SUMMARY
Utah Quaternary Fault Parameters Working Group Meeting
Wednesday, February 13, 2008
Utah Department of Natural Resources Building, Room 1060
1594 West North Temple, Salt Lake City

WELCOME AND INTRODUCTION

Bill Lund (Utah Geological Survey [UGS]) called the 2008 Utah Quaternary Fault Parameters Working Group (UQFPWG) meeting to order at 8:00 a.m. After welcoming Working Group members and guests (see attached list), Bill summarized the UQFPWG's past activities and outlined the Working Group's purpose and goals for the future.

UQFPWG History

- Expert panel convened in 2004 to evaluate the paleoseismic-trenching data available for Utah's Quaternary faults.
- Used experience and best professional judgment to assign preferred consensus recurrence-interval (RI) and vertical-slip-rate (VSR) estimates, and "best estimate" confidence limits for faults under review.
- Resulting consensus RI and VSR estimates and associated confidence limits represent the best presently available information regarding the faults/fault sections reviewed.
- Recommended additional paleoseismic study of 20 faults/fault sections to characterize Utah's earthquake hazard to "a minimally acceptable level."
- In 2007, recommended an additional five faults/fault sections for further paleoseismic study.

UQFPWG Today

- Helps set and coordinate the earthquake-hazard research agenda for the State of Utah.
- Reviews ongoing paleoseismic research in Utah, and updates the Utah consensus slip-rate and recurrence-interval database as necessary.
- Provides advice/insight regarding technical issues related to fault behavior in Utah and the Basin and Range Province.
- Identifies and prioritizes future Utah Quaternary fault studies.

TECHNICAL PRESENTATIONS

The remainder of the morning was devoted to presentations on current paleoseismic research/activities in Utah. Presentations were as follows:

- Nephi segment, Spring Lake trenching update: Daniel Horns, UVSC
- Weber segment, Rice Creek trenching results; Chris DuRoss, UGS
- East Cache fault zone trenching update; Stephanie Davi, USU
- East Canyon and Main Canyon fault trenching results; Larry Anderson, USBR
- Washington fault reconnaissance; Tyler Knudsen, UGS
- Upcoming Brigham City segment trenching; Greg McDonald, UGS
- Vertical displacement on the central segments of the Wasatch fault zone; Chris DuRoss, UGS
- Update on EarthScope/Lidar studies in Utah, new GPS data for the Wasatch Front, and ideas on fault segment scale; Robert Smith, UUGG

TECHNICAL DISCUSSION ITEMS

After lunch, the Working Group considered the following technical discussion items:

- New Levan segment vertical-slip-rate estimate; Mike Hylland, UGS
- New Nephi segment vertical-slip-rate and recurrence-interval estimates; Chris DuRoss, UGS/Steve Personius, USGS
- UQFPWG fault priorities for 2009
- Wasatch Front community fault model
- Time dependent earthquake models – is the Wasatch fault a candidate?

New Levan Segment Slip-Rate Estimate

Based on data from previous paleoseismic investigations on the Levan segment of the Wasatch fault at Deep Creek (Schwartz and Coppersmith, 1984; Jackson, 1991) and Skinner Peaks (Jackson, 1991), the UQFPWG determined a consensus vertical slip rate for the segment of 0.1-0.6 mm/yr (Lund, 2005). At Deep Creek, timing of the most recent surface-faulting earthquake (MRE) is well constrained at shortly after 1000 ± 200 cal yr B.P. based on ^{14}C and thermoluminesence (TL) ages from a paleosol beneath the MRE colluvial wedge (Hylland and Machette, 2008). Penultimate earthquake (PE) timing at Deep Creek was based on a single, uncalibrated ^{14}C age of 7300 ± 1000 yr B.P. on detrital charcoal collected from a debris-flow deposit in the fault footwall (Schwartz and Coppersmith, 1984). Structural and stratigraphic relations at the Deep Creek exposure (stream bank) provide evidence for only the MRE. Therefore, the PE must be older than the faulted debris-flow deposit that contained the detrital charcoal. Because the charcoal is detrital, it is older than the debris-flow deposit in which it was found, but how much older is unknown; the difference could be as much as several hundred years. Therefore, due to the uncertainties related to the age of the detrital charcoal and the debris-flow deposit in which it was found, and the unknown amount of time that elapsed between the PE and deposition of the debris flow, the detrital charcoal age estimate from Deep Creek provides a very poorly constrained minimum limit on PE timing.

