

**Urban and Regional Seismic Monitoring<sup>3/4</sup> Wasatch Front  
Area, Utah, and Adjacent Intermountain Seismic Belt**  
01HQAG0014 (October 1, 2002–September 30, 2003)

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**Investigations Undertaken (October 1, 2002 – September 30, 2003):**

The cooperative agreement identified here, combined with funding from the State of Utah, provided major support for the operation of (1) the University of Utah Seismograph Stations' (UUSS) regional and urban seismic network and (2) a regional earthquake-recording and information center on the University of Utah campus in Salt Lake City.

At the end of September 2003, UUSS operated and/or recorded 200 stations (55% short-period, 35% strong-motion, 10% broadband). USGS support is focused on the seismically hazardous Wasatch Front urban corridor of north-central Utah, but also encompasses neighboring areas of the Intermountain Seismic Belt. During the report period, project efforts involved: (a) continued development of a real-time earthquake information system in the Wasatch Front area as an element of an Advanced National Seismic System (ANSS); (b) timely study of new data acquired with our modernized network—including studies of increased seismicity in Utah remotely triggered by the November 3, 2002, Denali Fault, Alaska, earthquake; (c) ongoing network operations; and (d) miscellaneous related activities.

**Results:**

**Real-Time Earthquake Information System.** During the past three years, we have successfully (1) integrated weak- and strong-motion monitoring within a modernized regional/urban seismic network and (2) developed an effective real-time earthquake information system in advance of the 2002 Salt Lake City Winter Olympics. In FY 2003 we modestly expanded strong-motion instrumentation in Utah's rapidly-growing Wasatch Front urban corridor for emergency response and long-term risk reduction, and we began efforts to make our real-time information system more robust. Accomplishments in FY 2003 included the following:

□ *Earthworm* <sup>3/4</sup> Our Earthworm system (hardware and software) for real-time earthquake monitoring and automated alerts is in a constant state of development and is fragile (Nava et al., 2003). Efforts were made during FY 2003 to monitor the system performance, fine tune the system to maximize efficiency and minimize false earthquake alarms, transfer some functions from PCs to a smaller number of more powerful SUN workstations, and install Earthworm v6.2 (5/2003). V6.2 is not yet completely operational due to problems with the Oracle database interface. We are working with the USGS Earthworm team to resolve these problems.

□ *ShakeMap and Attenuation Studies* <sup>3</sup>/<sub>4</sub> We continued to implement ShakeMap and customize it for use in the Wasatch Front urban corridor. We also worked with the ShakeMap Working Group, contributing code and helping to prepare a ShakeMap Manual. During FY 2003, four automatic ShakeMaps were generated and posted to our Web site. ShakeMap developments involved initiating information transfer directly to a USGS Webserver, which is backed up by Akamai, and to Weathercentral, a private forecast company that specializes in providing TV stations with state of the art graphic capabilities. Results from predictive ground motion studies begun last year (see Pankow and Pechmann, 2004) were fully implemented into ShakeMap in the Wasatch Front urban corridor. A new study this year involved using the scenario option to (1) explore the sensitivity to the choice of attenuation relation and uncertainty in site amplification and (2) model the MMI values for an M5.2 shock that occurred on the western edge of the Salt Lake Valley (near the town of Magna, Utah) in 1962 (Pankow, 2003).

□ *10 New Strong-Motion Stations* <sup>3</sup>/<sub>4</sub> In FY 2003 we received ANSS equipment and funds for adding 10 stations to Utah's real-time urban strong-motion network, bringing the network total to 75 stations (Figure 1). Strong-motion instruments (REF TEK ANSS-130) were received in mid-to-late June. Seven of the stations were installed before September 30, 2003, and the remaining three stations were completed shortly thereafter. The 10 new stations include two urban reference stations in small buildings, four urban reference stations on open ground, and four free-field rock stations. Installing and troubleshooting sequential versions of firmware and software provided to us by ANSS instrument vendors for beta testing, both for new and earlier-installed instruments, were greatly time consuming. Major efforts were made to implement point-to-multipoint digital radio telemetry in our Utah network using Time Division Multiple Access (TDMA) technology in order to reduce operational costs.

