Seismic Network Operations Along the Wasatch Front
Urban Corridor and Adjacent Intermountain Seismic Belt

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Investigations Undertaken (October 1, 1999 - September 30, 2000):

This cooperative agreement partially supports the operation of the University of Utah's regional seismic network—expanded during FY 2000 to include urban strong-motion monitoring. 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, this project involved (a) the installation of 20 new digital strong-motion stations with continuous real-time telemetry and recording and (b) ongoing network operations—including regional monitoring (100short-period stations and six broadband stations) and the operation of a regional earthquake-recordingand information center at the University of Utah in Salt Lake City.

Results:

New Real-Time Urban Strong-Motion Monitoring. We have installed the first 20 stations of a new real-time urban strong-motion network in Utah's rapidly-growing Wasatch Front urban corridor (Ogden-Salt Lake City-Provo). These stations were funded as part of a USGS program for initiating elements of an Advanced National Seismic System (ANSS) in San Francisco, Seattle, and Salt Lake City. Under conditions of the Government Performance and Results Act (GPRA), the new instruments had to be installed and operational by September 30, 2000. Project planning began in January 2000, funding and instruments (Kinemetrics K2s with EpiSensors) were received in the April-May time period, and by late August we had met our part of the GPRA deadline by siting and installing the 20 new strong-motion stations in the Wasatch Front area (see Figure 1 and Arabasz et al., 2000).

Siting and installation of these stations were coordinated closely with the USGS and followed COSMOS guidelines for urban strong-motion reference stations. Siting includes 15 reference sites in small structures, four free-field rock sites, and one free-field alluvial site. For system robustness, and to advance our experience, we chose to use diverse communication links (all TCP/IP addressable), including frame-relay telephone (nine sites), spread-spectrum radio (eight sites), and public Internet (three sites). Real-time data recording and processing of the accelerographic data rely principally on USGS-supplied "Earthworm" modules (NT/UNIX), interfaced with our existing UNIX software for network data analysis. By September 30, 2000, continuous data files were being recorded from the nine frame-relay and three Internet stations; data from the spread-spectrum radio stations were being recorded on-site in a triggered mode—awaiting the resolution of software problems to enable continuous, real-time telemetered recording. Continuous data streams (100 samples/sec) from all stations will automatically be archived in the IRIS Data Management

Center.

Anticipating additional funds in FY 2001, we began planning to install 20 more strong-motion stations in the Wasatch Front urban corridor and to implement a basic end-to-end real-time monitoring system—including capabilities for automated alerts and ShakeMaps—by the end of 2001, before the 2002 Winter Olympics in the Salt Lake City area.

Accomplishments in Ongoing Network Operations. Besides routine operations, notable accomplishments during the report period included: (1) successful Year-2000 (Y2K) performance of all critical network systems; (2) submitting a 19-year inventory of waveform data to the IRIS DMC in SEED format; (3) advancing real-time integration with other networks; (4) improving the quality of our earthquake catalog and other information products; and (5) organizing state and regional stakeholders in preparation for implementing an Advanced National Seismic System. The following is a more detailed summary of these and other accomplishments:

•*Y2K* — On January 1, 2000, with only a few minor problems, our network systems continued to perform reliably, thanks to earlier major efforts to make needed changes to all network-related computer systems and equipment for Year-2000 compliance. This involved operating-system upgrades of all computers, subsequent testing of those systems, and revision of non-compliant earthquake-analysis software.

•*Archiving waveform data* — In mid-June 2000, we completed the massive task of submitting all digital waveform data collected by the University of Utah regional seismic network since January 1, 1981 (when digital recording of the network began) to the IRIS Data Management Center in SEED format. This submission was a culmination of a three-year effort which included (1) a compilation of a database inventory of instrument components for all stations in our network since digital recording began in 1981; (2) use of this database to compute system response information for all past and present stations (more than 700 individual instrument response calculations); and (3) software development to automatically convert archived Utah waveform data to SEED format. Since mid-June 2000, data from our six UUSS digitally-telemetered broadband stations have been automatically submitted to the IRIS DMC on a daily basis.

