Operation and Development of an Earthquake Information System, the Yellowstone Seismic Network (YSN)

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

The YSN cooperative agreement supports the operation and development of an earthquake and GPS information system at Yellowstone. Specific tasks include technical support of the 22-station seismic and 5-station GPS (Global Positioning System) network, station installation and maintenance, recording and processing, and analyses of data from these systems. The primary goals of the YSN are to monitor and assess seismicity and ground deformation that may be related to both volcanic and tectonic earthquake activity. Data are provided for NPS and USGS management, public safety and interpretation, as well as information for scientific research interests for interested users. In this report period we expanded our efforts by assisting Cascade Volcano Observatory personnel, USGS Volcano Hazard program, for installing and recording two continuous GPS systems in Yellowstone. The USGS Volcano Hazards Program jointly funds this cooperative project with partial support form the National Park Service (NPS) for field work and the National Science Foundation for some GPS stations. The primary products for the project include earthquake catalogs, ground deformation information, and the services of a regional earthquake and GPS recording and information center, including timely release of unusual earthquake activity reports to the USGS and the NPS.

Results (October 1, 1999 - September 30, 2000):

General Accomplishments.

The YSN is designed to monitor earthquakes by seismic and GPS methods of the Yellowstone volcanic system, including Yellowstone National Park (YNP) and the nearby Hebgen Lake fault zone (Fig. 1). This project provides real-time earthquake surveillance by an upgraded 22-station, 32-component, seismic network telemetered via FAA microwave links (at no cost to the project) to Salt Lake City, Utah that is digitally recorded at the University of Utah Seismograph Stations. Five continuously recording GPS stations, with partial support from an NSF grant, provide monitoring of the crustal deformation that is focused on the caldera and related features.

In addition to routine network operations, notable efforts under this cooperative agreement during the report period related to:

- Continued upgrading of seismograph stations against the harsh winter conditions of Yellowstone. This included 1) VCO system repairs and upgrades; 2) replacement of batteries at numerous sites; and 3) repair of ice damage to radio antennas, solar panels, and cables, and 4) relocation of the Little Thumb Creek seismograph station from a noisy site to bedrock

- Traced a serious noise problem for the broadband, digitally-telemetered seismograph station at Madison River, WY, to Qwest telephone noise;

- Technical and field assistance to the Dan Dzurisin, U.S.G.S. Volcano Hazards Program, for the repair

of two new continuously recorded GPS stations in the back country of Yellowstone National Park at Hayden Valley and at White Lake.

- Maintenance of a continuous recording, high-precision GPS station at the U.S. National Seismograph Station (LKWY) with telemetry provided by the USGS VSAT satellite system;

- Installed RF filter cavity on the Purple Mountain repeater to eliminate radio interference from National Park Service transmitters.

- Continued upgrade and repairs from winter ice damage of the central receive sites for all stations in the Yellowstone network (Mt. Washburn, Wyoming and Sawtelle Peak, Idaho);

- Assistance to the USGS-NEIC for maintenance of a cooperative U.S. National Seismograph Station (USNSN) located near Yellowstone Lake (LKWY).

- Old Faithful Visitor Center - Installed filter cavity and instructed NPS personnel in procedures for helicorder adjustments.

- Continuous cooperative CGPS sites at Old Faithful and Mammoth - Changed Trimble firmware to new version, changed session programming and documented site parameters.

- Sawtelle Peak FAA Relay station – repaired receivers that had been knocked out by lightning and installed surge suppression on the receiver output to prevent it in the future.

- Assistance to the National Park Service with long-term plans for implementing volcano and earthquake hazard assessment and identifying manpower needs;

The following accomplishments were made jointly under this award and the companion U.S.G.S. cooperative agreement, *Seismic Network Operations Along the Wasatch Front Urban Corridor and Adjacent Intermountain Seismic Belt*, no. 1434-HQ-98-01939:

- *Archiving waveform data* In mid-June 2000, we completed the task of submitting all digital waveform data collected by the University of Utah regional seismic network (Yellowstone and Utah) 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.

- *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 Yellowstone and Utah 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.

- *Analysis of catalog magnitudes* We have 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 (MC) and local magnitude (ML). Since 1994, we have determined ML 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 MLs can be determined, and has provided a solid data base for checking and revising, as appropriate, the calibration of coda magnitude.