To better constrain the vertical slip rate on the Levan segment, Hylland and Machette (2008) used CALIB 5.0.1 to calendar calibrate the 7300 ± 1000 yr B.P. detrital charcoal age at Deep Creek. They obtained a median age and uncertainty limits rounded to 100 years of 8300 ± 2300 cal yr B.P. They then reexamined the paleoseismic data for Skinner Peaks, where Jackson (1991) found evidence for two surface-faulting earthquakes. Based on TL and ^{14}C ages from a burn layer in the fault footwall, Jackson (1991) reported a preferred maximum limit on MRE timing of 1000-1500 cal yr B.P. Using a ^{14}C age from a buried incipient soil A horizon on the hanging wall, Jackson reported a preferred minimum limit on PE timing of 3900 cal yr B.P. Hylland and Machette (2008) used CALIB 5.0.1 to recalibrate Jackson's hanging-wall ^{14}C age (3720 ± 90 yr B.P.), and after subtracting a 100-year mean-residence-time correction to conform with Jackson's (1991) calibration procedure, obtained a median age and uncertainty limits rounded to the nearest 100 years of 4000 ± 300 cal yr B.P.

Hylland and Machette (2008) then used MRE net vertical tectonic displacements from Deep Creek and Skinner Peaks, MRE timing from both sites, and their recalibrated minimum estimates of PE timing to make vertical-slip-rate estimates for Deep Creek (0.18 – 0.38 mm/yr) and Skinner Peaks (0.55 - 2.3 mm/yr). Both slip-rate estimates are maximums because the PE timing estimates are both minimums, resulting in the shortest possible elapsed time between the MRE and PE being used to calculate the vertical slip rates.

Based on their reexamination of PE timing on the Levan segment, Hylland and Machette (2008) concluded (1) that a Holocene vertical slip rate of 2.3 mm/yr is unreasonably high for the segment, (2) the remainder of their slip-rate estimates fall within the range of the UQFPWG's consensus vertical-slip-rate estimate for the segment, and (3) no change in the UQFPWG's consensus values for the Levan segment is warranted at this time.

New Nephi Segment Slip-Rate and Recurrence-Interval Estimates

Based on data from previous paleoseismic trenching investigations on the Nephi segment of the Wasatch fault at North Creek (Hanson and others, 1981) and Red Canyon (Jackson, 1991), the UQFPWG established the following consensus paleoseismic parameters for the segment (Lund, 2005).

Earthquake Timing:

P1: ≤ 1000 ± 400 cal yr B.P., possibly as young as 400 ± 100 yrs
P2: ~3900 ± 500 cal yr B.P.
P3: > 3900 ± 500, < 5300 ± 700 cal yr B.P.

Recurrence Interval:

1200-2500-4800 (three events in 5 kyr)

Vertical Slip Rate:

0.5-1.1-3.0 mm/yr

When the Working Group determined their consensus values, they noted that the paleoseismic data for the Nephi segment were poorly constrained, and placed the Nephi segment first on their priority list of faults recommended for further paleoseismic study.

In 2005, the UGS and the U.S. Geological Survey (USGS) undertook a cooperative investigation of the Nephi segment. The Nephi segment consists of a northern 17-km-long strand, and a southern 25-km-long strand separated by an approximately 5-km-wide right step-over in the fault trace. The USGS trenched the southern strand at Willow Creek (Machette and others, 2007), and the UGS trenched the northern strand at Santaquin (DuRoss and others, in press). Results of the two trenching studies were as follows:

Willow Creek

Three surface-faulting earthquakes in < 2.5 kyr (timing from OXCAL modeling):
P1: 140-340 cal yr B.P.
P2: 1100-1350 cal yr B.P.
P3: 1450-2310 cal yr B.P.

Two-sigma recurrence interval (from OXCAL modeling):
P1-P2: 830-1150 yr
P2-P3: 220-1070 yr
P1-P3: 595-1045 yr

Late Holocene Vertical Slip Rate:
2.6 mm/yr (6m/2.3 kyr)

Santaquin

One surface-faulting earthquake in < 6-7 kyr
P1: 330-550 cal yr B.P.
P2: > 6-7 ka

Recurrence Interval:
Indeterminate at present

Latest Pleistocene Vertical Slip Rate:
0.5 mm/yr based on vertical displacement of a nearby Bonneville shoreline.