•*CNSS earthquake catalog* — Since late 1996 we have routinely submitted all of our catalog data to the composite CNSS earthquake catalog. During the report period, analyst-reviewed earthquake locations for the Utah (and Yellowstone) regions were automatically submitted to the CNSS catalog four times per day during the Monday-Friday work week.

•*IASPEI network inventory* — In January 2000 we submitted a comprehensive inventory of our seismic network for inclusion in the *IASPEI Handbook of Earthquake Engineering and Seismology, Chapter 75, An Inventory of Seismograph Networks*. The summary can be viewed at <http://www.seis.utah.edu/behind/netfacts.shtml>.

•*Near-real-time integration with other networks* — During the report period, we continued to expand and enhance the exchange of parametric and waveform data in near-real-time with the National Earthquake Information Center, the Idaho National Environmental and Engineering Laboratory, the U.S. Bureau of Reclamation, the Montana Bureau of Mines and Geology, and the University of Nevada, Reno. Data exchange is done via the Internet using Earthworm import/export software modules.

•*Critical analysis of catalog magnitudes* — We have found and critically analyzed time-dependent differences of up to 0.5 units between the two types of magnitude measurements used in the University of Utah Seismograph Stations (UUSS) earthquake catalog since digital

recording began in 1981: coda magnitude (M_C) and local magnitude (M_L). Since 1994, we have determined M_L using synthetic Wood-Anderson (W-A) seismograms from up to six UUSS and seven USNSN broadband digital telemetry stations in our region. The use of synthetic W-A records has greatly increased the fraction of earthquakes for which M_Ls can be determined, and has provided a solid data base for checking and revising, as appropriate, the calibration of coda magnitude. (See Pechmann et al., 2000, for more details.)

•*Enhanced Web site following USGS standards* — In early 2000 we unveiled a major upgrade of our earthquake information center's Web site <http://www.quake.utah.edu> which includes interactive seismicity maps and earthquake listings created with modified, USGS- supplied software. We also implemented a USGS-supplied Earthworm module (heli_ew) for creating Webicorder images (digital renditions of live seismograms) for display on our Web site.

•*Coal-mining-induced seismicity* — We pursued detailed, ongoing studies of abundant seismicity ($M_L \leq 4.2$) induced by underground coal mining in east-central Utah in order toserve 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 (see Arabasz and Wyss, 1999; Arabasz and McCarter, 2000).

•*Organizing ANSS stakeholders* — In June 2000 we co-organized and hosted an organizational meeting for a nine-state Intermountain West Region to be part of an Advanced National Seismic System (ANSS) (Arabasz and Anderson, 2000; Anderson and Arabasz, 2000). The homepage for the ANSS Intermountain West Region is located at <http://www.seis.utah.edu/anss/index.shtml>. In July 2000, formation of an ANSS stakeholder/steering group for the state of Utah was begun in partnership with the Utah Seismic Safety Commission.

Network Seismicity. Figure 2 shows the epicenters of 1847 earthquakes ($M_L \leq 4.4$) located in part of the University of Utah study area designated the "Utah region" (lat. 36.75˚ - 42.5˚ N, long. 108.75 ˚ -114.25 ˚ W) during the period October 1, 1999 to September 30, 2000. The seismicity sample includes 26 shocks of magnitude 3.0 or greater, and five felt earthquakes ($3.3 \leq M_L \leq 4.4$) . The largest earthquake within the Utah region during the report period was a shock of M_L 4.4 on May 27, 2000 (21:48 UTC) near the Utah-Colorado border (specifically labeled in Figure 2). A shock of M_L 4.3 on January 30, 2000, was associated with a panel collapse at a trona mine in southwestern Wyoming. More than 1080 seismic events ($0.7 \leq M \leq 4.2$) located during the report period were associated with areas of ongoing coal-mining-related seismicity, within a 60-km radius of Price in east-central Utah. The largest of these, a shallow shock of M_L 4.2 on March 6, 2000, was caused by shear slip on an unknown structure near an active mine. Other notable earthquake activity during the report period included several spatially and temporally distinct earthquakes swarms ($M_L \leq 4.2$) in south-central Utah, located within about a 100 km radius of Richfield, Utah.

