OPERATION AND DEVELOPMENT OF AN EARTHQUAKE INFORMATION SYSTEM AT YELLOWSTONE

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December 1998 - November 1999

OBJECTIVES

The principal tasks of the University of Utah-USGS cooperative agreement are to support seismic and continuous GPS station installation, maintenance, recording, and routine analyses of the Yellowstone Seismograph Network (YSN). The primary objectives of the YSN are to monitor and assess seismicity and crustal deformation that may be related to both volcanic and tectonic earthquake activity. The YSN provide information for public safety, park and surrounding community management and planning, public information and interpretation, and for scientific research interests. The YSN is designed to monitor earthquakes and ground deformation of the entire Yellowstone volcanic field, including Yellowstone National Park and the nearby Hebgen Lake fault zone. This seismic component provides real-time earthquake surveillance by a recently upgraded 22-station, 32-component, seismic network telemetered via FAA microwave links (at no cost to the project) to Salt Lake City, Utah, and digitally recorded at the University of Utah Seismograph Stations. The cooperative continuous GPS component consists of three stations that telemeter their data in real time via the USGS NSN site at Lake, Wyoming with daily telephone downloads at the Mammoth and Old Faithful sites. The USGS Volcano Hazards Program jointly funds this cooperative project with partial support from the National Park Service (NPS) for field work. The primary products for this USGS support are annual earthquake catalogs, and the services of a regional earthquake recording and information center, including timely release of unusual earthquake activity reports to the USGS and the NPS.

RESULTS

Network Upgrade Accomplishments

During the project period, the Yellowstone seismograph network has expanded to 22 stations, 32 components (Figure 1, Table 1). Five new seismograph stations were installed, including the addition of three new 3-component, broadband stations (with analog telemetry) to the network. Reconditioned L4C seismometers were installed at 13 sites (only 18 require an upgraded L4 sensor). All of the stations have been upgraded electronically. GPS-determined station locations were calculated for each station using

Trimble SSI dual frequency receivers. Table 1 details the improvements made to the seismograph network during the report period.

Significant efforts went into making the seismograph stations and relay points rugged enough to survive Yellowstone's harsh winter environment. The majority of the seismograph stations in YNP are powered by solar panels that trickle-charge a series of batteries. Weather conditions within YNP have been shown to provide insufficient solar power to keep the several of the stations online for an entire winter. To solve this problem, our technical staff designed a new power system consisting of a primary traditional solar charging system using lead-acid batteries for power storage with backup power provided by air cell batteries for time periods when there is insufficient sun to charge the lead-acid batteries. A simple circuit switches the station power source to the air cells when the charge of the lead-acid batteries drops below 11.6 volts. Installation of low-voltage cutoff solar regulators keep the lead-acid batteries from discharging completely when there is an insufficient power charge.

Two continuous GPS stations were installed at Old Faithful and Mammoth. These sites use the University of Utah Invar rod monument and Trimble 4000 SSi receiver. The data are transmitted in daily telephone downloads to the University of Utah GPS recording lab for processing using the Bernese Processing Engine. The Rinex files from these sites are archived and available for any interested user via daily ftp data release at the UNAVCO facility.

Most of the stations in the network were visited for routine maintenance during the report period. This often requires logistical support from the National Park Service who kindly provide helicopter, boat, and horse-pack support to transport both equipment and personnel to these remote seismograph stations. Table 2 summarizes the accessibility of each station within the network under summer and winter conditions. The National Park Service provides in-park housing for our personnel from minimal cost, allowing our field crews a local base of operations for maintenance. We especially thank the National Park Service for all of the support they have given to our operations.

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.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. GPS data are available by contacting Dr. Robert Smith, tel: (801) 581-7129; e-mail: rbsmith@mines.utah.edu.

