Final Technical Report

USGS Award Number: G09AC00471

Title: Upgrade of Selected Montana Regional Seismograph Network Stations

Author and Affiliation:

Michael Stickney
Director, Earthquake Studies Office
Montana Bureau of Mines and Geology
Montana Tech of the University of Montana
1300 W Park St
Butte, MT 59701

(406) 496-4332 Voice
(406) 496-4451 Fax
mstickney@mtech.edu
http://mbmgquake.mtech.edu

Contract Start and End Dates: September 29, 2009 – September 14, 2011

Abstract

Using this contract, the Montana Bureau of Mines and Geology upgraded three analog, short-period, vertical seismograph stations in the Montana Regional Seismograph Network to multiple channel digital stations. Two of the stations were upgraded to 4-channel systems consisting of three components of accelerometer data and a short-period, vertical seismometer channel. The third station was upgraded to a 6-channel system consisting of three components of broadband seismometer data and three components of accelerometer data. These upgrades significantly improve the seismic monitoring capabilities of the Montana Regional Seismograph Network and will allow on-scale recordings of future significant earthquakes.

Introduction

The Montana Bureau of Mines and Geology operates the Montana Regional Seismograph Network (MRSN), which is an element of the Advanced National Seismic System. The MRSN provides seismic monitoring coverage of the northern Intermountain Seismic Belt in the mountainous western one-third of Montana and records, locates, and reports earthquake locations and magnitudes for approximately 1500 earthquakes in a typical year. Prior to this project, all 35 stations that comprised the MRSN were short period analog instruments except for one that is recorded digitally along with three components of strong motion data. We selected three existing seismograph stations and upgraded them from analog to digital stations.

Jette Lake seismograph upgrade

We chose the Jette Lake seismograph station (JTMT) in northwest Montana (Figure 1) because it is a secure and quiet bedrock site with good sun exposure that is located approximately midway between the broadband station operated by the Canadian Geological Survey at Waterton Lake to the north and the U.S. Geological Survey ANSS Backbone station near Missoula to the south. The JTMT site is underlain by hard bedrock of the Spokane Formation of the Precambrian Belt Supergroup (Figure 2). Upgrading the JTMT station benefited greatly from the fact that this station is located on the Flathead Indian Reservation and is operated cooperatively with the Confederated Salish and Kootenai Tribes. They enthusiastically supported this project using their own funding sources to fabricate instrument vaults and provide materials and labor for the upgrade (Figures 3 and 4). Although we used a portable generator to power drills and the jackhammer to excavate the vault holes, all work at the site was completed using hand tools.

After a lengthy permissions and planning process, actual work at the JTMT site began on July 13, 2011 by excavating the surface vault hole into solid bedrock (Figure 3) and setting the vault housing in concrete (Figure 4). Because we are concerned about the possibility of lightning damage at this site, we constructed both instrument enclosures (seismometer/accelerometer vault and data logger vault) with electrically conductive tops, sides, and bottoms. Of course for the seismometer/accelerometer vault, a solid metal floor would be very undesirable for ground motion monitoring, so instead we used the technique of Arabasz and others (2006; Arabasz, Walter J., David L. Drobeck, Relu Burlacu, Kristine L. Pankow, and James C. Pechmann, 2006, Station CCUT—Cooperative Broadband Seismograph Station Near Cedar City, Utah (ANSS/USArray National Backbone Network); FINAL REPORT Incorporated Research Institutions for Seismology Subaward Agreement No. 383 Under NSF Cooperative Agreement No. EAR-0004370. http://www.seis.utah.edu/Reports/iris2006/CCUT_Report.pdf, accessed 12/5/2011.) and bolted a sheet ½-inch galvanized steel mesh (hardware cloth) to the bottom of the vault box. Before installing the vault box, a generous layer of concrete was placed on the cleaned and prepared bedrock

