SUMMARY
Utah Quaternary Fault Parameters Working Group Annual Meeting
Wednesday, February 28, 2007
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 2007 Utah Quaternary Fault Parameters Working Group (UQFPWG) annual meeting to order at 8:00 a.m. After welcoming Working Group members and guests (see attached list), Bill summarized the Working Group's activities to the present, and outlined the purpose and goals of the Working Group for the future. Bill also reviewed the work of the Basin and Range Province Earthquake Working Group (BRPEWG), a team of subject-matter experts convened in 2006 under the auspices of the U.S. Geological Survey (USGS) National Seismic Hazard Mapping Project, the Western States Seismic Policy Council, and the UGS to consider five seismic-policy issues of importance to the Basin and Range Province (BRP). The seismic-policy issues were originally identified at the Basin and Range Province Seismic Hazard Summit II (Lund, 2005a), held in Sparks, Nevada, in April 2004. The goals of BRPEWG were to establish consensus recommendations on the issues, and to provide recommendations to the USGS on how those issues should be handled in the next update of the National Seismic Hazard Maps (NSHMs). Where consensus was not possible, the BRPEWG outlined possible research programs to resolve technical issues for the USGS to consider when setting future research priorities. Results of the BRPEWG process are available in UGS Open-File Report 477 (Lund, 2006).

UQFPWG History

- Expert panel convened in 2005 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."

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 fault slip-rate and recurrence-interval database when necessary.

- Provides advice/insight regarding technical issues related to fault behavior in Utah/BRP.

- Identifies and prioritizes future Utah Quaternary fault studies.

Seismic Policy Issues Considered by BRPEWG

- Use and relative weighting of time-dependent, Poisson, and clustering models to characterize BRP fault behavior.

- Proper magnitude-frequency distributions (Gutenberg-Richter vs. characteristic earthquake models) for BRP faults.

- Use of length vs. displacement relations to estimate earthquake magnitudes.

- Probabilities and magnitudes of multi-segment ruptures on BRP faults.

- Resolving discrepancies between horizontal geodetic extension rates and vertical geologic slip rates.

TECHNICAL PRESENTATIONS

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

- Nephi segment, Santaquin trench site results; Chris DuRoss, UGS

- Nephi segment, Willow Creek trench site results; Tony Crone, USGS

- Great Salt Lake fault zone update; Dave Dinter/Jim Pechmann, University of Utah (UU)

- Mapleton megatrench update; Susan Olig, URS Corp

- East Canyon fault trenching; Larry Anderson, U.S. Bureau of Reclamation (USBR)

- Sevier fault reconnaissance update; Tyler Knudsen, UGS

- Update on GPS studies of active tectonics in Utah; WuLung Chang, UU

- New Weber segment paleoseismic data; Bill Lund/Chris DuRoss, UGS; Tony Crone, USGS

TECHNICAL DISCUSSION ITEMS

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

- Revise the consensus slip rate for the Salt Lake City segment of the Wasatch fault zone; Bill Lund, UGS

- Utah Quaternary faults recommended for the 2007 update of the NSHMs; Chris DuRoss, UGS

- BRPEWG recommendations and the 2007 update of the NSHMs; Kathy Haller, USGS

Revise the Consensus Slip Rate for the Salt Lake City Segment of the Wasatch Fault Zone

The VSR estimate for the Salt Lake City segment (SLCS) of the Wasatch fault zone (WFZ) is based on data from a single location in southeastern Salt Lake Valley where the WFZ displaces glacial moraines of Bull Lake and Pinedale age at the mouths of Little Cottonwood and Bells Canyons. Scott (1988) reported an age for the younger moraines (Pinedale) of 18-26 ka, and Swan and others (1981) reported 14.5 +10/-3 meters of net vertical slip in the crest of the young moraines, resulting in a VSR since the latest Pleistocene of 0.7 +0.7/-0.3 mm/yr.

The 26 ka maximum limiting age for the young moraines is provided by a ^{14}C age on total organics from the Majestic soil; a paleosol developed on the older Bull-Lake-age moraine and which directly underlies the Pinedale-age moraine (Madsen and Currey, 1979). The 18 ka minimum limiting age is based on relations between the Pinedale-age moraine and high-stand deposits and geomorphic features of Pleistocene Lake Bonneville. The most recent paleoseismic study at the mouth of Little Cottonwood Canyon (McCalpin, 2002) identified a period of quiescence on the WFZ in latest Pleistocene and early Holocene time, followed by shorter earthquake recurrence intervals since the mid-Holocene. Therefore in its original deliberations, the UQFPWG concluded that most of the Pinedale moraine displacement likely occurred during the Holocene, and that the reported late Pleistocene VSR for the SLCS was too low. By comparison with VSRs reported for adjacent WFZ segments, the UQFPWG determined a consensus VSR for the SLCS of 1.2 +2.8/-0.6 mm/yr.