In 2007, Utah Valley State College (UVSC) trenched the northern strand of the Nephi segment at Spring Lake, about a kilometer north of the Santaquin trench site. The Spring Lake trench shows evidence for two surface-faulting earthquakes, but determining the timing of those earthquakes is on hold pending the availability of funds for radiocarbon dating.

Comparison of OXCAL age-distribution-probability curves for the MREs at Santaquin and Willow Creek shows only a small area of overlap between the two curves, making it unlikely that the two MREs represent the same earthquake. Conversely, the age-distribution-probability curves for the Santaquin MRE and the Mapleton MRE on the Provo segment to the north (Olig, unpublished data) show a large area of overlap, suggesting that those MREs represent the same earthquake. If so, the Santaquin strand of the Nephi segment has ruptured sympathetically during at least one large paleoearthquake on the Provo segment. When complete, results from the UVSC trench at Spring Lake will provide additional information on the timing of the northern strand (Nephi segment) MRE, and will possibly permit comparison of the timing of the northern strand PE with the PEs on the southern Nephi strand and the Provo segment.

Because the pending paleoseismic information from the Spring Lake trench site may help clarify the relation of the northern strand of the Nephi segment to both the Provo segment to the north and the remainder of the Nephi segment to the south, the Working Group chose to postpone revising the consensus earthquake timing, recurrence-interval, and vertical-slip-rate values for the Nephi segment until the new Spring Lake data are available.

UQFPWG 2008 Fault Study Priorities

In 2005, the UQFPWG recommended that 20 Quaternary faults/fault segments in Utah receive further investigation to "adequately characterize Utah's earthquake hazard to a minimally acceptable level" (Lund, 2005). In 2007, the Working Group recommended an additional five faults/fault segments for study (table 1). The UQFPWG reviews the progress made toward investigating the recommended faults/fault sections annually, and based on that review adjusts their list of highest priority faults/fault segments. Two faults from the Working Group's 2007 highest priority list were funded by the National Earthquake Hazards Reduction Program (NEHRP) for study in 2008. They are the Brigham City segment of the Wasatch fault zone - most recent event (UGS/USGS), and the Utah Lake faults and folds (UUGG; table 2). Considering the two newly funded studies, the Working Group elevated the rapidly urbanizing Washington fault to their 2008 list of highest priority faults/fault segments for study (table 2).

Table 1. Quaternary faults/fault segments identified by the UQFPWG as requiring additional study to adequately characterize Utah's earthquake hazard to a minimally acceptable level.

Fault/Fault Segment	Original UQFPWG Priority (2005)
Nephi segment WFZ	1
West Valley fault zone	2
Weber segment WFZ – most recent event	3
Weber segment WFZ – multiple events	4
Utah Lake faults and folds	5
Great Salt Lake fault zone	6
Collinston & Clarkston Mountain segments WFZ	7
Sevier/Toroweap fault	8
Washington fault	9
Cedar City-Parowan monocline/ Paragonah fault	10
Enoch graben	11

East Cache fault zone	12
Clarkston fault	13
Wasatch Range back-valley faults	14
Hurricane fault	15
Levan	16
Gunnison fault	17
Scipio Valley faults	18
Faults beneath Bear Lake	19
Eastern Bear Lake fault	20
Bear River fault zone	Added 2007
Brigham City segment WFZ – most recent event	Added 2007
Carrington fault (Great Salt Lake)	Added 2007
Provo segment – penultimate event	Added 2007
Rozelle section – Great Salt lake Fault	Added 2007

Table 2. UQFPWG 2008 priority list of Quaternary faults/fault segments requiring additional study to adequately characterize Utah's earthquake hazard to a minimally acceptable level and status of current paleoseismic investigations.