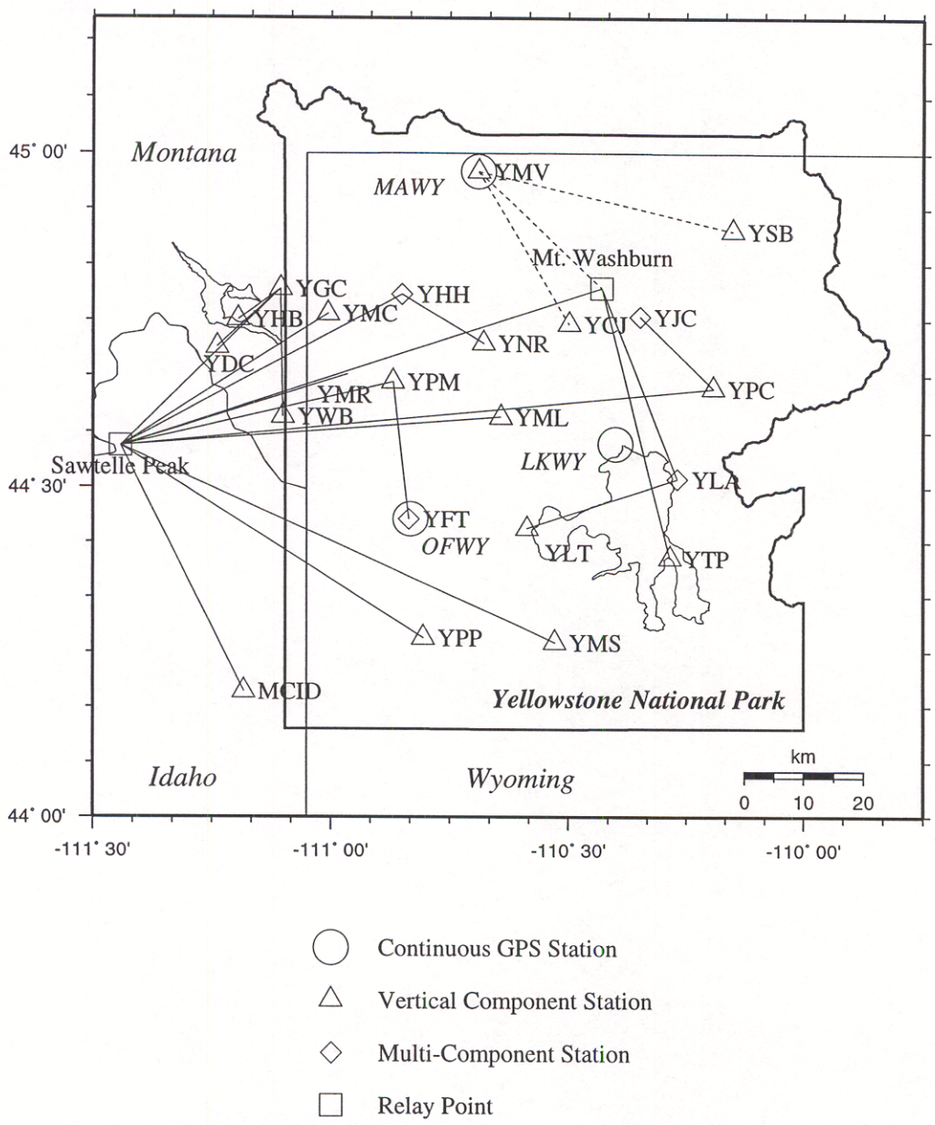

Figure 1. Map of seismograph stations and telemetry links in the Yellowstone National Park seismograph network, November 1999. Seismic station symbols correspond to sites in Table 1. Dashed lines are telephone telemetry links, solid lines are VHF, UHF radio links.

TABLE 1
Detailed Summary of Seismograph Network Improvements
December 1998 - November 1999

	Station ID	Station Name	Upgrade/repairs made
Digitally-telemetered Broadband Stations			
1.	YMR	Madison River	**New station.** Installed new digitally-telemetered broadband station; made measurements of the transmitter and receiver and adjusted output levels; installed drain in seismometer barrel: endured time-consuming and lengthy efforts to track down problem in complicated transmission path to the central recording lab in Salt Lake City, resolved with telephone company segment repairs; installed GPS clock to correct a timing problem, later removed after discovery that timing was related to the transmission problem; discovered problem with data acquisition system and resolved it after lengthy dialog with manufacturer.
Analog Stations			
1.	MCID	Moose Creek	Changed battery; made measurements on the transmitter and VCO and adjusted frequency and output levels; performed oscillator test designed by K. Whipp as a simple check of any L4 or S13 site (a small battery powered oscillator whose output is applied to the seismic calibration coil and the amplified output is observed on an oscilloscope); repaired bad amplifier on VCO board which was causing major frequency drifts.
2.	YCJ	Canyon Junction	No visit.
3.	YDC	Denny Creek	Changed battery; made measurements on transmitter and VCO, adjusted frequency and output levels; performed oscillator test.
4.	YFT	Old Faithful	Installed four batteries; checked and adjusted transmitter and VCOs.
5.	YGC	Grayling Creek	Installed two batteries; checked receiver fade margins from YWB, YDC, and YHB; made measurements on transmitter and VCO and adjusted frequency and output levels; performed oscillator test.
6.	YHB	Horse Butte	Investigated the origin of occasional excursions; checked VCO; performed oscillator test.
7.	YHH	Holmes Hill	Changed air cells; checked for winter damage; changed receiver and VCO levels.
8.	YIT	Gravel Pit	Removed station, moved to YLT.
9.	YJC	Joseph's Coat	Installed three batteries; made measurements on transmitter and VCO, adjusted frequency and output levels.