Recent work by Lips (Lips, 2005; Godsey and others, 2005), has established a younger age for the Pinedale moraines at Little Cottonwood and Bells Canyons. Based on new stratigraphic exposures, which show that the younger till is interfingered with and deposited on top of Lake Bonneville sediments, and new ^{10}Be cosmogenic exposure ages from boulders on the youngest moraines, Lips concluded that the maximum Pinedale glacial advance occurred at

approximately 16.9 ± 0.4 to 15.2 ± 0.4 ^{10}Be ka (mean 15.9 ± 0.7 ^{10}Be ka). His study produced no new measurements of moraine displacement, but the new mean moraine age (2 sigma uncertainty) combined with the pre-existing displacement measurement resulted in a new VSR estimate for the SLCS of 0.9 +0.8/-0.2 mm/yr.

The UQFPWG considered whether this new slip-rate data made it necessary to revise their consensus VSR for the SLCS. Their conclusion was that the new slip-rate information falls well within their broad consensus VSR estimate for the SLCS, and that it is not necessary to revise the consensus slip rate at this time.

Utah Quaternary Faults Recommended for the 2007 Update of the National Seismic Hazard Maps

The NSHMs presently include 23 Utah Quaternary faults. For the 2007 NSHM update, the UGS recommended that three fault zones, the West Cache fault zone (Clarkston fault), the Southern Oquirrh Mountain fault zone, and the Utah Lake faults and folds, be added to the map.

West Cache fault zone (Clarkston fault)

The Clarkston fault (CF) is the northernmost segment of the West Cache fault zone (WCFZ). It has a rupture length of 22 km in Utah and extends northward into Idaho. Black and others (2000) documented a large-magnitude, surface-faulting earthquake on this fault at 3600–4000 cal yr, and reported 9 m of displacement on the fault between approximately 3.8 and 16.8 ka. Using that information, Black and others (2000) calculated a VSR for the CF of 0.7 mm/yr. The UQFPWG determined a consensus VSR for the CF of 0.4 +0.3/-0.3 mm/yr, and the UGS recommended that the USGS add the CF to the NSHMs and use the UQFPWG consensus VSR for the next NSHM update. The UQFPWG concurred.

Southern Oquirrh Mountain fault zone

The Southern Oquirrh Mountain fault zone (SOFZ) has a surface rupture length of 27 km, and has generated 5–7 surface-faulting earthquakes between 4.6 and 92 ka with displacements ranging from 1.3–2.2 m per event (Olig and others, 2001). Using seismic cycles, Olig and others (2001) determined a long-term VSR of 0.09–0.14 mm/yr for the SOFZ, which is similar to the VSR determined for the Northern Oquirrh fault zone (NOFZ) directly on trend to the north. The UGS recommended that the SOFZ and the NOFZ be combined as a single seismic source (combined length 54 km), and that the UQFPWG consensus VSR for those faults of 0.2 +0.2/-0.15 mm/yr be used by the USGS for the next NSHM update. The UQFPWG concurred.

Utah Lake faults and folds

The Utah Lake faults and folds (ULF&F) lie entirely beneath Utah Lake. The faults and folds are poorly mapped, but high-resolution continuous seismic-reflection profiles (Baskin and Berryhill, 1998) in a restricted area of the lake show several west- and east-dipping normal faults displacing lake sediments, the most prominent of which exhibits 6–8 meters of west-dipping Holocene displacement (David Dinter, University of Utah, personal communication, 2007).

Black and others (2003) report a VSR of <0.1–0.4 mm/yr for the ULF&F, and Dinter (personal communication, 2007) believes the slip rate is 0.6–0.8 mm/yr. Based on this limited available data, the UGS recommended that the ULF&F be considered independently seismogenic, and that the USGS assign a VSR to the fault zone as a whole of 0.4 +0.3/-0.3 mm/yr.

However, Working Group members were not yet sufficiently comfortable with the paleoseismic data and mapping for the ULF&F to recommend adding this fault zone to the NSHMs. They instead recommend to the USGS that the ULF&F not be added to the NSHMs until additional, more detailed paleoseismic data and mapping are available.

