

Geochemical data identified four locations in Utah where displaced basalts are correlative across the Hurricane fault: two on the Anderson Junction segment, one at the proposed boundary between the Anderson Junction and Ash Creek segments, and one on the Ash Creek segment. A fifth basalt site is 12 kilometers east of the fault in Cedar Canyon and consists of a basalt remnant that occupies the ancestral channel of Coal Creek high on the north canyon wall. The basalt flow displaced Coal Creek, forcing the stream to incise a new channel and leaving the basalt remnant stranded above the present stream. Coal Creek grades to Cedar Valley and crosses the Hurricane fault at the mouth of Cedar Canyon. Fault movement controls the stream base level and therefore the stream-incision rate, which is a proxy for slip on the fault.

The new long-term slip rates range from 0.21 to 0.57 mm/yr and generally increase from south to north along the fault. Additionally, slip appears to increase incrementally across the suspected Ash Creek/Anderson Junction segment boundary. Although little change in long-term slip rate is apparent across the proposed Ash Creek/Cedar City segment boundary, slip rates reported for segmented faults elsewhere in the western United States indicate that a seismogenic boundary could still be present. A comparison of these new long-term slip rates with late Quaternary rates shows that slip has slowed on the Hurricane fault in more recent geologic time, and that the average recurrence for surface-faulting earthquakes is now several thousand to more than ten thousand years.

Of the three seismogenic segments in Utah, the newly proposed Cedar City segment has gone the longest without a surface-faulting earthquake. The proxy slip rate available for the Cedar City segment closely approaches that of the adjacent Ash Creek segment, which has had a Holocene surface-faulting earthquake. Given its long-term record of activity and because it has gone the longest without a surface-faulting earthquake, the Cedar City segment is considered the most likely location for surface faulting on the Hurricane fault in Utah.

Arizona

Studies to characterize the late Quaternary rupture history of the Shivwitz segment of the Hurricane fault included: geologic and geomorphic mapping, scarp profiling, trenching, and geochemical correlation and dating of a displaced basalt flow. The mapping showed that Quaternary units displaced by the fault include the Moriah Knoll basalt and late Pleistocene to early Holocene (?) alluvial and colluvial deposits. Slip-rate estimates from scarp profiles and carbonate-rind-thickness surface-age estimates range from 0.03 to 0.61 mm/yr. The data show a trend for higher scarps to be older, but this was not true for all profiles. In contrast to results in Utah, slip rates on the Shivwitz segment are generally higher when determined using younger geomorphic surfaces. The reasons for this are not fully understood, but possible sources of slip-rate error include uncertainty in the age of displaced surfaces and underestimation of net slip due to burial of the hanging-wall surface by younger deposits.

The trench was excavated on a large, Pleistocene alluvial fan that is an estimated 15,000-33,000 years old near Moriah Knoll. The scarp there is 4.5 meters high, shows little evidence of erosion, and likely represents multiple surface-faulting events. Stratigraphy in the trench consisted of debris-flow deposits in the footwall, and fault-scarp colluvium, fissure-fill deposits, slope-wash deposits, and a likely fluvial gravel deposit in the hanging wall. Two distinct colluvial-wedge deposits provide evidence for two surface-faulting earthquakes. No stratigraphic units in the trench correlate across the fault. Secondary geologic relations indicate that total slip for the two events is 4.33 to 4.66 meters. Retro-deformation analysis suggests that the MRE produced about 2.5 meters of vertical displacement. Detrital charcoal recovered from fissure-fill material below the MRE colluvial wedge had an age of 9,300 +1070, -430 cal B.P., which is considered close to the maximum age for the MRE.

Geochemical data show that the Moriah Knoll flow is correlative across the fault, and a new $^{40}Ar/^{39}Ar$ date establishes the age of the basalt at 0.83 ± 0.06 Ma. There has been about 200 meters of displacement since the flow was extruded, resulting in a long-term slip rate for the Shivwitz segment of 0.24 mm/yr.

A MRE single-event maximum surface displacement of 2.5 meters along the southern Shivwitz segment gives an estimated moment magnitude of 7-7.1. Using an estimated segment length of 57 kilometers, the Shivwitz segment is capable of producing M 6.8-7 events.