	Station ID	Station Name	Upgrade/repairs made
10.	YLA	Lake Butte	Replaced 40T with L4 from YNR; removed four batteries and installed two new batteries (due to decrease in power requirements); installed charging regulator; removed solar panels and installed one 50 watt panel; set damping of L4C; re-aimed receiver antenna; made measurements of the transmitter out, receiver fade, and VCO, adjusted frequency and output levels.
11.	YLT	Little Thumb	**New Station.** Installed equipment from YIT in barrel with concrete base and glass plate; adjusted damping; made measurements on transmitter and VCO, adjusted frequency and output levels.
12.	YMC	Maple Creek	Changed and damped L4; installed new VCO; installed new transmitter antenna and new battery; made measurements on transmitter and VCO, adjusted frequency and output levels.
13.	YML	Mary Lake	No visit.
14.	YMR	Madison River	Converted to digitally -telemetered broadband station
15.	YMS	Mount Sheridan	Installed air cells and removed lead acid batteries; repositioned solar panel; made measurements on transmitter and VCO and made necessary adjustments to frequency and output levels.
16.	YMV	Mammoth Vault	Repaired amplifier on VCO; installed surge protection at telephone line connection; made measurements of VCO, adjusted frequency and output levels.
17.	YNR	Norris Junction	Removed L4C equipment for trade with 40T equipment at YLA; installed two larger insulated barrels; reconfigured cabling and land lines; fabricated and installed solar panel mount and two 50 watt panels; made measurements on the transmitters and VCOs, adjusted frequencies and output levels.
18.	YPC	Pelican Cone	Made measurements on transmitter and VCO, adjusted frequency and output levels; checked fade margin from YJC receiver.
19.	YPM	Purple Mountain	Improved battery barrel; made measurements on transmitter and VCO, adjusted frequency and output levels; checked fade margin from YFT receiver; performed oscillator test.
20.	YPP	Pitchstone Plateau	Replaced solar panel; modified and repaired audio mixer; replaced VCO; made measurements of transmitter and VCO, adjusted frequency and output levels; checked polarity.
21.	YSB	Soda Butte	Replaced L4; performed oscillator test; installed concrete base and glass plate in barrel; installed VCO package; installed solar panel, battery with barrel, charging regulator; set damping on L4; checked polarity.
22.	YTP	The Promontory	Replaced battery; repaired wire damage; made measurements on transmitter and VCO, adjusted frequency and output levels.

	Station ID	Station Name	Upgrade/repairs made
23.	YWB	West Boundary	No visit.
		Mt. Washburn	No significant work done.
		Sawtelle Peak	Repaired antennas; modified audio filtering to accommodate a station conversion to multi-component; measured incoming signals; modified one antenna to improve signal to noise ratio and boost signal strength.
		Salt Lake City	Resolved long-standing problems with telephone lines which bring data into the central recording lab.