Non-technical Summary:

This cooperative agreement partially supports urban and regional seismic monitoring in the seismically hazardous Wasatch Front urban corridor of north-central Utah and neighboring areas of the Intermountain Seismic Belt. It also helps support the operation of a regional earthquake-recording and information center. During the report period, we installed the first 20 stations of a new real-time urban seismic network designed to record strong ground shaking from large earthquakes on-scale in Utah's rapidly-growing Ogden-Salt Lake City-Provo metropolitan area. More than 7900 seismic events were recorded by the regional seismic network, including 1847 earthquakes in our Utah study region; twenty-six of these had a magnitude of 3.0 or larger. The largest was an earthquake of magnitude 4.4 on May 27, 2000 near the Utah-Colorado border. During the report period we made major efforts to (1) avoid Year-2000

system failures, (2) make our archived data readily available through a national data center, (3) advance our network capabilities for rapid earthquake alert, and (4) improve our earthquake information products .

Reports and Publications:

Anderson, J.G. and W.J. Arabasz (2000). Workshop summary—organizational workshop for ANSSIntermountain West Region, June 19-20, 2000, Salt Lake City, Utah <http://www.seis.utah.edu/anss/wkshopsum.shtml>.

Arabasz, W.J. and J.G. Anderson (2000). Organizing an "Intermountain West" Region as part of an Advanced National Seismic System (ANSS), <http://www.seis.utah.edu/anss/ANSS_IMW.html>.

Arabasz, W.J. and M.K. McCarter (2000). Mine seismicity and the interface between mining engineers and seismologists (abs.), *Seism. Res. Lett.* **71** (2), 220.

Arabasz, W.J. and S.J. Nava (2000). New urban earthquake monitoring in Utah, *Fault Line Forum*(published by the Utah Division of Comprehensive Emergency Management) **16** (1), 1-3.

Arabasz, W.J., S.J. Nava, D.C. Cluff, D.L. Drobeck, A. Moeinvaziri, and J.C. Pechmann (2000). New real-time urban strong-motion network in Utah (Phase I) (abs.), *Eos, Trans. Am. Geophys.Union* **81** (2000 Fall Meeting), in press.

Arabasz, W.J. and M. Wyss (1999). Spatially-varying b-values in coal-mining seismicity in Utah: Inferred influence of heterogeneity and stress differences on local mean magnitude (abs.), *EOS,Trans. Am. Geophys. Union* **81** (46), F651.

Nava, S.J. (1999, 2000). Earthquake activity in the Utah region [summaries and maps of seismicity in the Utah region, published quarterly by the Utah Geological Survey in *Fault Line Forum*.]

Pechmann, J.C., S.J. Nava, J.C. Bernier, and W.J. Arabasz (2000). A critical analysis of systematic time-dependent coda-magnitude errors in the University of Utah earthquake catalog, 1981-1999 (abs.), *Eos, Trans. Am. Geophys. Union* **81** (2000 Fall Meeting), in press.

Youngs, R.R. [and multiple authors, including W.J. Arabasz and R.B. Smith] (2000). Probabilisitic fault displacement hazard analysis (PFDHA), *Earthquake Spectra* (submitted).

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 via anonymous ftp <ftp.seis.utah.edu: pub/UUSS_catalogs>, or by e-mail request to webmaster@seis.utah.edu, or via the Council of the National Seismic System's composite earthquake catalog, <http://quake.geo.berkeley.edu/cnss>. See also the University of Utah Seismograph Stations homepage on the World Wide Web <http://www.quake.utah.edu>. The contact person for data requests is Susan J. Nava, Network Manager, tel: (801) 581-6274; e-mail: nava@seis.utah.edu.

