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Calendar of Events

AUGUST 2004

19-20
**DPS/DES Public Officials
 Conference**
 Park City, Utah

SEPTEMBER 2004

26-30
WSSPC Annual Conference
 St. Louis, Missouri

OCTOBER 2004

18-22
**Southwest User Group
 Conference**
 Telluride, Colorado

BASIN & RANGE SEISMIC HAZARDS SUMMIT II

MAY 16-19, 2004; RENO-SPARKS, NEVADA

In May 2004, the Western States Seismic Policy Council (WSSPC), U.S. Geological Survey, and Federal Emergency Management Agency, along with western states geological surveys, sponsored the second Basin and Range Province Seismic Hazards Summit (BRPSHSII) in Reno-Sparks, Nevada. The meeting was successful in highlighting technical issues important to understanding earthquake hazards in the extensional Basin and Range Province (BRP), and in developing policy recommendations to aid BRP states in reducing losses. The BRPSHSII built on the results of the original BRPSHS in May 1997, also in Reno and sponsored by the same groups. Craig M. dePolo, Nevada Bureau of Mines and Geology (NBMG), was chairman of the organizing committee and general conference chair for both meetings.

The purpose of the BRPSHSII was to bring together geoscientists, engineers, emergency managers, and policy makers to present and discuss the latest earthquake hazards research and to evaluate its implications for hazard reduction and public policy. Sessions addressed: 1) general earthquake hazards issues, 2) estimating earthquake size and hazards from faults, 3) determining fault activity, 4) earthquake recurrence intervals, and 5) ground motions. The agenda included 26 invited speakers and 38 poster presentations, and nearly 100 attended the meeting.

Some of the specific important earthquake issues in the BRP identified and discussed at the BRPSHSII included: 1) using time-dependent, Poisson, and clustering models in characterizing fault behavior, 2) using displacements to estimate earthquake magnitudes, 3) the need for both short- and long-term paleoseismic records for faults, 4) modern geodetic extension rates and geologic slip rates, and 5) appropriate attenuation relations and stress drops in modeling ground motions, including consideration of evidence from precarious rock studies. The final session addressing ground motions also covered near-fault, site, and basin effects on ground shaking levels in the BRP.

Following each day's papers and panel discussions, John Price (Director, NBMG) led a discussion to identify important policy-related issues and develop policy recommendations for WSSPC to consider adopting. Five policy recommendations were developed at the BRPSHSII and were presented to the WSSPC Board in June. Final policy recommendations will be considered for adoption by WSSPC at the National Earthquake Conference in St. Louis in September 2004.

Papers presented at the BRPSHSII will be published in a proceedings volume edited by William R. Lund, Utah Geological Survey (UGS). The proceedings of the original BRPSHS were published and are still available as UGS Miscellaneous Publication 98-2. The BRPSHSII proceedings are scheduled for release by the end of the year.

UTAH GEOLOGICAL SURVEY EARTHQUAKE-RESPONSE PLANNING

BY BARRY J. SOLOMAN, UTAH GEOLOGICAL SURVEY

INTRODUCTION

Large earthquakes can disrupt lives with devastating effects on communities and individuals. Large earthquakes are infrequent in Utah, but when one occurs it may result in a costly tragedy. How can we best prepare for this paradoxical event that may be destructive but so infrequent that we could be complacent with a false sense of security? The best way to prepare is to follow the advice of our childhood music teachers—practice, practice, practice.

The Utah Geological Survey (UGS) is the lead state scientific agency responsible for understanding, documenting, and responding to earthquakes. To fulfill this responsibility, the UGS prepared a plan (*Utah Geological Survey Earthquake-Response Plan and Investigation Field Guide*, UGS Open-File Report 384) that provides guidelines for our response to significant earthquakes in Utah. The plan defines criteria for selection of earthquakes to be investigated, delineates roles of UGS personnel during response, and outlines investigation objectives and procedures. Realizing that writing a plan is not in itself enough for effective response, the UGS has coordinated a series of exercises to assess plan procedures and practice relevant activities to prepare for the unwanted but inevitable large earthquake.