surface in the bottom of the vault hole and leveled. Then the vault box was placed screen-side down onto the concrete and an additional 3-inch concrete layer was placed both inside and around the outside of the vault box. Thus, within the seismometer/accelerometer vault, there is a concrete floor that is directly coupled to solid bedrock but an electrically conductive housing completely enclosing the instruments, effectively placing them inside a faraday cage. All of the instrumentation enclosures are grounded with a stranded, uninsulated, heavy-gauge wire that is buried between enclosures and coupled to grounding rods in the old analog equipment housing.
During the period August 15-18, 2011, Ken Whipp, seismograph technician recently retired from the University of Utah Seismograph Stations, join me and Confederated Salish and Kootenai Tribal personnel to finish remaining construction details at the JTMT site and install equipment. Remaining construction details included installing 2-inch rigid insulation inside the instrument housings, installing a flexibly mounted conduit between the seismometer/accelerometer vault and the data logger vault, installing a 200-watt solar panel array along with regulation and surge protection, excavating trenches for direct-burial cables, and installing a steel post on which to mount the GPS antenna for timing control. Power and data cables have surge protection devices at each end. Although the JTMT station lies at a relatively low elevation of 1469 m (4820 feet), we anticipate the possibility of multiday cloudy periods during winter inversions and so designed the 200-watt solar array to charge four 96-amp hour batteries. The voltage regulator has a low-voltage disconnect that will prevent the battery bank from being completely discharged and ruined in the event of inadequate solar gain or other power supply problems. However, we believe the installed power system should be adequate through the winter months because it is identical to those that successfully power similar stations through the severe winter conditions of the Yellowstone back country.

I made a final trip to JTMT September 13, 2011 to install a matched battery set and complete a few installation details. On October 25, tribal personnel hauled in a truckload of road mix and buried the seismometer/accelerometer vault to a depth of at least one foot to provide additional thermal stability. Continuous data streams for all six channels are sampled 100 times per second and telemetered via spread spectrum radio to the Tribal Safety of Dams Office located 27 km to the southwest in Ronan, Montana.

After setting up a RefTek data server on the Ronan Earthworm node, modifying our Earthworm system to receive the new JTMT data streams, and generating dataless SEED volumes with the new response data, continuous data are archived at the IRIS DMC beginning September 29, 2011. We continue to operate the old analog short-period vertical seismometer in parallel with the new broadband/accelerometer channels for comparative purposes and until the new system proves reliable. The data quality of the new broadband instrument is excellent as indicated by a weekly probability density function plot (Figure 6). Figures 7 and 8 show example seismograms that clearly illustrate the improved capabilities of the digital broadband seismometer over the old analog seismometer.

Limekiln Ridge seismograph upgrade

We selected the Limekiln Ridge seismograph station (LRM) for upgrade because it is a relatively quiet bedrock site with a direct line-of-sight telemetry path to the Earthquake Studies Office in Butte that does not require any telemetry repeaters. LRM is the longest continuously operating telemetered seismograph station in the Montana network; it opened in October 1981. LRM sits on thermally metamorphosed carbonate rocks (marble) immediately above Cretaceous granitic rocks of the Boulder Batholith; granodiorite outcrops within a few hundred meters of the station. Sitting at an elevation of 2326 m (7631

feet) just west of the Continental Divide, LRM does experience some wind noise but it is typically not a problem. There is a rough forest road on the opposite side of the ridge that carries relatively light numbers of vehicles (5-10 per day), which produce visible noise on the seismograms. However, this road snows in between November and April each year so traffic noise is only observed for about half of each year. The old analog instrumentation was housed in a 30-gallon open-head barrel that was buried to within 6 inches of the ground surface. Cable connections to the seismometer, which was buried outside the barrel and power and telemetry connections were made through water-tight cable passes. This configuration made a dry and electrically protected instrument housing but it was unsuitable for housing an accelerometer, which must be bolted down to a concrete foundation.