TABLE 2
Yellowstone National Park Seismograph Network Accessibility

Station Name	Type	Comp.	Elevation	Winter Accessibility	Summer Accessibility
Moose Creek	SP	Z	2169 m (7116 ft)	Snowmobile ~15 miles	Hike ~1 mile
Canyon Junction*	SP	Z	2426 m (7959 ft)	Snowmobile ~40 miles	Drive
Denny Creek	SP	Z	2025 m (6644 ft)	Ski ~1 mile	Drive
Old Faithful	SP	Z, E, N	2292 m (7520 ft)	Snowmobile ~30 mile	Drive
Grayling Creek	SP	Z	2075 m (6808 ft)	Drive	Drive
Horse Butte	SP	Z	2157 m (7077 ft)	Snowmobile ~5 miles	Drive
Holmes Hill	SP	Z, E, N	2717 m (8914 ft)	not accessible	Hike ~15 mi (2 days) or HC
Joseph's Coat	SP	Z, E, N	2684 m (8806 ft)	Not accessible	Hike ~15 mi (2 days) or HC
Lake Butte	SP	Z, E, N	2580 m (8465 ft)	Snowmobile ~65 miles	Drive
Little Thumb	SP	Z	2390 m (7768 ft)	Ski ~0.5 miles	Hike ~0.5 miles
Maple Creek	SP	Z	2073 m (6801 ft)	Not accessible	Hike ~10 mi (1 day) or HC
Mary Lake	SP	Z	2653 m (8704 ft)	Not accessible	Hike ~11 mi (1 day) or HC
Madison River	BB	Z, E, N	2149 m (7051 ft)	Snowmobile ~15 miles	Hike ~1 mile
Mt. Sheridan	SP	Z	3106 m (10190 ft)	Not accessible	Hike ~20 mi (2 days) or HC
Mammoth Vault*	SP	Z	1829 m (6001 ft)	Long drive	Drive
Norris	SP	Z, E, N	2336 m (7664 ft)	Snowmobile ~30 miles	Drive
Pelican Cone	SP	Z	2939 m (9642 ft)	Not accessible	Hike ~10 mi (1 day) or HC
Purple Mtn.	SP	Z	2582 m (8471 ft)	Not accessible	Hike ~3 mi (2000 foot elevation gain)
Soda Butte	SP	Z	2072 m (6798 ft)	Long drive	Drive
The Promontory	SP	Z	2384 m (7822 ft)	Not accessible	~12 mile boat trip only
West Boundary	SP	Z	2310 m (7579 ft)	Snowmobile ~1 mile	Drive
Lake - USNSN	BB	Z, E, N	2424 m (7953 ft)	Snowmobile ~60 miles	Drive
Mt. Washburn	RX	-	3122 m (10243 ft)	Snowmobile ~60 miles	Drive
Sawtelle Peak	RX	-		Drive	Drive

HC = helicopter support
* AC power source; all others solar powered

General Accomplishments

- continued upgrading and maintenance of seismograph stations against the harsh winter conditions of Yellostone. This included (1) VCO system repairs and upgrades; (2) replacement of 5-year old batteries at numerous sites; and (3) repair of ice damage to radio antennas, solar panels, and cables. Eighty-six percent (19/22) of the stations of the Yellowstone seismograph network were visited for maintenance during the report period;

- installation of a broadband, digitally-telemetered, seismograph station at Madison River, WY;

- relocation of a redundant 3-component, broadband, analog-telemetered seismograph station from Lake Butte toNorris Junction, located on the northeast side of the Yellowstone caldera;

- installation of a continuously recorded GPS receiver at Old Faithful, WY to complement receivers located at Lake and Mammoth, WY. These stations monitor the deformation of the YNP caldera. Data are automatically retrieved via a dial-up telephone line every 24 hours and then incorporated into the UNAVCO GPS archives;

- 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;

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

- technical and field assistance to the Dan Dzurisin, U.S.G.S. Volcano Hazards Program, for the installation of two new continuously recorded GPS stations in the back country of Yellowstone National Park at Hayden Valley and at White Lake.

- relocation of station YIT (Gravel Pit) to a site located closer to swarm activity near Little Thumb Creek, just west of Yellowstone Lake (new station, YLT);

- installation of two reconditioned L4 seismometers (Maple Creek and Soda Butte), completing a systematic upgrade of all L4 seismometers in the YSN with refurbished seismometers and calibration coils;

- upgrade of station Soda Butte to standard UUSS installation specifications (UUSS VCO, solar panel, and battery charging system, and concrete base in the seismometer barrel), completing the systematic upgrade of all YSN stations to standard electronics and construction;

- 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);

- detailed study of inadvertent temporal changes in the Yellowstone coda magnitude scale, based on comparison with the new M_L data; and,

- assistance to the USGS-NEIC for maintenance of a cooperative U.S. National Seismograph Station

(USNSN) located near Yellowstone Lake (LKWY).