EARTHQUAKE-RESPONSE EXERCISE ACTIVITIES

Because of the numerous plan components and participants interacting with the UGS when responding to an earthquake, exercises to date were related to individual aspects of the plan with the cooperation of appropriate state agencies and organizations. Participants included the Utah Department of Natural Resources (DNR) Administration and its Information Systems program, the Utah Division of Emergency Services and Homeland Security, the University of Utah Seismograph Stations, and the Structural Engineering Association of Utah. The exercises were not tests, but learning experiences to identify gaps and weaknesses in the plan.

Two exercises have been conducted, each examining an individual aspect required to respond to earthquakes. The first exercise looked at the system of communications required for UGS geologists in the field to rapidly transmit their findings to the DNR Emergency Operations Center (EOC—a facility established to coordinate the department's emergency-response effort), the state EOC (a similar facility to coordinate state efforts), and the University of Utah Seismograph Stations (UUSS). The exercise started with the UUSS notifying the UGS by e-mail of earthquake characteristics such as magnitude, instrumental location of the earthquake epicenter, and intensity of ground shaking using their new real-time Shake-Map capability. Upon notification, UGS geologists were dispersed throughout Salt Lake Valley and communicated their simulated findings by two-way radio with the DNR EOC. The locations of earthquake hazards were then posted on maps in the DNR EOC to direct the most effective use of emergency-response resources, and transmitted to the state EOC for use by other state agencies and emergency responders.

The second exercise looked at computer-aided communications and data-display procedures and their incorporation into the operations of a post-earthquake information clearinghouse. The clearinghouse is a facility that will be used to coordinate the gathering of information by a diverse group of earthquake pro-

EARTHQUAKE-RESPONSE PLANNING CONTINUED

professionals and maximize information availability. An important aspect of this exercise was the creation of a digital database enabling investigators to directly input field data through a clearinghouse Web page, e-mail, or other computer-aided devices. The database, consisting of text and pictures, may then be accessed through the Internet, sorted to assist investigators and other emergency responders in gathering appropriate data, and linked to a digital location map for easy reference.

WHERE DO WE GO FROM HERE?

The exercises serve as reminders of the complexity of earthquake emergency-response activities and the need for their continual practice. Several specific improvements in emergency-response procedures identified during the exercises emphasize that the UGS plan, although published on a specific date, is not static and can be enhanced. Additional exercises will be undertaken in the future and all plan components will be periodically reviewed and practiced. Future exercises will include one that will combine the activities of previous exercises and include participation by the U.S. Geological Survey, one of the federal agencies responsible for coordinating post-earthquake investigations supported by the National Earthquake Hazards Reduction Program. Another exercise will examine procedures needed to establish emergency-response facilities elsewhere if UGS offices in Salt Lake City are inaccessible or for an earthquake outside of the Wasatch Front region. Through these exercises, the UGS and related agencies and organizations hope to be ready when “the big one” strikes Utah.

EARTHQUAKE-HAZARDS SCENARIO FOR A M7 SLC EARTHQUAKE

The Utah Geological Survey (UGS) has released its newest CD publication, *Earthquake-Hazards Scenario for a M7 Earthquake on the Salt Lake City Segment of the Wasatch Fault Zone, Utah*, by Barry Solomon, Neil Storey, Ivan Wong, Walt Silva, Nick Gregor, Douglas Wright, and Greg McDonald. The authors mapped geologic hazards expected in a magnitude 7 earthquake in the Salt Lake City metropolitan area on the Salt Lake City segment of the Wasatch fault zone, a major active zone of normal faulting. This event is typical of large earthquakes expected in the central Wasatch Front region of northern Utah.

The CD includes maps showing the severity of ground shaking for the entire Wasatch Front caused by such an earthquake in the Salt Lake City area. Other maps in the publication show areas where surface faulting, liquefaction, and landslides may occur anywhere in the Wasatch Front area from the scenario earthquake.