- *Enhanced Web site following USGS standards* In early 2000 we released a major upgrade of our earthquake information centers 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.

- *Organizing ANSS stakeholders* In June 2000 the University of Utah co-organized and hosted an organizational meeting for a nine-state Intermountain West Region to be part of an Advanced National Seismic System (ANSS). The Yellowstone seismic network was highlighted as a key component of this system. The homepage for the ANSS Intermountain West Region is located at <http://www.seis.utah.edu /anss/index.shtml>.

- *Installation and configuration of the Antelope real-time data acquisition.* Data from the Yellowstone, state of Montana, Teton, Snake River Plain (INEEL) and Utah seismic networks were integrated into a the Antelope recording system providing a prototype, integrated Intermountain Seismic Belt regional seismic network.

- *USGS-NPS Volcano Hazards Workshop.* In September 2000 the University of Utah participated in a workshop to convey information on volcano hazards in national parks, including a presentation on the volcano-earthquake hazard of Yellowstone National Park that used data from this project.

Network Seismicity. Fig. 2 shows the epicenters of 1881 earthquakes (M < 4) located the University of Utah study area designated the Yellowstone region (lat. 44 - 45.17 N, long. 109.75 - 111.5 W) during the period October 1, 1999 to September 30, 2000. The seismicity sample includes 28 shocks of magnitude 3.0 or greater and no shocks of magnitude 4.0 or greater. The largest earthquakes within the Yellowstone region during the report period were shocks of magnitude 3.9. The first occurred on May 23, 2000 (01:10 UTC), located 19.7 mi WNW of Gardiner, MT and the other occurred on August 7, 2000 (9:07 UTC), located 7.3 mi WNW of Norris Junction, WY.

Swarm Seismicity – A notable earthquake swarm was recorded in the vicinity of Norris Geyser Basin from July 2000 to late August, 2000. The swarm was located about 12 km northwest of Norris Geyser Basin and generated interest because of its coincidence with notable hydrothermal changes observed in the northwest side of Norris Geyser Basin. The swarm events define two features: a narrow cylindrical feature from 1.5 km - 5 km depth and a plane with a shallow dip to the southwest. However there was not any migration of activity from one area to another with time.

Communication of information on this earthquake sequence was made with NPS personnel and other interested geologists by phone calls and by a release of detailed seismic information on a web site <http://www.mines.utah.edu/~ggcmpsem/UUSATRG/Norrisswarm.html>.

Non-technical Summary: The principal task of the Yellowstone Seismic and GPS Networks (YSN) is to monitor earthquake activity and crustal deformation in Yellowstone National Park and surrounding region. The 22-station seismic network is centrally recorded in Salt Lake City, Utah, as part of the University of Utah's regional seismic network. Data from the 5-station continuous GPS network are archived at recorded at the University of Utah and archived at the UNAVCO national data center in Boulder, CO. A total of 1881 earthquakes were located in the study region, including 28 shocks of magnitude 3.0 and larger. The largest earthquakes within the Yellowstone region during the report period were shocks of magnitude 3.9. The first occurred on May 23, 2000 (01:10 UTC), located 19.7 mi WNW of Gardiner, MT and the other occurred on August 7, 2000 (9:07 UTC), located 7.3 mi WNW of Norris Junction, WY. A notable earthquake swarm was recorded in the vicinity of Norris Geyser basin from mid

July 2000 to late August, 2000. The swarm was located about 10 km northwest of Norris Geyser Basin and generated interest because of its coincidence with notable hydrothermal changes observed in the northwest side of Norris Geyser Basin. The swarm events define two features: a narrow cylindrical feature from 1.5 km - 5 km depth and a plane with a shallow dip to the southwest. However there was not any migration of activity from one area to another with time.

Papers and Related Reports:

Humphreys, G., D. Schutz, K. Dueker and R. B. Smith, 2000, Plume or no plume at Yellowstone, GSA Today, (in press).

Lowry, A. R., N. M. Ribe, and R. B. Smith, 2000, Dynamic elevation of the Cordillera, western United States, J. Geophys. Res., 23,371-23,390.

Miller, D. S. and R. B. Smith, 1999, P and S velocity structure of the Yellowstone volcanic field from local earthquake and controlled source tomography, J. Geophys. Res. v. 104, 15,105-15,121.

Puskas, C., 1999, Contemporary deformation of the Yellowstone Plateau and Hebgen Lake fault zone, M.S. thesis, University of Utah, Salt Lake City.