We installed a new surface vault with characteristics similar to that installed at JTMT. A concrete floor is poured directly on bedrock. The bottom of the vault enclosure is made of steel mesh hardware cloth that is set three inches into the concrete floor. With a locking metal lid, the enclosure forms a faraday cage. Mature Douglas Fir trees block a ground-level view to the Earthquake Studies Office in Butte so the spread spectrum radio antenna is mounted approximately 50 feet up in a tree, which provides a clear line-of-sight telemetry path. A GPS antenna used for timing control is mounted at the same place. An adjacent tree has an ideal configuration for mounting two 100-watt solar panels that provides good sun exposure during the winter months of low sun angle (Figure 9).

In October 2010, we installed a four-channel NetDAS 24-bit data logger manufactured by DAQ Systems of Bozeman, Montana. The NetDAS contains a 3-component Micro-Electro-Mechanical System accelerometer package configured for 2 g full scale. We connected the fourth channel to the Teledyne Geotech S-13 short period seismometer that previously operated at this site. Figure 10 shows the instrumentation at the LRM station. All four channels are sampled at 200 samples per second. Buffered data are telemetered to the Earthquake Studies Office approximately once per second via the spread spectrum radio link where they are received by the GRFHub data server. The Earthworm module GRF2EW extracts LRM data from the GRFHub data server, converts it to Earthworm format, and places it in Earthworm wavetanks where it is available for routine processing and analysis along with the rest of the Montana network data. We continue to operate the old analog system alongside the new digital system for comparative purposes and until the reliability of the new system is proven.

DAQ Systems, which manufactures the NetDAS data loggers, has provided the response of the digital filters used in the data loggers only in terms of Z-transforms. This representation of digital filter response is apparently not compatible with a dataless SEED volume. We are currently working with personnel at IRIS DMC to covert the Z-transforms to poles and zeros representation, which can be incorporated into SEED volumes. As soon as poles and zeros representation is available for the NetDAS data loggers (expected within a month), we will finish generating dataless SEED volumes for LRM and submit them to IRIS DMC (http://www.iris.edu/data/metadata/) where dataless SEED volumes and waveform data for all of the rest of the MRSN stations are currently available. Following receipt of response files, the IRIS DMC will be able to archive the digital LRM data that is currently stored there.

Helena York Bridge seismograph upgrade

The seismograph northeast of the city of Helena, Montana near York Bridge (HRY) was installed in the summer of 1980 by the Holter Research Foundation with assistance of the Montana Bureau of Mines and Geology. The station telemetered a single channel of analog short period vertical data to the Holter

Research Foundation office in uptown Helena where it was recorded on a drum recorder. After the passing of Dr. Jeff Holter, Director of the Holter Research Foundation in 1983, Dr. Holter's estate donated the seismograph equipment to the Montana Bureau of Mines and Geology. After installing a series of mountain-top telemetry repeaters in July 1984, continuous HRY data were recorded at the Earthquake Studies Office in Butte.

We selected the HRY station for digital upgrade because it has an existing surface vault with a concrete floor that is large enough to accommodate the new digital instrumentation, it has a clear line-of-sight into Helena, and no other digital seismographs that stream continuous data are anywhere close to this important station. The vault is installed in competent bedrock of the Greyson Formation of the Precambrian Belt Supergroup. The instrumentation used to upgrade HRY is identical to that used at LRM. The only difference in the installation details is that there are no trees in the vicinity of HRY so the solar panel array and antennas are mounted on a steel mast.

We installed the NetDAS data logger at HRY in October 2010. However, finding an agency or organization in Helena that would allow us to telemeter data to their building and connect to their computer network for internet access without charging a monthly fee proved surprisingly time consuming and difficult. So we are currently operating the data logger in triggered mode and storing triggered event files on site for later retrieval. We have just received received permission to telemeter HRY data to the University of Montana, Helena College of Technology in downtown Helena for internet access. We will be working through the winter as weather permits to install this new telemetry link.