□ *Integration of USGS/NSMP Strong-Motion Data* <sup>3</sup>/<sub>4</sub> The USGS National Strong-Motion Program (NSMP) operates several digital strong-motion stations in the Wasatch Front area from which data are retrieved by telephone remotely from Menlo Park, CA. In FY 2003 we began recording continuous data streams from two more of these stations via telemetry links we installed; we now record data from four NSMP stations in real time. We also use an import protocol to automatically receive from NSMP both parametric data (in XML format) and waveform data for all their strong-motion stations in the Wasatch Front area operating with telephone connections. The NSMP data usefully contribute to our ShakeMap database.

□ *"Earthquakes in the News"* <sup>3</sup>/<sub>4</sub> In mid-June 2003 our computer professional installed the "Earthquakes in the News" listening script, enabling our UUSS home page to feature "Earthquakes in the News" links. By completing this task, our network staff reached, in advance, full compliance with all of the network-performance expectations (except for standards yet to be developed) set forth by the USGS in Program Announcement 04HQPA0002 for funding seismic networks during FY 2004-2006.

### **Seismicity Remotely Triggered by Denali Fault Earthquake—and Other Studies**

□ *Triggered Seismicity following the Denali Fault, Alaska, earthquake* <sup>3</sup>/<sub>4</sub> Following the Denali Fault, Alaska, earthquake on November 3, 2002, the University of Utah's regional seismic network recorded an abrupt increase in local microseismicity during the first 24 hours (~10x above background level), beginning with the arrival of surface waves; elevated seismicity continued for tens of days throughout much of Utah's main seismic belt. Data from 37 ANSS strong-motion stations in Utah contributed importantly to enabling the estimation and mapping of peak dynamic stresses that occurred during the

passage of surface waves through Utah; the level of the peak dynamic stresses (1.2–3.5 bars) is consistent with the interpretation of remote triggering of local seismicity by the Alaskan earthquake. During FY 2003 we undertook a detailed analysis of the triggered seismicity. Initial results were presented at the 2002 Fall American Geophysical Union meeting (Pankow et al., 2002) and were also reported in the Utah Geological Survey's public outreach bulletin (Pankow et al., 2003a). A full manuscript is being prepared for the BSSA's forthcoming special issue on the Denali Fault earthquake.

□ *Receiver Function Analysis* <sup>3/4</sup> In conjunction with a University of Utah graduate student we have been analyzing teleseismic earthquakes recorded by both regional broadband instruments and the ANSS urban strong-motion network. The student has been migrating these data to image crustal/upper-mantle structure. Preliminary results will be presented at the 2003 Fall AGU meeting (Sheng et al., 2003).

□ *Space Shuttle Columbia* <sup>3/4</sup> In response to requests via the USGS from NASA, which was seeking clues to the possible locations of debris from the space shuttle Columbia, we undertook analyses of data from our seismic network stations in southwestern Utah in the vicinity of Columbia's February 1, 2003, ground track. Ultimately, analyses of University of Utah data by J. C. Pechmann and others did not lead to the recognition of any seismic signals that could unambiguously be attributed to falling objects hitting the ground. However, besides Columbia's primary sonic boom, other unidentified signals were recognized which could have been (a) downward-refracted or reflected sonic booms from the shuttle, (b) seismic and/or sonic waves generated by impacts of shuttle debris, or (c) signals of some other origin.

□ *Coal-mining-induced seismicity* <sup>3/4</sup> We continued studies of seismicity induced by underground coal mining in east-central Utah (Arabasz et al., 2002, 2003) in order to serve the needs of (1) mining engineers and mine operators concerned with mine safety and (2) decision-makers dealing with the potential hazards of mining seismicity to off-site structures and facilities. The studies involved cooperative research with the USGS and the U.S. Bureau of Reclamation, including accelerographic recording and ground-motion modeling of the mining seismicity in order to evaluate the hazard of surface ground shaking.