This publication will be a valuable tool for scientists and emergency-response planners to estimate expected losses in this “worst-case” scenario earthquake. The Federal Emergency Management Agency (FEMA) and Utah Division of Emergency Services are now using the data and maps to estimate the extent of damage and disruption, approximate number of casualties, repair and replacement costs, losses of function for critical facilities, and extent of induced hazards using FEMA’s HAZUS loss-estimation software.

This CD is available at the Natural Resources Map & Bookstore, 1594 West North Temple, Salt Lake City (801-537-3320 or 1-888-UTAHMAP; <http://mapstore.utah.gov>) at a cost of \$24.95.

NON-STRUCTURAL MITIGATION

The Nevada Earthquake Safety Council and the Nevada Bureau of Mines and Geology sponsored a workshop, "Effective Nonstructural Mitigation Strategies of Earthquakes in Nevada", on April 28 in Verdi, Nevada. The workshop targeted facilities and maintenance operators and managers, engineers, safety professionals, emergency managers and other professional.

Several talks from public and private sector professionals offered a variety of mitigation techniques. The speakers discussed the non-structural risks in detail, including motivations for non-structural mitigation with historical examples, securing building contents and non-structural building infrastructure, and planning effective individual and statewide mitigation strategies.

Near the end of the workshop, participants broke out into interest groups to develop strategies on implementing non-structural activities. One group, Rural Communities, had a very lively discussion dealing with how to approach the public and private sectors. The group discussions resulted in several quality strategies for dealing in the rural political environment.

RELU BURLACU NEW UUSS MANAGER

BY WALTER J. ARABASZ

In mid-March 2004, the University of Utah Seismograph Stations (UUSS) gained a new network manager, Relu Burlacu, who replaces Sue Nava, following her move to Florida (*FLF*, vol. 19, no.4, 2003). Relu completed a master's degree in physics at the University of Bucharest and subsequently worked in network seismology for nine years in his native Romania. In 1990, he moved to the U. S. and completed five years of graduate work in seismology at Southern Methodist University in Dallas, Texas. Following his studies at SMU, Relu worked for nine years at Mission Research Corporation in Arlington, Virginia, on techniques and systems for nuclear test monitoring.

Relu's extensive background in seismic research, network data processing, and database management all suit him well to oversee and manage UUSS's modern real-time earthquake information system (www.quake.utah.edu). The system was emplaced in early 2002, in part to serve public safety for the 2002 Winter Olympics but also to meet Utah's long-term earthquake-information needs for emergency management, earthquake engineering, and science. We welcome Relu to UUSS—and to Utah's state earthquake program. As part of the ongoing partnership between UUSS, the Utah Geological Survey (UGS), and the Utah Division of Emergency Services (DES), Relu will follow in Sue Nava's footsteps in working closely with Gary Christenson of UGS and Bob Carey of DES.



ANNUAL ELECTION OF CHAIR AND CO-CHAIR FOR THE UTAH SEISMIC SAFETY COMMISSION

On July 9th, 2004, the Utah Seismic Safety Commission held its annual election of Chair and Co-Chair. Barry H. Welliver has been voted as the Chair and the position of Vice-Chair to include Peter McDonough and Rick Allis as Vice-Chairs for the coming year.



U.S. GEOLOGICAL SURVEY “SHAKES UP” SALT LAKE VALLEY AGAIN

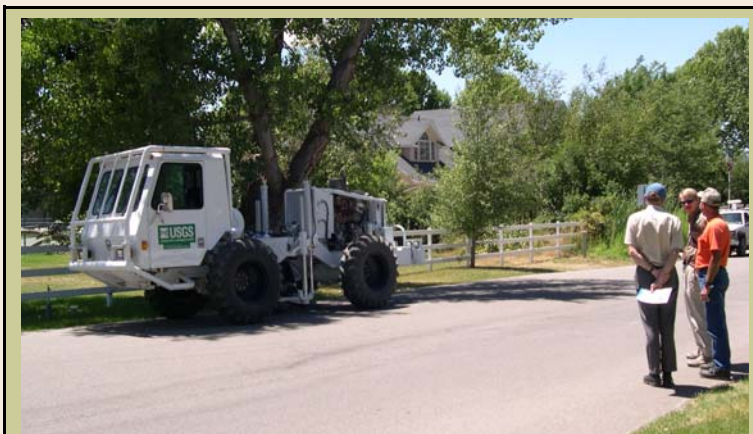
BY GARY E. CHRISTENSON, UTAH GEOLOGICAL SURVEY