- developed APS-supported recording software on a dedicated Sun workstation at the University of Utah.

- developed protocols for daily downloads of CGPS data to the UNAVCO archive.

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. HQ98AG01939:*

- for Year 2000 compliance, implementation of needed changes to all network-related computer systems and equipment, including required operating system upgrades of all computers, subsequent testing of those systems, and revision of non-compliant earthquake-analysis software;

- installation of *Earthworm* real-time-alert software system version 4.0 (Year 2000 compliant), submission of two new software modules (to continuously record waveform data in SAC format) to Earthworm Central for community-wide distribution, installation and use of a second *Earthworm* system for local testing purposes, continued work on tuning *Earthworm* automatic earthquake location software for optimized use with Utah and Yellowstone data, and installation of new REF TEK digital telemetry software, replacing CPU-intensive software previously used;

- completion of software to integrate regional digital telemetry data streams (1 Univ. of Utah REF TEK station and 3 USNSN stations located within and near the YSN) with existing analog telemetry data streams for routine analysis, including real-time data exchange with the National Earthquake Information Center;

- in-situ calibration of the Univ. of Utah three-component broadband digital telemetry station (YMR) and one USNSN station (LKWY) using software we developed during the report period;

- installation and configuration (with the assistance of F. Vernon and J. Eakins, Univ. California, San Diego) of the *Antelope* real-time data acquisition and information system, cooperatively developed by Kinemetrics and Boulder Real-time Technologies;

- near-completion of preparatory work for submitting 19 years of Univ. of Utah regional network waveform data to the IRIS Data Management Center in SEED format, including (1) software development to automatically convert Utah waveform data to SEED format for submission to the IRIS Data Management Center, (2) compilation of a database inventory of instrument components for all stations in our network since digital recording began in 1981 (this task has proven to be greatly time consuming because all the required information had to be researched from handwritten field notes for almost 30 YSN stations), and (3) use of this database to compute system response information for all past and present stations in our network (more than 140 individual instrument response calculations for the YSN);

- determination of local magnitudes (M_L) and M_L station corrections using synthetic Wood-Anderson seismograms from local USNSN and Utah broadband stations, for most coda magnitude (M_C) 3.0 and greater earthquakes located in the Yellowstone region since January 1, 1994 (project involved the analysis of more than 1800 earthquakes in the Intermountain seismic belt, including 220 shocks located within the Yellowstone region);

- major efforts towards of an upgrade of our Web pages (URL: www.seis.utah.edu), to include (1) USGS seismicity map presentation format, (2) providing seismic data to GIS users in Arc/Info native format, and (3) complete reorganization of pages to make them more user friendly; and,

- near-completion of a comprehensive station inventory for the IASPEI handbook.

Network Seismicity

Figure 2 shows the epicenters of 3147 earthquakes ($M_c \leq 3.25$) located in part of the University of Utah study area designated the "Yellowstone region" (lat. 44 ° - 45.17° N, long. 109.75° - 111.5° W) during the period December 1, 1998 to November 30, 1999. The seismicity sample includes 2 shocks of magnitude 3.0 or greater. The largest earthquake within the Yellowstone region during the report period was a shock of magnitude 3.25 on May 23, 1999 (06:47 UTC), located 7.9 km NNE of Madison Junction, WY. Intense earthquake swarms continued to be recorded in the Yellowstone National Park.

Reports Published

Lowry, A.R., N.M. Ribe, and R.B. Smith (1999). Dynamic elevation and seismicity of the western U.S. Cordillera, *J. Geophys. Res.* (submitted).

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.* **104**, 15,105-15,121.

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.

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

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, 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., 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.

Waite, G.P. and R.B. Smith (1998). Space-time variations of seismic source mechanisms and related stresses of Yellowstone (abs.), *Eos, Trans. Amer. Geophys. Un.* **79** (45), F976.

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.

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 (in press).