Conclusions

We have successfully upgraded three MRSM analog single-channel seismograph stations to multi-component digital stations. These upgrades significantly improve the seismic monitoring capabilities of the the MRSN. The new accelerometer data will be useful for the future implementation of ShakeMap in Montana.

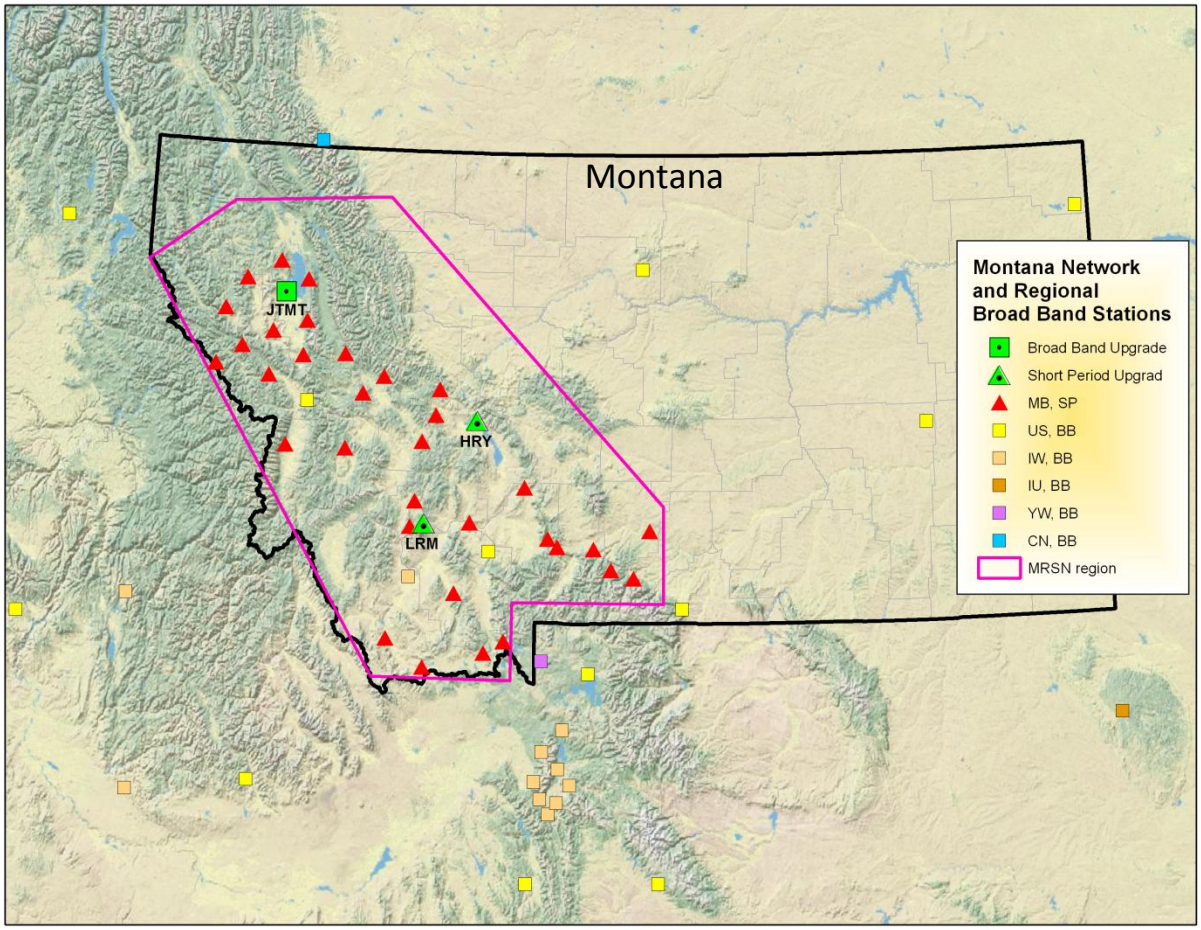

Figure 1. Upgraded broadband/strong motion (green square) and short-period/strong motion (green triangles) stations of the Montana Regional Seismic Network (MRSN). Red triangles show short-period stations of the MRSN. Squares show regional broadband stations continuously recorded by the MRSN that are operated by the USGS as part of the ANSS Backbone (yellow) and Intermountain West (tan) networks; and also the Global Seismic Network (brown), the University of Utah (lavender), and the Canadian National Network (blue). The magenta polygon shows the MRSN authoritative region.