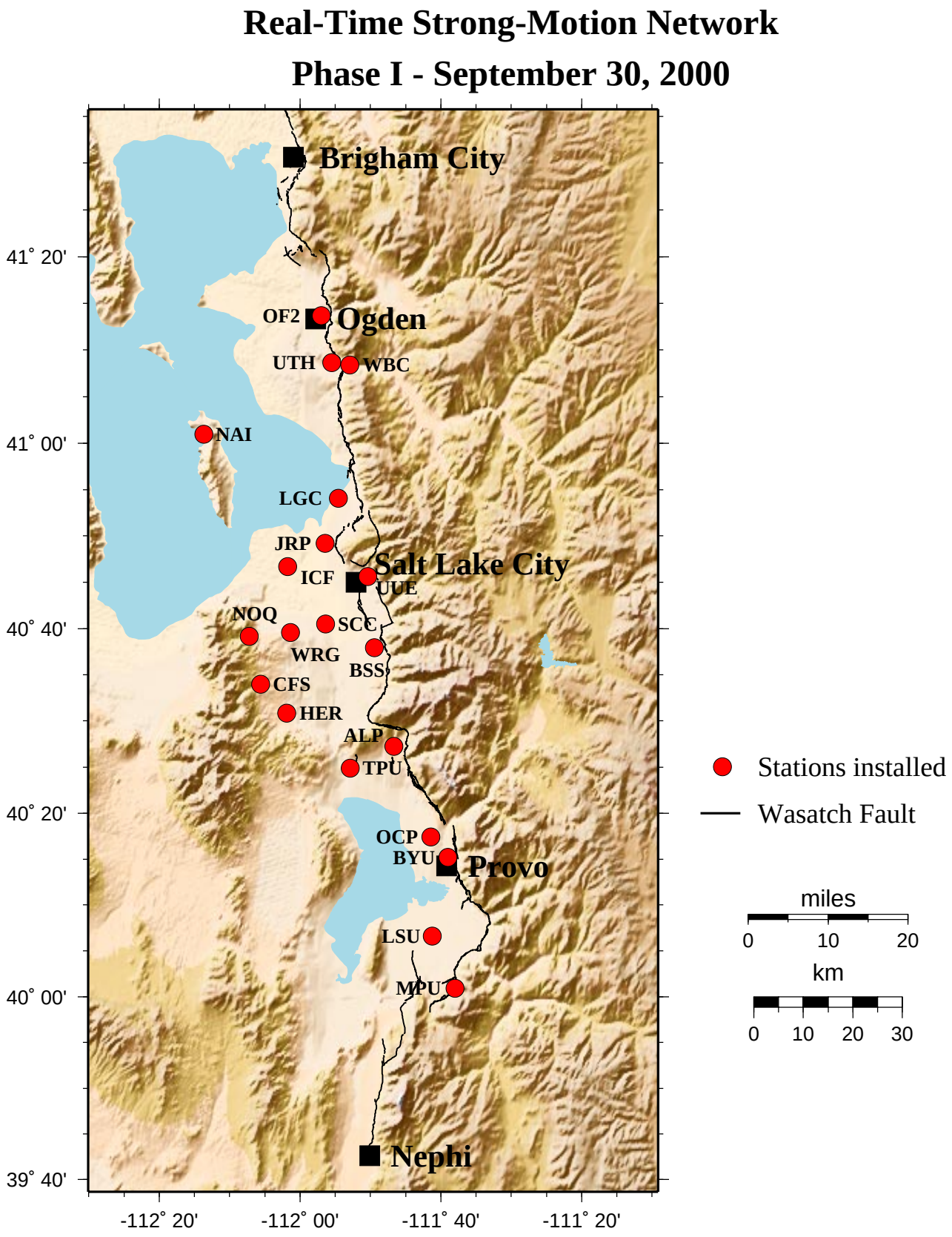

Figure 1 Map of the Wasatch Front, Utah, depicting the locations of the first twenty stations of a new real-time urban strong motion network.