BRPEWG Recommendations and the 2007 Update of the NSHMs

The BRPEWG recommendations for updating the NSHMs were presented to the USGS at the NSHM Intermountain West Regional Meeting in Reno, Nevada, in June 2006. Kathy Haller (USGS) reviewed the most important effects that resulted from incorporating the recommendations in the 2007 NSHM update.

Issue 5 – Resolving Discrepancies Between Geodetic Extension Rates and Geologic Slip Rates

The BRPEWG recommended changing the fault dip used to model BRP normal faults on the NSHMs from 60° to 50±10°. An examination of the literature has shown that there is no consensus on this issue. Reducing the fault dip raises the hazard and the effect is non-linear. Changing the dip from 50^{o} to 40^{o} has a greater effect on the hazard than changing the dip from 60^{o} to 50^{o}.

The BRPEWG recommendation to use the province-wide kinematic (GPS) boundary condition (12-14 mm/yr) as a constraint on the sum of geologic slip rates, and to modify the boundaries of the geodetic zones in the western Great Basin used in the 1996 NSHMs to better reflect the areas of high strain depicted on the GPS-based strain-rate map, were implemented on the 2007 NSHMs.

Issue 1 – Use and Relative Weighting of Time-dependent, Poisson, and Clustering Models in Characterizing Fault Behavior

The BRPEWG recommended that the USGS incorporate uncertainties in VSR and RI for significant BRP faults. This was done for those faults in Utah included on the NSHMs and for which the UQFPWG provided consensus VSR estimates and uncertainty limits. For most other BRP faults, VSRs are poorly constrained and their associated uncertainty limits are large and imperfectly known. In the BRP only the WFZ has reasonably well constrained segment RIs. The UQFPWG consensus RI estimates were used for five of the six Holocene active segments of the WFZ. The sixth segment (Levan) lacks trench-documented RI data and retained the same recurrence as the 2002 version of the NSHMs.

The West Cache fault zone (Clarkston fault), and the Southern Oquirrh Mountain fault zone were added to the NSHMs and assigned VSRs as recommended by the UGS (see above).

As per the UQFPWG's recommendation, the two Joes Valley fault sources shown on the 2002 NSHMs were combined to create a single seismic source and modeled using a RI of 10,000 years.

Issue 4 – Probabilities and Magnitudes of Multi-Segment Ruptures

The BRPEWG recommended that hazard calculation for the NSHMs consider the possibility of multi-segment ruptures on BRP faults, and that the two faults that ruptured together in the 1959 Hebgen Lake earthquake be treated as a single seismic source.

Most BRP faults are not characterized as segmented. The size of the maximum earthquake is based on the mapped length of the fault up to M7.5. Half of the moment budget is spent in earthquakes of this size (M±0.2). The remaining half of the moment budget is allocated to smaller earthquakes, generally from M6.5 up to the maximum magnitude. This approach allows a fault to generate earthquakes that affect smaller parts of the fault at random and avoids creating artificially high hazards at poorly constrained segment boundaries. One of the few exceptions to the unsegmented characterization is the Wasatch fault. Earlier versions of the national seismic hazard maps included the six central segments of the Wasatch fault as independent sources. The first draft of the 2007 maps includes the possibility (10%) of multiple-segment rupture along the Wasatch fault using a floating M7.4 earthquake with no fixed end points, which therefore may include currently defined segment boundaries and produce spill-over ruptures. The alternative model allows single-segment rupture using the UQFPWG consensus segment recurrence intervals and the other variables as assigned in the 2002 model.

The two faults that ruptured together during the Hebgen Lake earthquake were combined to create a single source on the NSHMs.

Issue 3 – Use of Length Versus Displacement Relations to Estimate Earthquake Magnitude

The BRPEWG recommended (a) including uncertainty in surface rupture length (SRL) and its consequences for magnitude, (b) using magnitude-displacement regressions to improve magnitude estimates where the magnitude from SRL appears inconsistent, and (c) constraining the minimum magnitude assigned to surface-faulting earthquakes to M 6.5 to be consistent with the hazard related to background seismicity.

Implementation of these recommendations requires considerable analysis and testing, and the USGS has not yet had time to perform those tasks.