Figure 2. Jette Lake seismograph site prior to digital upgrade. Analog instrumentation and telemetry is housed in brown metal enclosure with solar panel and telemetry antenna mounted outside on separate pole. The digging bar standing just below the outcrop of Spokane Formation argillite marks the future site of the broadband seismometer vault.

Figure 3. Confederated Salish and Kootenai Tribal personnel excavating into bedrock for instrument vaults. The broadband seismometer and accelerometer are installed in far vault. The data logger is housed in the near vault.

Figure 4 Tribal personnel placing concrete inside and around the seismometer/accelerometer vault. The vault enclosure was fabricated by tribal employees using ¼-inch-thick plate steel with locking lids.

Figure 5 Finished seismometer vault showing placement of broadband seismometer (under insulated cover) and accelerometer. North-south lines are scribed on concrete vault floor. Note 2-inch-thick rigid insulation lining vault walls. A similar piece of insulation is installed beneath the vault lid to help provide temperature stability. The entire vault as buried with over one foot of soil to provide aditional temeprature stability. The instrument cables feed through a flexibly mounted conduit into the adjoining vault, which houses the data logger and surge supression components.

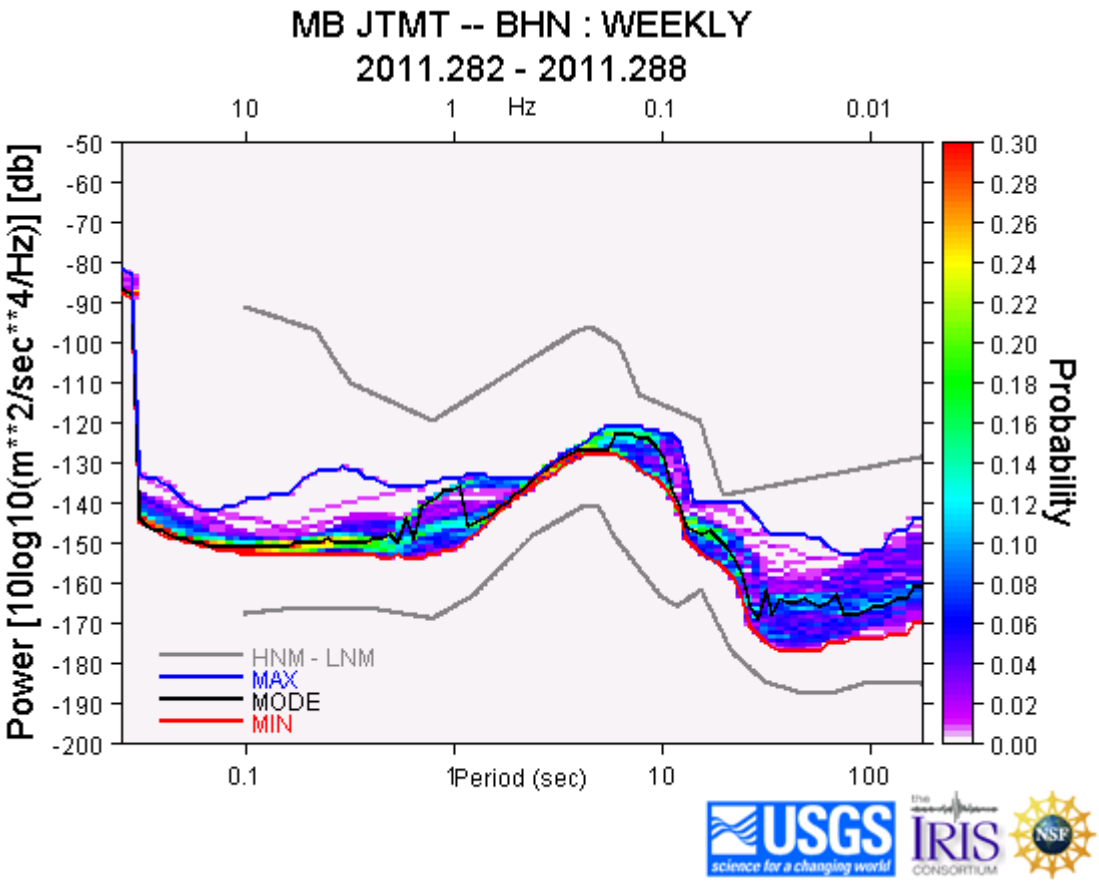

Figure 6. Probability Density Function plot for the BHZ channel of JTMT for the week of October 9-15, 2011 from the IRIS website (http://www.iris.edu/servlet/quackquery/pdfDrill.do?station=JTMT&yyyyDDD=2011.282&length=7&location=++&channel=BHN&network=MB). The minimum signal level is approximately 10-12 db above the level of the low noise model. The maximum signal level is below the high noise model and well below the high noise model at frequencies with periods less than about 5 seconds.

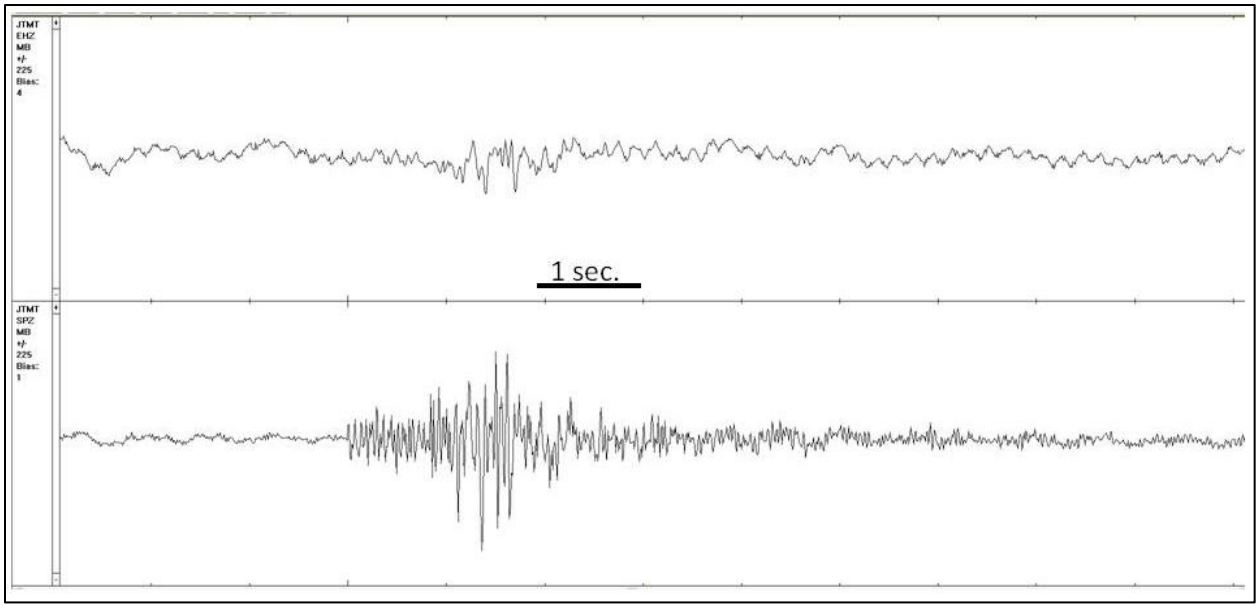

Figure 7. Time-aligned traces for JTMT short-period analog (top) and high-pass filtered broadband vertical (bottom) seismograms for a microearthquake centered within 5 km of JTMT on September 27, 2011 at 22:24 UTC. The dramatically better digital recording of this event results from improved sensitivity of the seismometer, better high-frequency content of the seismogram (25 Hz Nyquist frequency for the analog channel versus 50 Hz for the digital channel), and lack of telemetry noise that affects the analog channel. Estimated magnitude for this event is -0.6.