2008 Highest Priority Faults/Fault Sections For Study			
Fault/Fault Section	**Priority[1]**	**Investigation Status**	**Investigating Institution**
Provo segment – penultimate event	1	No activity	
West Valley fault zone	1	No activity	
Washington fault	3	Reconnaissance study	UGS
Carrington fault (Great Salt Lake)	4	No activity	
Rozelle section, Great Salt Lake fault	5	No activity	
Other Priority Faults/Fault Sections Requiring Further Study			
Fault/Fault Section	**Original UQFPWG Priority**	**Investigation Status**	**Investigating Institution**
Cedar City-Parowan monocline/ Paragonah fault	10	No activity	
Enoch graben	11	No activity	
Clarkston fault	13	No activity	
Wasatch Range back-valley faults	14	No activity	
Gunnison fault	17	No activity	
Scipio Valley faults	18	No activity	
Faults beneath Bear Lake	19	No activity	
Eastern Bear Lake fault	20	No activity	
Bear River fault zone	2007	No activity	
Faults/Fault Sections Studies Complete or Ongoing			
Fault/Fault Section	**Original UQFPWG Priority**	**Investigation Status**	**Investigating Institution**
Nephi segment WFZ	1	UGS Special Study 124/USGS Map 2966/UVSC study ongoing	UGS/USGS/UVSC
Weber segment WFZ - most recent event	3	Ongoing	UGS/USGS
Weber segment WFZ – multiple events	4	Ongoing	UGS/USGS
Utah Lake faults and folds	5	Study begins summer 2008	UUGG
Great Salt Lake fault zone	6	Ongoing	UUGG
Collinston & Clarkston Mountain segments WFZ	7	UGS Special Study 121	UGS
Sevier/Toroweap fault	8	UGS Special Study 122	UGS
East Cache fault zone	12	Ongoing	USU
Hurricane fault	15	UGS Special Study 119	UGS
Levan	16	UGS Map 229	UGS
Brigham City section - most recent event	2007	Study begins summer 2008	UGS/USGS

[1]Provo segment PE and West Valley fault zone were both ranked as first priority by the UQFPWG for future study.

Wasatch Front Community Fault Model

Robert Smith, UUGG, and Mark Petersen, USGS, facilitated a discussion of the need for a Wasatch Front Community Fault Model (WFCFM) similar to the CFM developed for southern California. The discussion was wide ranging, and the following key points surfaced regarding a WFCFM.

- Creating a CFM is a costly undertaking; it has only been done in Southern California under the auspices of Southern California Earthquake Center. That project required the multiyear, full-time commitment of a structural geologist and a computer programmer/GIS specialist at a major research university (Harvard). Salary support and hardware/software costs were major considerations. Some of the software used to create the Southern California CFM is specialized and not commonly available.

- Although useful for investigating the interaction of faults in a complex system and obtaining proxy fault slip rates where field data are lacking, the utility of a CFM to earthquake hazard reduction is otherwise limited, especially considering the high cost of creating a model.

- Too many "first order" technical questions about faults in the Wasatch Front region remain unanswered, particularly regarding their dips and relation to each other at seismogenic depths. It was estimated that only about 10% of the data need to construct a reliable WFCFM is available at the present time.

- A suggestion was made that if constructing a WFCFM is a high priority, future NEHRP grant proposal solicitations should focus on supporting the research required to generate the data necessary to build the model.

Time-Dependent Earthquake Models – Is the Wasatch Fault a Candidate?

Susan Olig (URS Corp.) and Kathy Haller (USGS) facilitated a discussion on Wasatch fault time-dependent earthquake models. Susan reported that URS routinely conducts time-dependent probabilistic seismic hazard analyses (PSHA) for projects on the Salt Lake City, Brigham City, and Provo segments of the Wasatch fault—the three Wasatch fault segments with the longest and best constrained paleoseismic records. URS uses a lognormal renewal model with a 50-year time period of interest. They calculate "equivalent Poisson" recurrence intervals (time-dependent recurrence intervals) for use in PSHA. The input needed for the URS model includes mean recurrence (from UQFPWG; Lund, 2005), elapsed time (from UQFPWG; Lund, 2005), and coefficient of variation, which measures the periodicity of earthquake occurrence. Time-dependent recurrence intervals calculated using the URS methodology show that the earthquake hazard goes up for the Brigham City and Salt Lake City segments compared to Poisson recurrence, and goes down for the Provo segment. These results reflect the comparatively long elapsed time since the most recent surface-faulting earthquake on the

Brigham City and Salt Lake City segments and the comparatively short elapsed time since the last surface-faulting earthquake on the Provo segment.

Kathy Haller reviewed the history and methodologies of the various Working Groups on California Earthquake Probabilities. Four Working Groups (WG88, WG90, WG99, and WG02) each developed a 30-year probability of a $M \geq 6.7$-7.0 earthquake in the San Francisco Bay region (SFBR). Each successive Working Group produced more sophisticated probability estimates by incorporating additional faults, constraining overall moment budget, considering background seismicity, and introducing alternative probability models. The current probability estimate (WG02) states that there is a 62% probability of a $M > 6.7$ earthquake in the SFBR over the next 30 years (2002-2031). The 95% confidence boundaries for the probability are 37–87%, which Kathy noted are quite broad.