**Accomplishments in Ongoing Network Operations.** Noteworthy accomplishments during the report period included the following:

□ *Improved magnitude determinations for very small earthquakes* <sup>3/4</sup> We modified our version of the earthquake location program Hypoinverse (originally written by F. W. Klein, USGS) to compute and report negative magnitudes instead of discarding them, and we changed the default magnitude from 0.00 to -9.99. These changes were needed because in some areas of our network we are able to locate very small earthquakes for which some or all of the single-station coda magnitude ( $M_c$ ) estimates are less than zero. Negative magnitudes are set to 0.0 before submission to the Quake Data Distribution System (QDDS) due to limitations in the QDDS software.

□ *Analysis of optimal record lengths for automatic determination of local magnitude ( $M_L$ )* <sup>3/4</sup> We analyzed the times of more than 10,000 maximum peak-to-peak amplitude measurements on synthetic Wood-Anderson records to provide a better basis for selecting the time intervals on such records to be analyzed in automatic local magnitude determinations. We found that 98% of the maximum peak-to-peak amplitudes occurred between the P-wave arrival time and 20 sec after the estimated  $S_g$  arrival time. Restricting the search for maximum peak-to-peak amplitudes to these time windows will minimize errors in automatic  $M_L$  determinations caused by including maximum amplitude measurements from the wrong seismic events. These errors are sometimes very large.

- *Near-real-time data exchange with other networks* <sup>3</sup>/<sub>4</sub> Throughout the report period, we continued to exchange waveform data in near-real-time with the National Earthquake Information Center, the Idaho National Engineering and Environmental Laboratory, the Montana Bureau of Mines and Geology, the U.S. Bureau of Reclamation, and the University of Nevada, Reno. In March 1993, we began exchanging waveform data with Northern Arizona University. These data exchanges are done via the Internet using Earthworm import/export software modules.
  
- *Assistance to other seismic networks* <sup>3</sup>/<sub>4</sub> In February 2003 our network staff successfully configured and installed a PC-based (Pentium III) Earthworm system in Flagstaff, Arizona, for the Arizona Earthquake Information Center (AEIC) at Northern Arizona University. Help was provided by Doug Bausch of FEMA (formerly of AEIC) and Dave Brumbaugh, director of AEIC. The Arizona Earthworm system is set up for remote system administration and control at the University of Utah. Continuous data from the 8-station Northern Arizona Seismic Network are exported via Internet to the University of Utah and then relayed to the IRIS DMC. Help to other networks also included the following: (1) we provided to Mike Stickney, the operator of Montana's regional seismograph network, UUSS customized software for calculating Richter local magnitude ( $M_L$ ) from broadband waveforms; we also gave him a tutorial on creating dataless SEED volumes (including instrument response information) for submission of his network data to the IRIS DMC; (2) we provided customized ShakeMap modules to the University of Washington seismic network; (3) we provided a ShakeMap module using the new Pankow and Pechmann (2003) ground-motion attenuation relations to the University of Nevada at Reno; (4) in April 2003, two of our group met in San Juan, Puerto Rico, with operators of the Puerto Rico seismic network during SSA2003 to offer technical advice and help on expansion and modernization of that network.
  
- *Archiving waveform data* <sup>3</sup>/<sub>4</sub> All digital waveform data collected by the University of Utah regional seismic network during the report period were submitted to the IRIS DMC in SEED format. This included data from two of the FY03 ANSS strong-motion stations.
  
- *Submission of earthquake catalog data to ANSS information outlets* <sup>3</sup>/<sub>4</sub> During the report period, Earthworm automatic (non-human-reviewed) hypocenters and magnitudes for earthquakes of magnitude 2.5 and larger in our authoritative regions (Utah and Yellowstone National Park) were automatically submitted to the QDDS. Analyst-determined hypocenters and magnitudes for all earthquakes in our authoritative regions were submitted to the QDDS as they were completed. These same data were automatically submitted to the ANSS catalog four times per day during the Monday-Friday work week. Events submitted to the QDDS are automatically posted on the ANSS RecentEqs Web pages.