The destructiveness of earthquake ground shaking depends not only on the size and location of the earthquake, but also on local geologic conditions that can amplify or reduce levels of ground shaking. Soil characteristics, as indicated by shear-wave-velocity measurements, and depth to bedrock are all important in predicting levels of ground shaking. To better characterize soils and depth to bedrock, the U.S. Geological Survey (USGS) is assisting Utah by performing sophisticated high-resolution seismic imaging along city streets in Salt Lake Valley. The USGS system uses a “vibroseis” truck that shakes the ground in a manner similar to a small earthquake. Levels of induced shaking are measured by a string of geophones along the street that can then be used to “image” the subsurface conditions.

In 2003, the USGS performed a 2-mile-long survey in South Jordan along 3200 W. Street to determine the depth to bedrock and semiconsolidated layers down to about 2500 feet. In July 2004, the USGS returned to Utah to perform six shorter lines (1000-foot-long) in selected areas of Salt Lake Valley to estimate intermediate-depth (0-1500 feet) shear-wave velocities. These lines were located primarily to characterize the three principal shear-wave-velocity units mapped by the UGS to estimate levels of ground-shaking amplification in Salt Lake Valley. In addition, one site was placed to characterize a reference bedrock site at the base of the Oquirrh Mountains, and several others were placed at seismograph sites where instruments in the University of Utah’s Advanced National

Seismic System (ANSS) are deployed. When an earthquake is recorded at the ANSS site, the shear-wave-velocity profiles at the instrument sites will help us to interpret the amount that soils amplify the reference bedrock ground motions recorded at the bedrock site.

The shear-wave-velocity information will be used to help generate a three-dimensional community velocity model for Salt Lake Valley so that we can estimate the shear-wave-velocity profile and depth to semiconsolidated material and bedrock at any locality. This model can then be used to estimate ground motions to improve earthquake-resistant design of buildings and bridges.



USGS “shaker” truck in action in the Cottonwood Heights area of Salt Lake Valley.

UNIVERSITY OF UTAH QUARTERLY SEISMICITY SUMMARY

EARTHQUAKE ACTIVITY IN THE UTAH REGION

July 1 – September 30, 2003

by F. M. Terra and W. J. Arabasz with contributions by P. M. Roberson, J. C. Pechmann, and K. L. Pankow

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During the three-month period July 1 through September 30, 2003, the University of Utah Seismograph Stations (UUSS) located 228 earthquakes within the Utah region (see accompanying epicenter map). The total includes three earthquakes in the magnitude 3 range and 35 earthquakes in the magnitude 2 range. Earthquakes of magnitude 3.0 or larger (plotted as stars and specifically labeled on the epicenter map) are described below. Three earthquakes were reported felt during the report period. Additional information on earthquakes within the Utah region is available from the University of Utah Seismograph Stations. (Note: Local time during the report period was Mountain Daylight Time, MDT).

Online Reports

A complete copy of this report, including maps and the earthquake catalog is available on the UUSS Web site at <http://www.seis.utah.edu/catalog/quarterly.shtml>. ShakeMaps—computer maps of the ground shaking produced by an earthquake—are automatically produced by UUSS for earthquakes of magnitude 3 and larger within the Wasatch Front urban area. The ShakeMaps are accessible on the

UUSS Web page at <http://www.seis.utah.edu/shake>. Earthquakes during the report period for which ShakeMaps are available are indicated below. For earthquakes of magnitude 3 and larger in the Utah region, the U. S. Geological Survey automatically posts a Community Internet Intensity Map (CIIM) on its "Did You Feel It?" Web page at <http://pasadena.wr.usgs.gov/shake/imw>. We urge anyone who feels an earthquake to report their observations on this interactive Web site; felt information is available by zip code on the CIIM site or can be obtained from UUSS directly. Earthquakes during the report period for which intensity maps are available are indicated below.