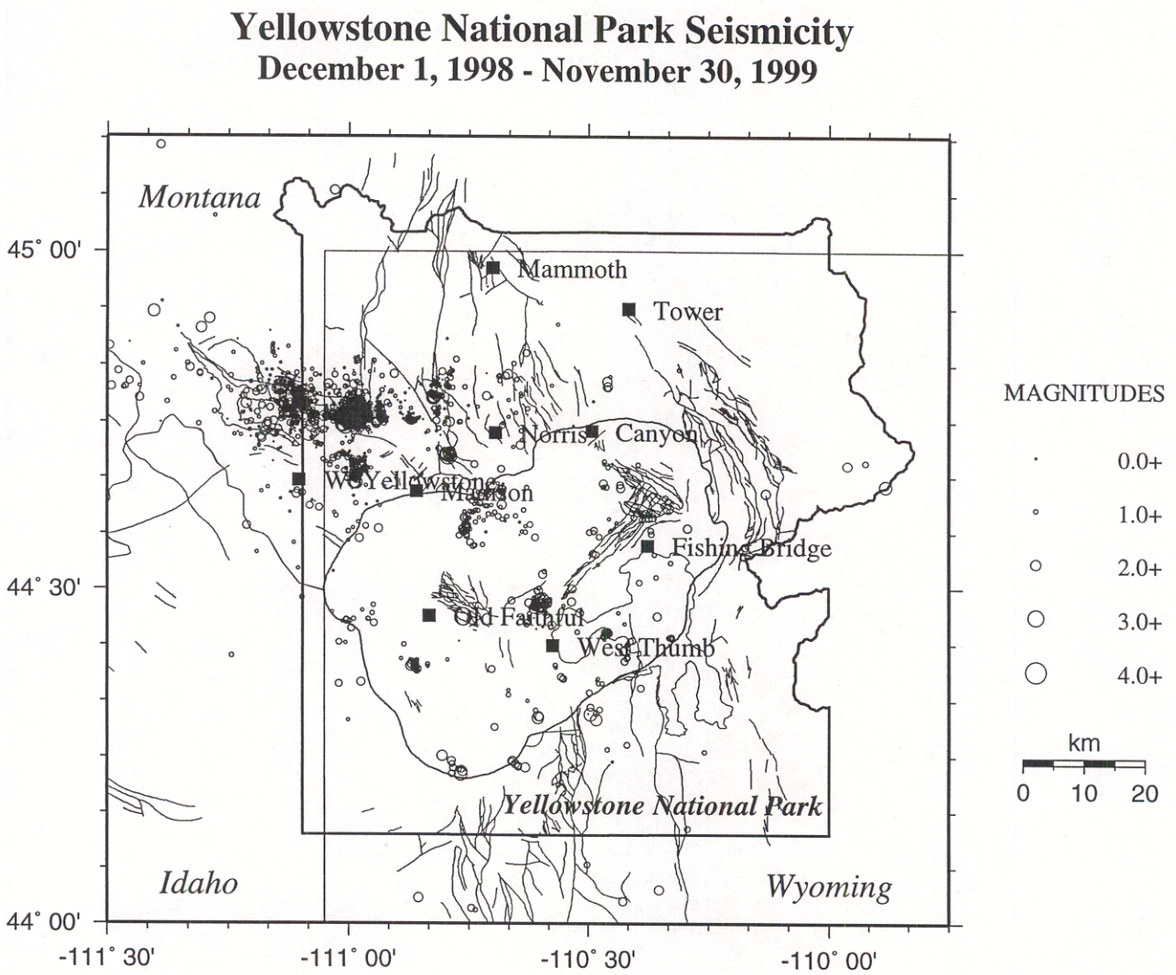

Figure 2. Earthquake epicenter map of the Yellowstone National Park region, December 1, 1998 to November 30, 1999.

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Non-technical Summary
December 1998 - November 1999

The principal tasks of the Yellowstone Seismic and GPS Networks (YSN) are to monitor earthquake activity and crustal deformation in Yellowstone National Park and surrounding regions. 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 3-station cooperative USGS-NFS continuous GPS network are recorded and processed at the University of Utah and archived at UNAVCO national data center in Boulder, CO. A total of 3147 earthquakes were located in the study region, including 2 shocks of magnitude 3.0 and larger. The largest earthquake within the Yellowstone region during the report period was a shock of magnitude 3.25 on May 23, 1999 (06:47 UTC), located 4.9 miles north northeast of Madison Junction, Wyoming. The most notable efforts during the report period related to continued upgrading of field electronics for survival in Yellowstone's harsh, rugged environment, installation of a state-of-the-art digital seismograph station, and installation of two additional global positioning stations at Old Faithful and Mammoth.