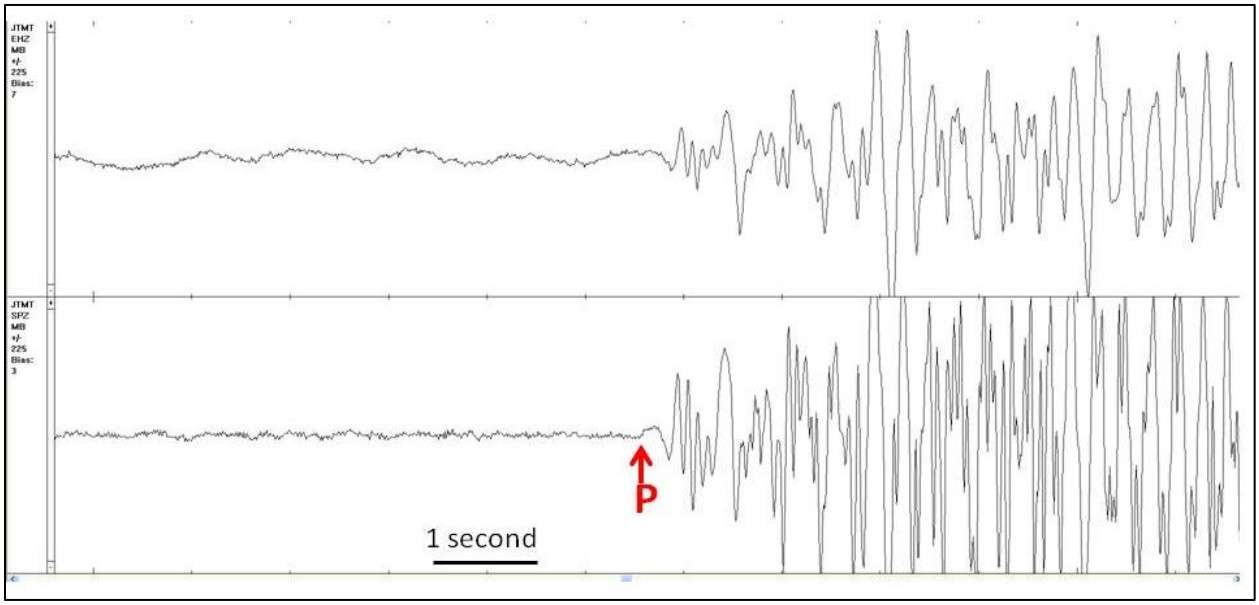

Figure 8. JTMT analog versus high-pass filtered digital records for a small regional earthquake on September 26, 2011 at 03:13 UTC. The weak upward first arrival of the P-wave that is clearly visible on the digital (lower) trace is impossible to pick on the analog (upper) trace. Using only the analog trace would likely have resulted in an erroneously picked first motion and arrival time.

Figure 9. LRM seismograph station viewed to the north-northeast, prior to removal of old analog solar panel and telemetry antenna (on pole at center). New instrument vault is in the lower right corner of photo. New solar panel array mounted in tree at upper left. Arrow at top center points to spread spectrum antenna and GPS antenna concealed in treetop.