Earthquakes of Magnitude 3.0 or Larger (or Felt)

ML 3.3 July 7 20:20 MDT 18 mi W of Page, AZ

ML 3.2 July 7 20:55 MDT 18 mi W of Page, AZ

Reported felt in Page, AZ

ML 3.5 July 11 19:54 MDT 8 mi ENE of Huntsville, UT (ShakeMaps available)

Reported felt in Huntsville, Ogden, Layton, Roy, and Salt Lake City, UT (CIIM intensity map available)

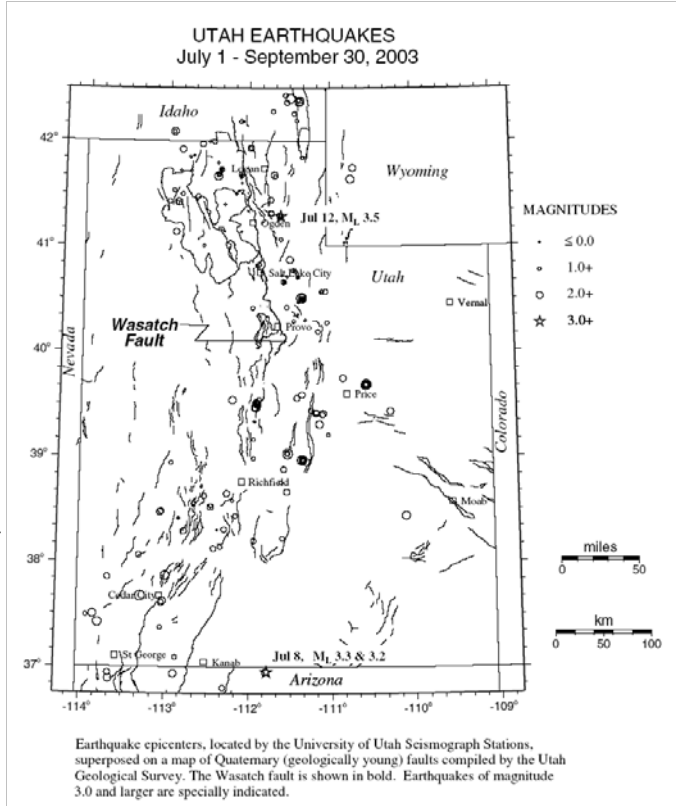
ML 2.9 August 2 23:16 MDT 13 mi WSW of Cedar City, UT

Reported felt in Cedar City and Beryl, UT

Other Notable Seismicity (see map)

During the report period, there were a few notable clusters of earthquake activity. For reporting purposes, we define a cluster as ten or more earthquakes occurring within a 10-km (6-mile) radius during the report period. As viewed on the epicenter map on the following page, these include the following:

- A cluster of 12 earthquakes occurred 9–12 miles WSW of Tremonton, UT (~30 miles W of Logan). The shocks ($0.4 \leq M \leq 2.3$) occurred intermittently between mid-July and early September.
- Twenty-seven earthquakes ($-0.1 \leq M \leq 2.9$) occurred 3–4 miles E of Heber City, UT (~30 miles SE of Salt Lake City) between July 18 and September 5.
- A cluster of 15 earthquakes ($0.9 \leq M \leq 2.6$) occurred 4–7 miles WSW of Levan, UT (~50 miles SSW of Provo). Most of the shocks occurred between August 15 and 17 and originated in the epicentral area of a magnitude 4.2 earthquake recorded earlier in the year on April 17, 2003.
- Seismic events within a radius of approximately 30 miles of Price and the densely clustered shocks about 50 miles to its southwest are interpreted to be coal-mining-related. These include a total of 36 located shocks ($1.0 \leq M \leq 2.7$) during the report period.