Puskas, C. M., R. B. Smith, and C. M. Meertens, 1999, Contemporary deformation of the Yellowstone Plateau and Heben Lake fault zone, 1999 Abstracts with Programs, Rocky Mountain Section, Geological Soc. America, v. 31, n. 4, A-53.

Puskas, C., R. B. Smith, and C. M. Meertens, 1999, GPS-measured deformation of the Yellowstone caldera, Hebgen Lake fault and the eastern Snake River Plain, Abst., 1999 UNAVCO Volcano Geodesy Workshop, Jackson Hole, Wyoming, p. 33.

Puskas, C.M., R.B. Smith, and C.M. Meertens, 1999, Contemporary deformation of the Yellowstone Plateau and Hebgen Lake fault zone (abs.), Geological Soc. America 31 (4), A-53.

Smith, R. B. and C. M. Meertens, 1999, The Yellowstone hotspot and contemporary deformation from geodetic surveys, 1999 UNAVCO Volcano Geodesy Workshop, Jackson Hole, Wyoming.

Smith, R. B. and W.L., Chang, C. M. Meertens, and P. Cervelli, 2000, Deformation and fault-modeling on the Wasatch Front, Utah, from continuous and campaign GPS measurements, 1992-1999, Abs. 95th Ann. Meeting, Seismol. Soc. America, Seismol. Res. Letters, v. 71, p. 256.

Smith, R. B., 1999, The Yellowstone Hotspot and the Yellowstone Geoecosystem, 1999 Abstracts with Programs, Rocky Mountain Section, Geological Soc. America, v. 31, n. 4, A-56.

Smith, R. B., C. M. Meertens, K. Lynch, A.R. Lowry, and R. Palmer, 1999, Active tectonics of the northern Basin-Range and Yellowstone hotspot, 1999 Abstracts with Programs, Rocky Mountain Section, Geological Soc. America, v. 31, n. 4, A-56.

Smith, R. B., C. M. Puskas, G. P. Waite, C.M. Meertens, and W. Chang, 1999, Tectonic and volcano interaction of the Yellowstone caldera and surrounding faults: models and deformation budgets from GPS and seismicity measurements, (invited talk), Eos, Trans. Amer. Geophys. Un. 80, 46, F970.

Smith, R.B. (1999). The Yellowstone Hotspot and the Yellowstone Geo-ecosystem (abs.), Geological Soc. America 31 (4), A-56.

Smith, R.B., C.M. Meertens, D. Lynch, A.R. Lowry, and R. Palmer, 1999, Active tectonics of the northern Basin-Range and Yellowstone hotspot (abs.), Geological Soc. America 31 (4), A-56.

Smith, R.B., C.M. Meertens, D. Lynch, R. Palmer, A. Lowry, and N. Ribe (1998). Kinematics of the northern Basin Range and the Yellowstone-Snake River Plain volcanic system (abs.), Eos, Trans. Amer. Geophys. Un. 79 (45), F559.

Smith, R.B., D. Miller, and D. P. Lynch, 2000, Tomographic imaging of crustal structure from the Yellowstone volcanic field and the Intermountain Seismic Belt using earthquake and controlled source data, , Abs. 95th Ann. Meeting, Seismol. Soc. America, Seismol. Res. Letters, v. 71, p. 254

Waite, G. P. and R.B. Smith, 1999, Earthquakes and variations of stress in the Yellowstone-Hebgen Lake fault zone, 1999 Abstracts with Programs, Rocky Mountain Section, Geological Soc. America, v. 31, n. 4, A-59.

Waite, G., 1999, Seismicity of the Yellowstone Plateau: Space-Time Patterns and Stresses From Focal Mechanism Inversion, M.S. thesis, University of Utah, Salt Lake City.

Waite, G.P. and R.B. Smith, 1999, Earthquakes and variations of stress in the Yellowstone-Hebgen Lake fault zone (abs.), Geological Soc. America 31 (4), A-59.

Availability of Data:

All seismic waveform data archived by the University of Utah Seismograph Stations are available upon request (typically delivered to the user in SAC ASCII or binary format). 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 request-quake@eqinfo.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.seis.utah.edu>. The contact person for data requests is Susan J. Nava, Network Manager, tel: (801) 581-6274; e-mail: nava@seis.utah.edu.