## **Miscellaneous**

- *ANSS Planning Activities* <sup>3</sup>/<sub>4</sub> During FY 2003, a 12-member state-level advisory committee continued to guide the development and effective use of urban strong-motion monitoring in Utah. The committee was created in FY 2001, both as part of the ANSS management structure and as part of Utah's state earthquake program. In October 2002, an ANSS implementation plan for FY 2003 was developed for the state of Utah and for the Intermountain West (IMW) Region (see Arabasz, 2002). In early- to mid-2003, we explored sites and coordinated with Alena Leeds (USGS/Golden) in connection with a new ANSS national backbone station near Cedar City in SW Utah.
  
- *Next-Generation Ground-Shaking Hazard Maps* <sup>3</sup>/<sub>4</sub> In April 2003 we participated in planning workshops sponsored by the USGS and the Utah Geological Survey for developing the next generation of

ground-shaking hazard maps in Utah. Four seismologists in our network group are now serving on a 13-member Utah Ground-Shaking Working Group, and two others are serving on a Utah Quaternary Fault Parameter Working Group, enabling close coordination between our UUSS/ANSS urban strong-motion network and researchers addressing local ground-motion-related issues.

**Network Seismicity.** Figure 2 shows the epicenters of 1,210 earthquakes ( $M_L \leq 4.2$ ) located in part of the University of Utah study area designated the "Utah region" (lat.  $36.75^\circ - 42.5^\circ$  N, long.  $108.75^\circ - 114.25^\circ$  W) during the period October 1, 2002 to September 30, 2003. The seismicity sample includes nine shocks of magnitude 3.0 or greater and five felt earthquakes ( $2.9 \leq M \leq 4.2$ ). The largest earthquake within the Utah region during the report period was a shock of  $M_L$  4.2 on April 16, 2003 (19:04 MDT) located 6 km (4 miles) south-southwest of Levan, UT (epicenter labeled in Figure 2). ShakeMaps were generated by our network for four earthquakes ( $3.2 \leq M \leq 4.2$ ) during the report period; see <http://www.seis.utah/shake/archive/>. Community Internet Intensity Maps were generated by the USGS for two of these shocks; see <http://pasadena.wr.usgs.gov/shake/imw/archives.html>.

### **Non-technical Summary:**

This cooperative agreement provides major support for urban and regional seismic monitoring in Utah and neighboring areas. During the report period we operated and improved a real-time earthquake information system in Utah's seismically hazardous Wasatch Front urban corridor. Ten new strong-motion stations were added to our urban network to meet needs for emergency response and earthquake engineering. More than 1,200 earthquakes were located in our study region during the report period; nine had a magnitude of 3.0 or larger, and five were reported felt. The largest local earthquake was a shock of magnitude 4.2 on April 16, 2003, in central Utah. Our modernized seismic network enabled the recording and study of an unusual increase in Utah earthquake activity triggered by long-distance effects of a large magnitude 7.9 earthquake in Alaska in November 2002.