UNIVERSITY OF UTAH QUARTERLY SEISMICITY SUMMARY

EARTHQUAKE ACTIVITY IN THE UTAH REGION

October 1 – December 31, 2003

by W. J. Arabasz and P. M. Roberson with contributions by S. J. Nava, J. C. Pechmann, F. Terra, J. E. Hoffman, J. M. Hale, and K. L. Pankow

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During the three-month period October 1 through December 31, 2003, the University of Utah Seismograph Stations (UUSS) located 340 earthquakes within the Utah region (Figure 1). The total includes nine earthquakes in the magnitude 3 range and 68 earthquakes in the magnitude 2 range. Earthquakes of magnitude 3.0 or larger (plotted as stars and specifically labeled on Figure 1) are listed below. Six earthquakes were reported felt during the report period (see Table 1, a cumulative tabulation of felt earthquakes in the Utah Region during 2003). Additional information on earthquakes within the Utah region is available from the University of Utah Seismograph Stations.

Online Information

A complete copy of this report, including maps and the earthquake catalog, is available on the UUSS Website at http://www.seis.utah.edu/catalog/q_quarterly.shtml. ShakeMaps—computer maps of the ground shaking produced by an earthquake—are automatically produced by UUSS for earthquakes of magnitude 3 and larger within the Wasatch Front urban area. The ShakeMaps are accessible on the UUSS Web page at <http://www.seis.utah.edu/shake>. Earthquakes during the report period for which ShakeMaps are available are indicated below and in Table 1. For earthquakes of magnitude 3 and larger in the Utah region, the U. S. Geological Survey automatically posts a Community Internet Intensity Map (CIIM) on its "Did You Feel It?" Web page at <http://pasadena.wr.usgs.gov/shake/imw>. We urge anyone who feels an earthquake to report their observations on this interactive Web site; felt information is available by zip code on the CIIM site or can be obtained from UUSS directly. Felt earthquakes during the report period for which intensity maps are currently available are indicated in Table 1.

Earthquakes of Magnitude 3.0 or Larger (or Felt)
ML 3.1 Nov 6 23:52 MST 17 mi W of Page, AZ
ML 3.0 Nov 17 16:18 MST 14 mi E of Wallsburg, UT
ML 3.2 Nov 29 15:33 MST 14 mi NNE of Beaver, UT
ML 3.2 Dec 12 14:04 MST 4 mi WSW of Levan, UT (felt; CIIM intensity map available, see Table 1)
ML 3.0 Dec 25 17:33 MST 4 mi WSW of Redmond, UT (felt; CIIM intensity map available, see Table 1)

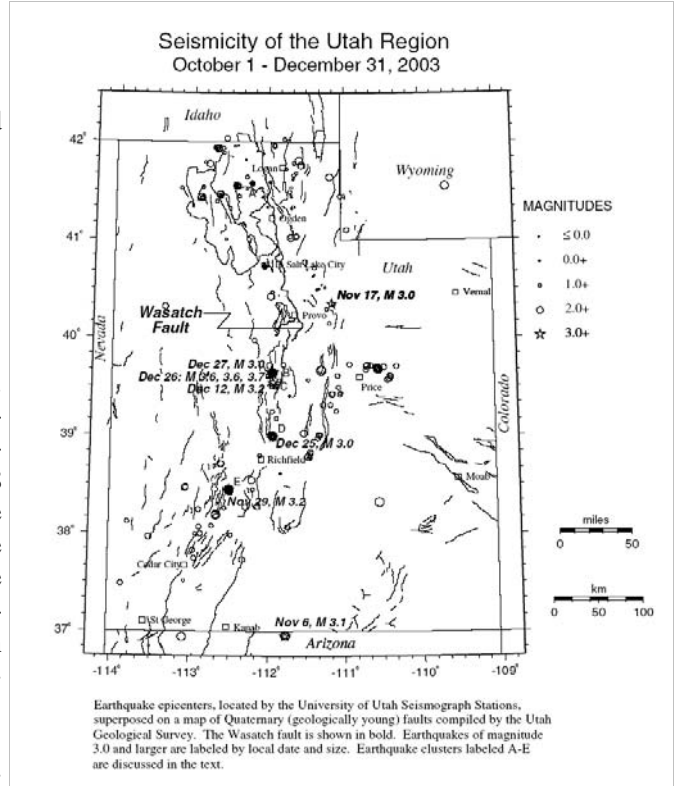
Earthquakes of Magnitude 3.0 or Larger (or Felt) — continued