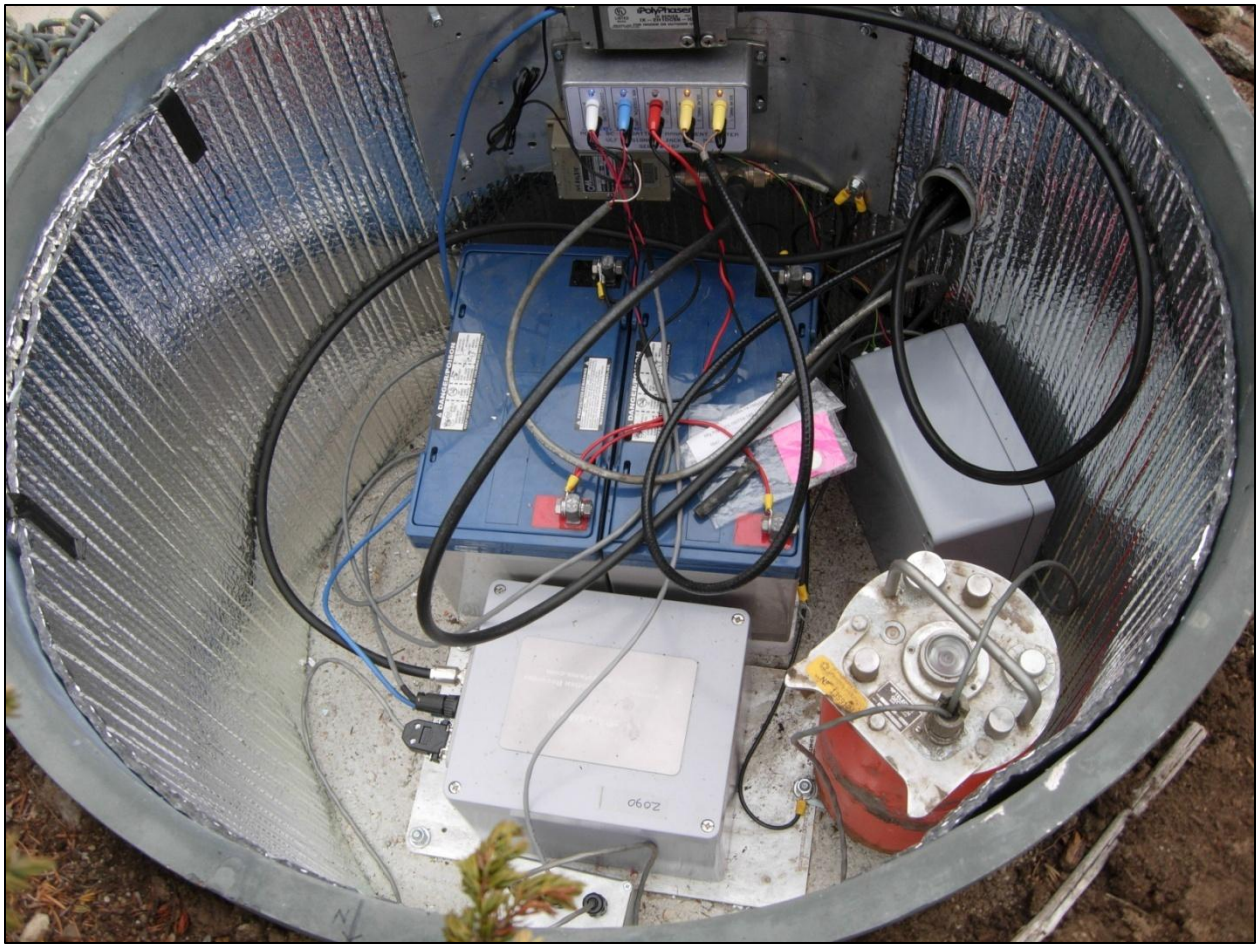

Figure 10. Instrumentation in the LRM surface vault including two deep cycle batteries, S-13 seismometer, NetDAS data logger bolted to mounting plate, and power regulation and surge protection (mounted on wall panel). Grey box to the right of batteries is the analog preamplifier that runs in parallel with the digital system.

Bibliography

No publications have resulted from this work.