Kathy then reviewed the current status of paleoseismic information available for the Wasatch fault, which is the best studied fault in the Intermountain West. Consensus fault parameters (Lund, 2005) are available to contribute to a preliminary time-dependent model, and recent studies continue to refine mean recurrence and most-recent-event timing. However, additional improvements are possible/necessary in the paleoseismic data (improved magnitude estimates, realistic rupture scenarios, longer paleoseismic records, etc.) before a time-dependent probability estimate for the Wasatch fault can be incorporated into the National Seismic Hazard Maps (NSHM). Currently, the USGS does not use time-dependent fault models in the NSHMs, and cautions against using unvetted research results to form the basis for public-policy decisions. The USGS considers time-dependent fault models a field of promising ongoing research, has constructed such models for faults in different parts of the country (California, Alaska, Utah), and will continue to make time-dependent models on a research basis as more data become available.

The Utah Quaternary Fault Parameters Working Group meeting was adjourned at 4:55 p.m.

ATTACHMENT 1
Meeting Attendees

Quaternary Fault Parameters Working Group

Larry Anderson, USBR
David Dinter, UUGG
Chris DuRoss, UGS
Jim Evans, USU
Kathleen Haller, USGS
Ron Harris, BYU
Daniel Horns, UVSC
Michael Hylland, UGS
William Lund, UGS
Susan Olig, URS Corp.
James Pechmann, UUSS
Steve Personius, USGS
Mark Petersen, USGS
Robert Smith, UUGG
Ivan Wong, URS Corp.

Guests

Rick Allis, UGS
Bill Black, Western Geologic
Stephanie Davi, USU
Jamie Farrell, UUGG
Rich Giraud, UGS
Tyler Knudsen, UGS
David Marble, DNR Dam Safety
Greg McDonald, UGS
Christine Puskas, UUGG
David Simon, SBI-Simon-Bymaster, Inc.

ATTACHMENT 2
References Cited

DuRoss, C.B., McDonald, G.N., and Lund, W.R., 2008, Paleoseismology of Utah, Volume 17 - Paleoseismic investigation of the northern strand of the Nephi segment of the Wasatch fault zone at Santaquin, Utah: Utah Geological Survey Special Study 124, 33 p., 1 plate, CD-ROM.

Hanson, K.L., Swan, F.H., III, and Schwartz, D.P., 1981, Study of earthquake recurrence intervals on the Wasatch fault, Utah: San Francisco, Woodward-Clyde Consultants, Sixth Semi-Annual Technical Report prepared for the U.S. Geological Survey, contract no. 14-08-0001-16827, 22 p.

Hylland, M.D., and Machette, M.N., 2008, Surficial geologic map of the Levan and Fayette segments of the Wasatch fault zone, Juab and Sanpete Counties, Utah: Utah Geological Survey Map 229, scale 1:50,000, 37 p.

Jackson, M.E., 1991, Paleoseismology of Utah, Volume 3 - The number and timing of Holocene paleoseismic events on the Nephi and Levan segments, Wasatch fault zone, Utah: Utah Geological Survey Special Studies 78, 23 p.

Lund, W.R., 2005, Consensus preferred recurrence-interval and vertical slip-rate estimates – Review of Utah paleoseismic-trenching data by the Utah Quaternary Fault Parameters Working Group: Utah Geological Survey Bulletin 134, 109 p., CD-ROM.

Machette, M.N., Crone, A.J., Personius, S.F., Mahan, S.A., Dart, R.L., Lidke, D.J., and Olig, S.S., 2007, Paleoseismology of the Nephi segment of the Wasatch fault zone, Juab County, Utah – Preliminary results from two large exploratory trenches at Willow Creek: U.S. Geological Survey Scientific Investigation Map 2966, 2 sheets, available on line at pubs.usgs.gov/sim/2007/2966.

Schwartz, D.P., and Coppersmith, K.J., 1984, Fault behavior and characteristic earthquakes – Examples from the Wasatch and San Andreas fault zones: Journal of Geophysical Research, v. 89, no. B7, p. 5681-5698.