Seismicity of the Utah Region
October 1, 1999 - September 30, 2000

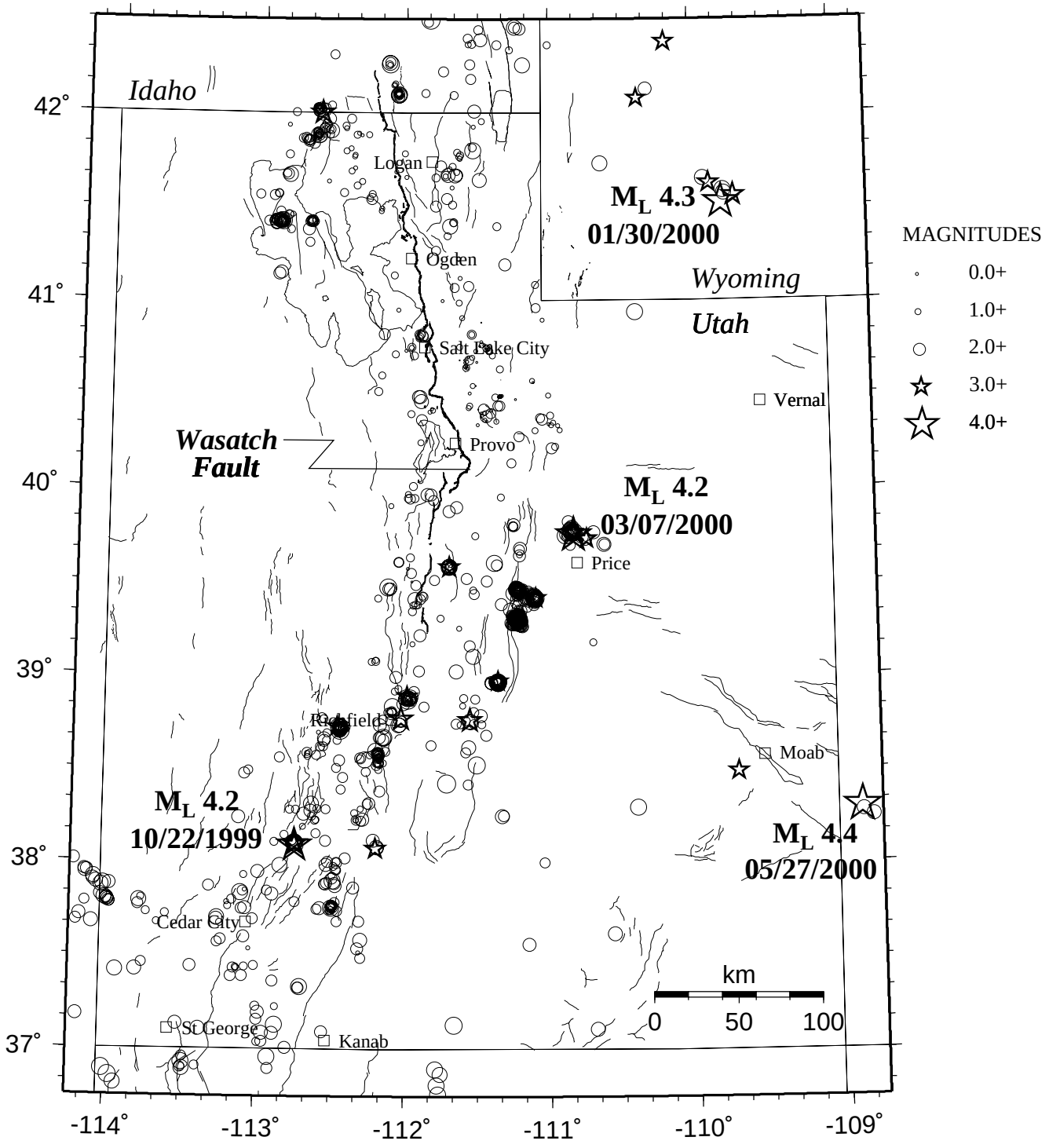

Figure 2 Earthquakes in the Utah Region, October 1, 1999 through September 30, 2000. Shocks of magnitude 3.0 and larger are plotted as stars; those less than magnitude 3.0, as circles.