Yellowstone CGPS data are available via ftp from the UNAVCO data archives in Rinex format at: <http://www.unavco.ucar.edu/data/ftp_rinex.html> or by contacting Dr. Robert B. Smith, tel: (801) 7129; e-mail: <rbsmith@mines.utah.edu>.

Yellowstone Seismograph and Continuous GPS Stations and Telemetry

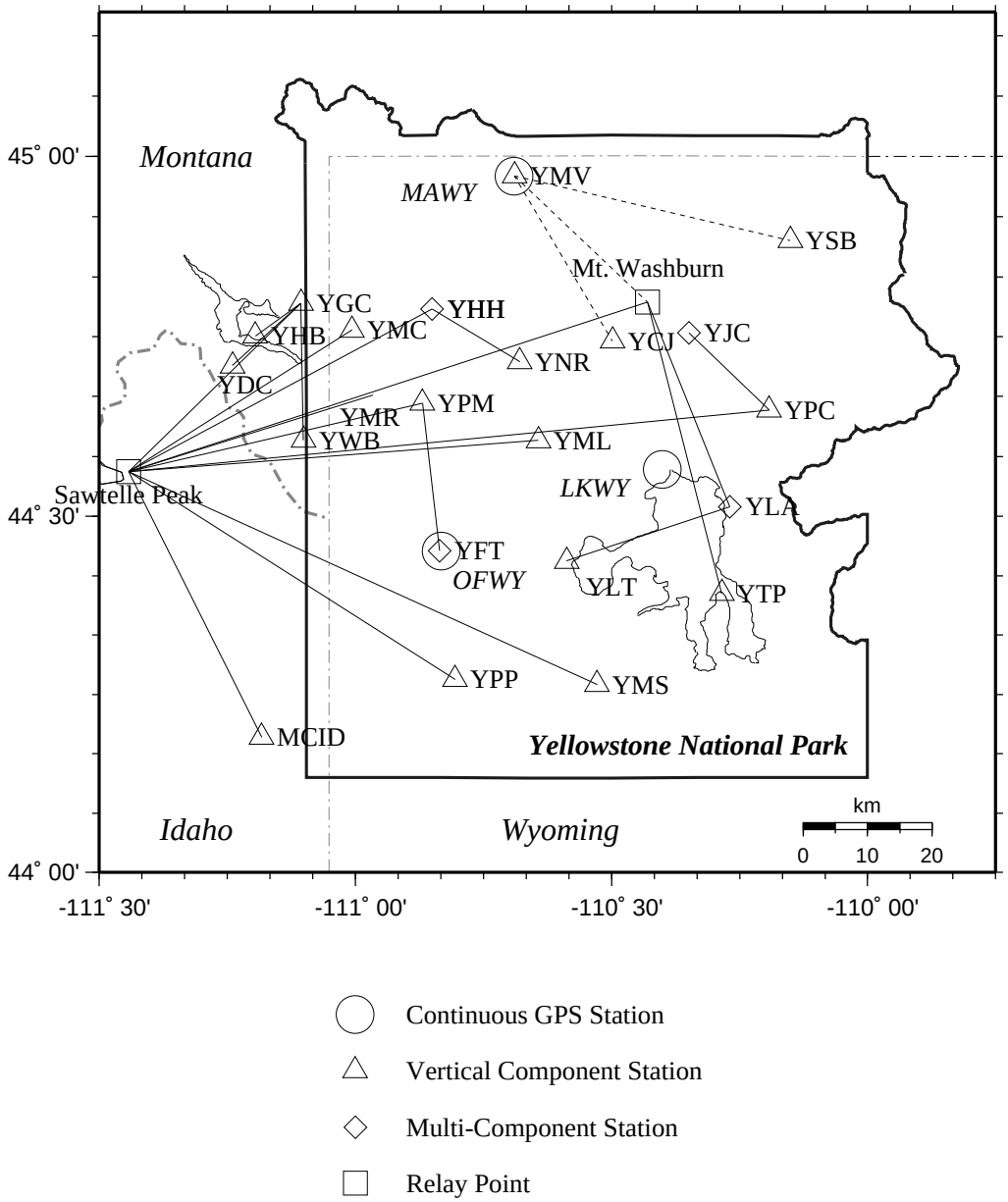

Figure 1. Map of seismograph stations and telemetry links in the Yellowstone National Park seismograph network, November 1999. Seismic station symbols correspond to sites in Table 1. Dashed lines are telephone telemetry links, solid lines are VHF, UHF radio links.