Issue 2 – Proper Magnitude-Frequency Distributions (Gutenberg-Richter versus Characteristic Earthquake Models) for BRP Faults

The BRPEWG recommended that the weights assigned to the maximum magnitude and "floating exponential" models used for BRP faults on the 2007 NSHMs should, at a minimum, have the same weights as those used for BRP faults in California (2/3 - 1/3) unless there is a technical basis for deviating from this characterization.

The USGS had not resolved this issue by the time of the UQFPWG meeting, and was considering a variety of possible options, including changing the weights used for California "B" faults to 50/50 (1/2 – 1/2), which is the same weight presently assigned to most BRP faults.

UQFPWG 2007 FAULT STUDY PRORITIES

The UQFPWG reviewed the progress made toward investigating the 20 faults/fault sections originally identified by the UQFPWG (table 8, Lund, 2005b) as requiring further paleoseismic study. Of those 20 faults/fault sections, six have studies that are either complete or ongoing; three will be investigated beginning in 2007; two were identified during the 2006 UQFPWH meetings as high priority for study, but no action has been taken yet; and the remaining 10 have received no attention (table 1).

Table 1. Status of paleoseismic investigations of Utah Quaternary faults and fault sections originally identified by the UQFPWG (Lund, 2005b) as requiring additional study to adequately characterize Utah's earthquake hazard to a minimally acceptable level.

Fault/Fault Section	UQFPWG Priority	Investigation Status	Investigating Institution
Hurricane fault zone	15	UGS Special Study 119[1]	UGS (Lund and others, 2007)
Collinston & Clarkston Mountain segments WFZ	7	UGS Special Study 121	UGS (Hylland, 2007)
Levan	16	In press	UGS
Nephi segment WFZ	1	In review	UGS/USGS
Sevier/Toroweap fault	8	In review	UGS
Great Salt Lake fault zone	6	On going	University of Utah
Washington fault	9	On going	UGS
Weber segment WFZ – most recent event	3	Study begins in 2007	UGS/USGS
Weber segment WFZ – multiple event	4	Study begins in 2007	UGS/USGS
East Cache fault zone	12	Study begins in 2007	Utah State University
West Valley fault zone	2	UQFPWG 2006 priority – no study presently planned	
Utah Lake faults and folds[2]	5	UQFPWG 2006 priority – no study presently planned	
Cedar City-Parowan monocline/ Paragonah fault	10	No activity	
Enoch graben	11	No activity	
Clarkston fault[2]	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	

[1]Study did not include trenching. [2]Fault recommended by the UGS for addition to the NSHMs.

Additionally, the UQFPWG identified the Brigham City segment of the WFZ, the Carrington fault beneath Great Salt Lake, and the Bear River fault zone in extreme northern Utah as additional faults requiring further paleoseismic study, and added them to the Utah priority

paleoseismic investigation list. With those additions, the UQFPWG established the following priority fault study list for 2007.

Table 2. UQFPWG 2007 priority list of Utah Quaternary faults/fault sections requiring additional paleoseismic study to adequately characterize Utah's earthquake hazard.

Priority A – First Priority (listed alphabetically)
• Brigham City segment, Wasatch fault zone – timing of most recent event
• Carrington fault (Great Salt Lake)
• Provo segment, Wasatch fault zone – timing of penultimate event
• Rozelle section, northern Great Salt Lake fault
• Utah Lake faults and folds
• West Valley fault zone
Priority B – Second Priority (listed alphabetically)
• Bear River fault zone
• Cedar City-Parowan monocline/Paragonah fault
• Clarkston fault
• Eastern Bear Lake fault
• Enoch graben
• Faults beneath Bear Lake
• Gunnison fault
• Hurricane fault zone (Cedar City section)
• Levan segment, Wasatch fault zone – trench
• Scipio Valley faults
• Wasatch Range back-valley faults
Priority C (study in progress; need for further investigation to be determined)
• East Cache fault, southern section
• Nephi segment, Wasatch fault zone
• Promontory section, Great Salt Lake fault zone
• Sevier/Toroweap fault
• Washington fault
• Weber segment, Wasatch fault zone

POSSIBLE PROJECTS ADDRESSING NEHRP AND/OR BRPEWG RESEARCH PRIORITIES

NEHRP 2008 Intermountain West Request for Proposals

Although the 2007 UQFPWG meeting took place prior to the release of the USGS 2008 NEHRP Request for Proposals (RFP), the draft RFP was available for UQFPWG consideration. The Working Group reviewed the following RFP topics as possible opportunities for cooperative projects.

General

Prepare accurate and precise, digital Quaternary fault data sets for the western and eastern margins of the Great Basin as a step toward developing a three-dimensional Community Fault Model and eventually integrated geodetic/geologic model *(BRPEWG recommendation)*.