### **Reports and Publications:**

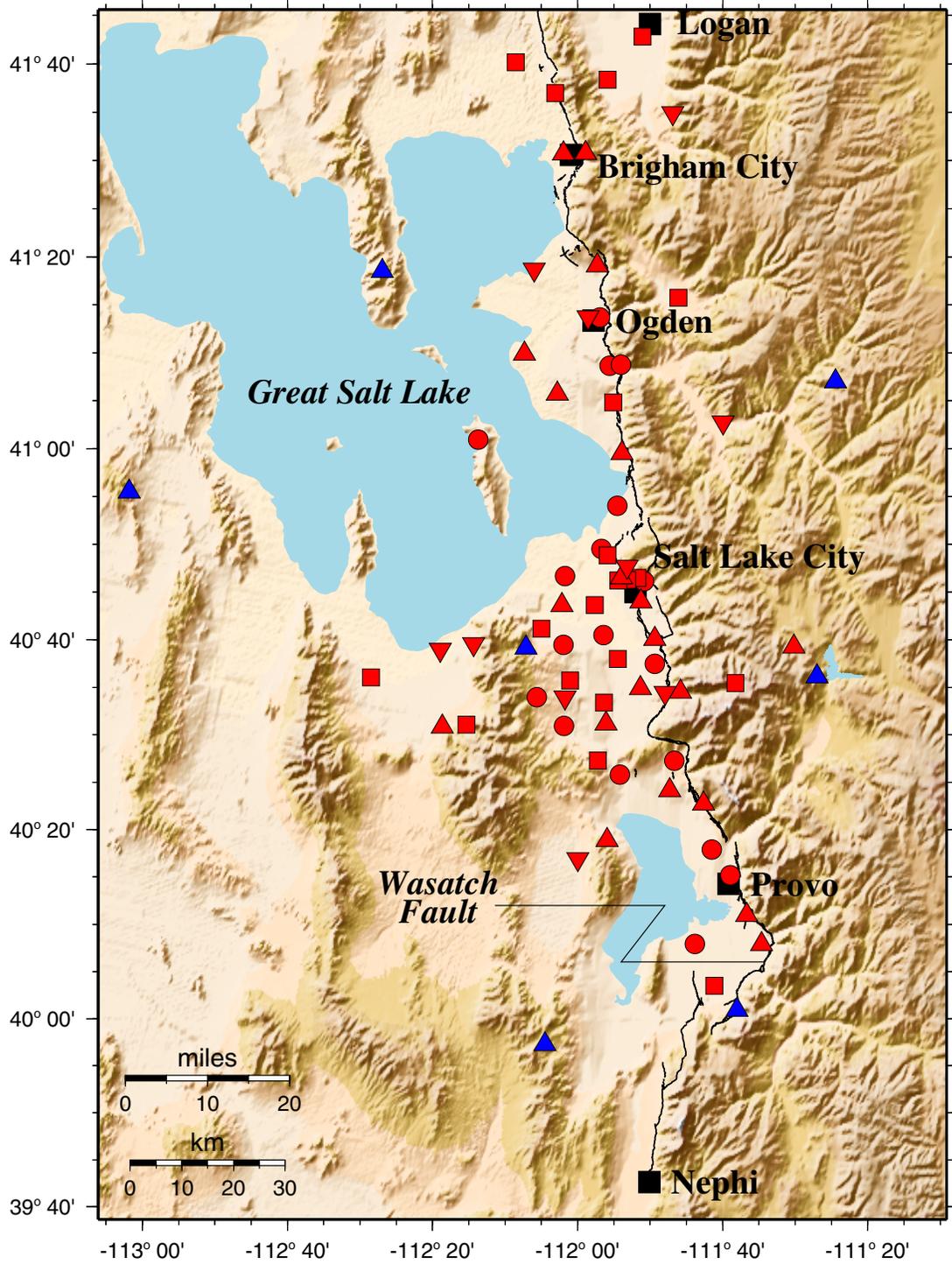
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#### **Availability of Data:**

All seismic waveform data archived by the University of Utah Seismograph Stations are available upon request directly from our office (typically delivered to the user in SAC ASCII or binary format). Alternatively, waveform data can be retrieved from the IRIS DMC using their SeismiQuery Web tool at <http://www.iris.washington.edu/SeismiQuery> (delivered in a variety of formats). Earthquake catalog data for the Utah region are available (1) via anonymous ftp [ftp://ftp.seis.utah.edu/pub/UUSS\\_catalogs](ftp://ftp.seis.utah.edu/pub/UUSS_catalogs), (2) by e-mail request to [webmaster@seis.utah.edu](mailto:webmaster@seis.utah.edu), or (3) via the Advanced National Seismic System's composite earthquake catalog, <http://quake.geo.berkeley.edu/cnss/cnss-catalog.html>. See also the University of Utah Seismograph Stations homepage at <http://www.quake.utah.edu>. The contact person for data requests is James C. Pechmann, tel: (801) 581-3858; e-mail: [pechmann@seis.utah.edu](mailto:pechmann@seis.utah.edu).