ML 3.6 Dec 26 17:39 MST 8 mi SW of Nephi, UT (felt; ShakeMaps and CIIM intensity map available, see Table 1)
ML 3.6 Dec 26 17:40 MST 8 mi SW of Nephi, UT (felt; ShakeMaps and CIIM intensity map available, see Table 1)
ML 3.7 Dec 26 17:43 MST 8 mi SW of Nephi, UT (felt; ShakeMaps and CIIM intensity map available, see Table 1)
ML 3.0 Dec 27 06:19 MST 8 mi SW of Nephi, UT (felt; CIIM intensity map available, see Table 1)

Other Notable Seismicity

During the report period, there were five notable spatial clusters of earthquake activity (labeled A–E in Figure 1). For reporting purposes, we define a cluster as ten or more earthquakes occurring within a 10-km (6-mile) radius during the report period. Referring to the epicenter map (Figure 1), these include the following—from north to south (all dates below are UTC unless otherwise noted):

A. A cluster of 24 microearthquakes ($0.5 \leq M \leq 1.5$) occurred about five miles SW of Bear River City, UT (~25 miles SW of Logan). All but two of the shocks occurred in a three-day period between December 29 and 31. B. Thirty-nine earthquakes



UTAH SEISMIC SAFETY COMMISSION MEETING NOTES

APRIL 2, 2004 BY AMISHA LESTER

The Utah Seismic Safety Commission (USSC) held its April meeting at the State Office Building in Salt Lake City, Utah.

The Commission held a discussion on the March 16th "Strategic Planning" meeting results. It culminated in a discussion of the Commission's priorities for the upcoming year. An action plan has been created with target areas to help guide the Commission through the next year. The Action Plan will be discussed in the next Commission meeting.

Other Commission notes... Walter Arabasz made a motion to request the Commission staff to write a letter to the SEAU president to indicate our enthusiasm for maintaining Barry Welliver as a representative of SEAU to the Commission and for his outstanding leadership on the Commission.

Gary Christenson spoke on the February 2004 Utah Earthquake Conference. The conference went well. It was mainly geo-science related. Gary thanked those for helping and contributing to the conference. Approximately 150 attended the conference.

Walter Arabasz made a motion that the Commission acknowledge with great thanks, first, the contributions made by Scott Behunin as a member of the Commission since April, 2001 and, second, his key supportive role in advancing Utah's state earthquake program as director of the Utah Division of Emergency Services and Homeland Security.

The Commission discussed the nominations for the Western States Seismic Policy Council (WSSPC) awards. The responsibility of the awards have now been transferred to the national level and will be given out at the national conference. The 4 nominations that the Commission has decided will be the Metro Water District, the Student Research Grant Program, the Ground-Shaking Brochure, and the Parapet Brochure.

The Commission held a discussion of the USSC 10-year anniversary. A press release of the anniversary will be issued, acknowledging the anniversary and all of USSC's accomplishments. The Commission plans to invite all past Chairperson's and Commissioners. The celebration is planned to be a separate function from the Commission meeting, although it will be held on the same day. A possible proclamation will be given to the Governor to also acknowledge the Commissions accomplishments.

UTAH SEISMIC SAFETY COMMISSION MEETING NOTES

JULY 9, 2004 BY AMISHA LESTER

The Utah Seismic Safety Commission (USSC) held its July meeting at the State Office Building in Salt Lake City, Utah.