Utah Fault Specific

1. Studies of faults in Utah should focus on those structures that have been identified as priority by the UQFPWG (http://geology.utah.gov/ghp/workgroups/pdf/priorities2008.pdf).

2. In and adjacent to the urbanized areas of Utah, conduct studies that are designed to better characterize the paleoseismic histories of major faults whose rupture histories will affect time-dependent models of Utah's seismic hazards.

3. Evaluate the utility of newly acquired LIDAR imagery for the Wasatch Front for detailed mapping of faults, landslides, and areas of ground deformation.

4. Investigate whether geodesy can identify specific faults in Utah where strain is being localized as an indicator of high seismic hazard.

5. Investigate the dip of normal faults in Utah (using chiefly geophysics) to determine the best dip value(s) for converting fault slip rates to extensional rates for consistency with GPS data.

Results of the review did not identify specific projects that would address the above NEHRP priorities. Mark Petersen and Tony Crone, USGS, noted that the current level of fault mapping along the Wasatch Front is probably adequate for developing a three-dimensional Community Fault Model (CFM), but that fault dips are poorly constrained and need to be improved (especially at seismogenic depths [< ~15 km]), for use in a CFM. Jim Pechmann stated that using geophysics to determine fault dip (#5 above) might not be possible over most of the depth range of interest. Jim Evans, Utah State University, noted that drill-hole data and other already available information could improve fault-dip estimates in some areas of the Wasatch Front and the back valleys to depths of as much as 5 kilometers.

New LIDAR information is presently available for limited areas of Utah, and more will become flown in the near future as part of EarthScope. It was agreed that this new source of imagery needs to be evaluated to determine its utility for mapping Quaternary faults (#3 above), and particularly for finding previously unrecognized faults. The University of Utah continues to make GPS geodetic measurements (both campaign and fixed station) in Utah, and it was hoped that as that program acquires more stations and data, #4 above may become possible.

BRPEWG Research Recommendations

The UQFPWG considered the following BRPEWG research recommendations (Lund, 2006) as possible opportunities for cooperative projects related to Quaternary fault investigations in Utah.

1. Compile long-term paleoseismic records for BRP faults and determine VSR and RI distributions, timing, and possible causes for clustering. Identify and trench faults that have the potential to produce long-term paleoseismic records

(regardless of proximity to urban areas) to improve databases and provide insight into time-dependent fault behavior and modeling.

2. Investigate how to recognize and characterize fault–rupture segments, and the quality and quantity of paleoseismic data needed to support earthquake-segmentation models along BRP faults.

3. Construct earthquake-segmentation models for important, presently unsegmented BRP faults (based chiefly on field mapping and ultimately trenching).

4. Compare SRL and displacement data for Utah faults where both are available to identify discrepancies among magnitude regressions.

5. Prepare consistent-resolution Quaternary fault maps for the western margin of the Great Basin as a step toward developing a CFM and eventually an integrated geodetic/geologic model.

It was noted that more paleoseismic data are required to address numbers 1, 2, and 3, and that hopefully future studies of the faults/fault sections on the UQFPWG 2007 priority fault study list (table 2) would help provide that information. Number 4 has largely been done for the WFZ (DuRoss, in press), which is the only structure in Utah with sufficient displacement data to make a meaningful comparison.

The Utah Quaternary Fault Parameters Working Group meeting was adjourned at 4:15 p.m.

ATTACHMENT 1
Meeting Attendees

Quaternary Fault Parameters Working Group

Larry Anderson, U.S. Bureau of Reclamation
WuLung Chang, representing Robert Smith, University of Utah
Tony Crone, USGS
David Dinter, University of Utah
Chris DuRoss, UGS
Jim Evans, Utah State University
Kathleen Haller, USGS
Michael Hylland, UGS
William Lund, UGS
Susan Olig, URS Corporation
James Pechmann, University of Utah Seismograph Stations
Steve Personius, USGS
Mark Petersen, USGS
Ivan Wong, URS Corporation

Guests

Gary Christenson, UGS
Ed Fall, Utah Division of Water Resources
Rich Giraud, UGS
Tyler Knudsen, UGS
David Marble, DNR Dam Safety
Greg McDonald, UGS
Pete McDonough, Utah Seismic Safety Commission
David Simon, SBI-Simon-Bymaster, Inc.

ATTACHMENT 2
References Cited

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