UUSS/ANSS  
 Real-Time Strong-Motion Network  
 Wasatch Front, Utah (9/30/2003)



Key:

	FY2000	FY2001	FY2002	FY2003
Strong-Motion Station	●	▲	■	▼
Strong-Motion <u>plus</u> Broadband		▲		
		▲		

Figure 1

# Seismicity of the Utah Region October 1, 2002–September 30, 2003

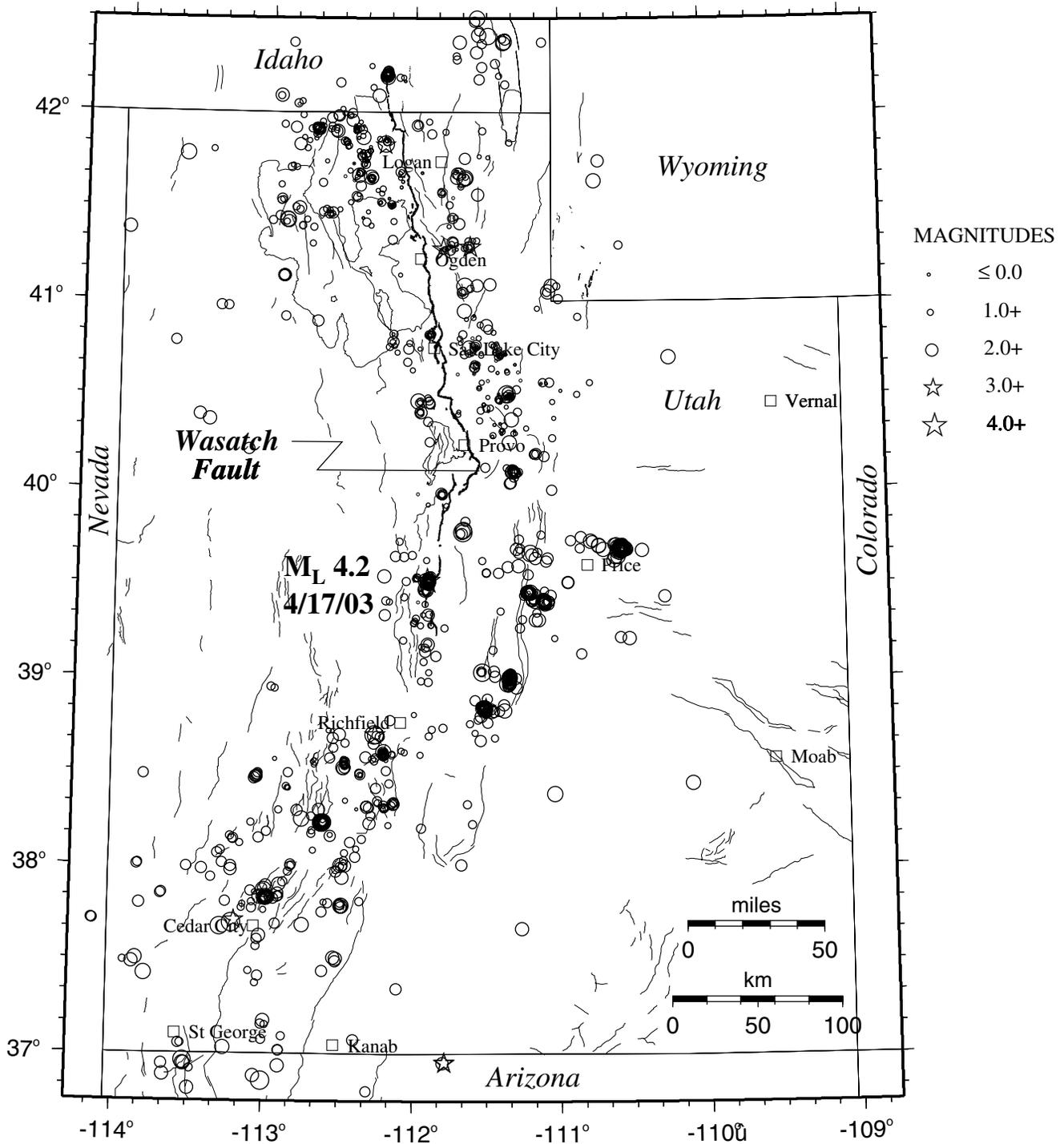


Figure 2. Earthquakes in the Utah Region, October 1, 2002 through September 30, 2003. Shocks of magnitude 3.0 and larger are plotted as stars; those less than 3.0, as circles. Base map of Quaternary (geologically young) faults from the Utah Geological Survey; Wasatch fault shown in bold.