Barry Welliver, Walter Arabasz and Mathias Mueller will be presenting to the State Building Board on July 14th, 2004. They will be identifying priority building projects within the state. Those interested in presenting, please contact Barry Welliver.

The Commission held a discussion on FY2005 Strategic Actions. Hot points and priorities for the coming year were handed out to all commissioners. Each committee gave a brief update and support of these action items. A motion was placed to allow funding for several Commissioners to attend the Nevada Seismic Commission meeting held in Reno, Nevada on August 4, 2004.

Other Commission notes...The Commission held its annual election of Chair and Vice-Chair. Barry Welliver remains Chair for the coming year. Rick Allis and Peter McDonough will be the Vice-Chairs for the coming year.

All WSSPC nominations have been placed. Winners should be announced by the end of the month. The Commission is to reimburse all travel expenses for the Chair for the upcoming WSSPC Conference held in September.

A brief report on the WSSPC BRPSHS II that was held in Reno in May was given. Several new policies were discussed during the conference. Supporting clearinghouses, developing technical working groups, defining of active faults, and support of ANSS external research are some of the policies that could be adopted by the St. Louis Conference.

USSC had a discussion on clearinghouse support. USSC proposed a website that should include a plan to activate the clearinghouse and instructions if it should be needed. Invitations and badges were also discussed.

UTAH SEISMIC SAFETY COMMISSION 10-YEAR ANNIVERSARY

JULY 9, 2004 BY AMISHA LESTER



Matthias Mueller, Keith Stepan, and Walter Arabasz at the Anniversary Celebration.

On July 9th, 2004, the Utah Seismic Safety Commission (USSC) held an open house to celebrate the 10-Year Anniversary of the USSC's existence. Many past and present Commissioners participated in a review of the USSC's successes of the past ten years. The celebration included presentations on the history of the USSC, recognition of past Chairs of the Commission, and accomplishments of the USSC. The USSC would like to thank those who have contributed to the success of the Commission.



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CONTINUED U OF U QUARTERLY SEISMICITY SUMMARY

($1.1 \leq M \leq 3.7$) clustered in the West Hills area about eight miles SW of Nephi, UT (~45 miles SSW of Provo). All but three of the shocks occurred between December 27 and 30 UTC (Dec. 26 and Dec. 30, MST) as part of a sequence that began with a triplet of earthquakes of magnitude 3.6, 3.6, and 3.7 within a four-minute time span. The other three earthquakes occurred earlier between November 1 and 19. C. Ten earthquakes clustered in the general source area of the magnitude 3.2 earthquake of December 12, located four miles SSW of Levan, UT (~50 miles SSW of Provo). The M 3.2 earthquake occurred as a single main shock without aftershocks but was preceded by nine close shocks ($1.1 \leq M \leq 1.8$) that occurred intermittently between October 26 and November 19.

Because of the proximity of clusters B and C, epicenters of two small earthquakes in cluster C actually lie to the NW of Levan, more closely associated with cluster B. D. Forty-one earthquakes ($1.0 \leq M \leq 3.0$) with tightly clustered epicenters occurred about four miles WSW of Redmond, UT (~20 miles NE of Richfield). All the shocks occurred in a three-day period between December 24 and 27. E. The magnitude 3.2 earthquake of November 29, located 14 miles NNE of Beaver, UT (~30 miles SW of Richfield) was associated with 26 other shocks ($0.5 \leq M \leq 2.8$) forming part of an apparent foreshock-main shock-aftershock sequence. The sequence began on November 28, culminated on November 29 with the M 3.2 earthquake, and ended on December 4. In Figure 1, the locally clustered seismic events within a radius of approximately 30 miles of Price, together with a localized cluster about 50 miles to its southwest, are associated with known areas of underground coal mining and are interpreted to be mining-related. These include a total of 58 located shocks ($1.3 \leq M \leq 2.9$) that occurred throughout the report period.