Yellowstone Seismicity: October 1, 1999 - September 30, 2000

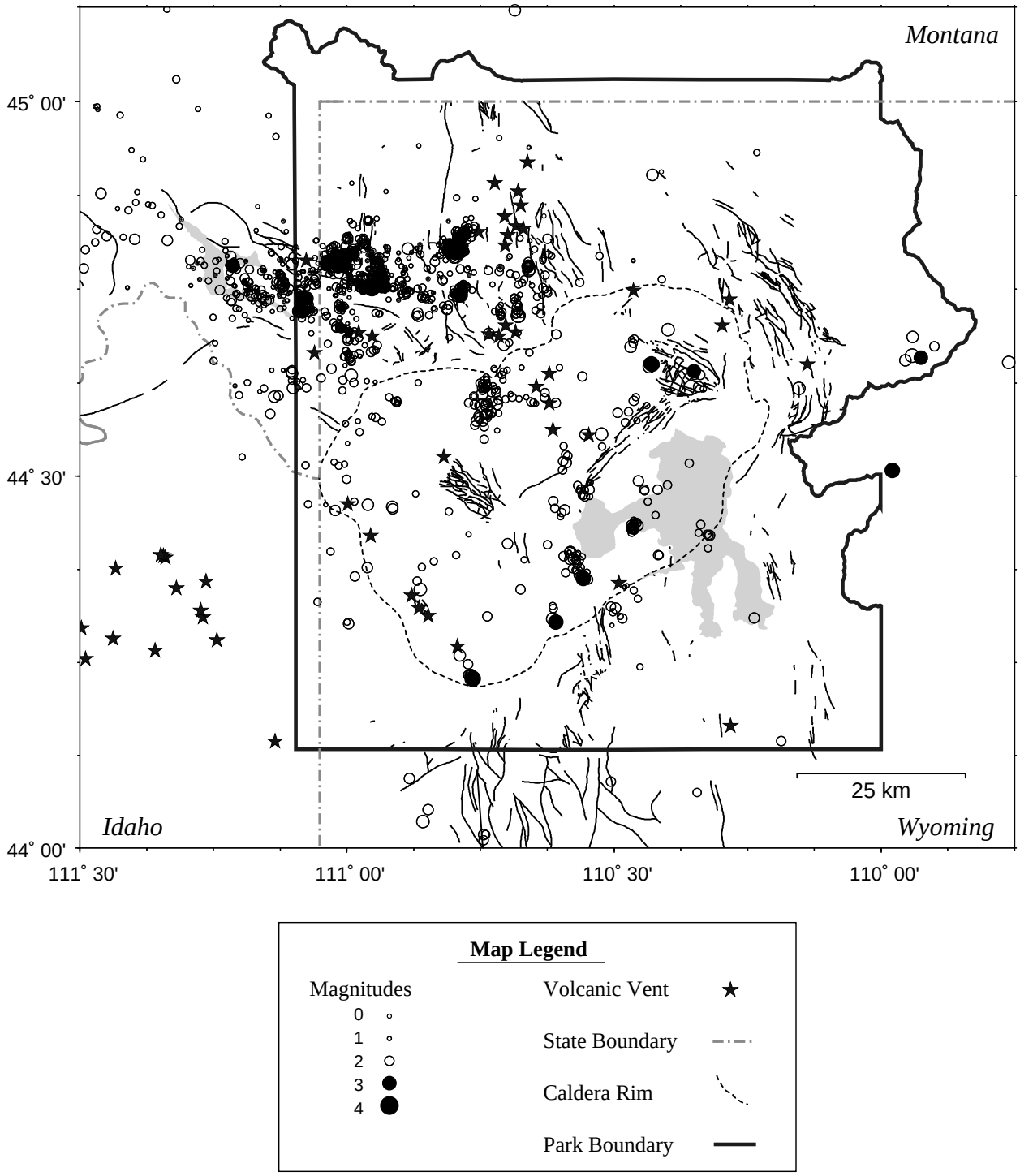

Figure 2. Earthquakes of the Yellowstone Region October 1, 1999 through September 30, 2000. Epicenters of earthquakes with magnitudes smaller than 3 are plotted as open circles; earthquakes with magnitudes 3 and larger are plotted as filled circles. Postcaldera volcanic vents are plotted as stars.