



# 2017 ANNUAL REPORT

UNIVERSITY OF UTAH SEISMOGRAPH STATIONS



# DEAR FRIENDS,

I am happy to report the University of Utah Seismograph Stations (UUSS) had another exciting and productive year in 2017. Thanks to all of you who support and promote our mission of reducing the risk of earthquakes in Utah through research, education, and public service.

An  $M_w$  5.3 earthquake on Sept. 2, 2017, in southeastern Idaho reminded us that we absolutely do live in earthquake country. Thankfully, this earthquake caused little damage, but its shaking was felt throughout northern Utah, as far south as Provo. UUSS responded to the earthquake by partnering with the U.S. Geological Survey and the Idaho Geological Survey to deploy a temporary array of seismographs in the source region. Using these data, we detected and located over 1,000 aftershocks in the two months following the mainshock. This allowed us to map out a previously unknown fault system.

UUSS also recorded enhanced seismicity in Yellowstone National Park during 2017. Between June 12 and Sept. 30, a swarm of over 2,400 earthquakes was recorded in the Maple Creek region of Yellowstone. The largest event in the swarm was an  $M_w$  4.4 earthquake on June 15 that was widely felt throughout the park. Although earthquake swarms in Yellowstone are common, this was the second longest swarm ever recorded. Yellowstone earthquake swarms are often related to the movement of fluids in the crust and usually do not portend a volcanic eruption; however, it remains important to monitor them closely.

In 2017, UUSS continued working with the University of Utah team vying to host the Frontier Observatory for Research in Geothermal Energy (FORGE). This project is sponsored by the U. S. Dept. of Energy and aims to build a facility for developing technologies related to enhanced geothermal energy production. The UUSS FORGE effort is led by Prof. Kris Pankow and is focused on quantifying the seismic hazard near the proposed FORGE site in Milford, Utah. Utah is one of two finalists for this project, and the winner will be announced in 2018.

We look forward to another exciting year in 2018. I encourage you to visit our web page at [quake.utah.edu](http://quake.utah.edu) to stay up-to-date on our initiatives and products as well as to find out about the latest seismic activity in Utah and Yellowstone. You can also follow UUSS on Twitter with the handle @UUSSquake.

Best wishes,  
Keith D. Koper  
UUSS Director



DR. KEITH D. KOPER  
DIRECTOR

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## SULPHUR PEAK EARTHQUAKE SEQUENCE

On Sept. 2, 2017, an  $M_w$  5.3 earthquake occurred in southeastern Idaho. The shock was reported felt by more than 1,800 people in southeastern Idaho, western Wyoming, and northern Utah. The epicenter was located 15 km east of Soda Springs, Idaho, near Sulphur Peak. Although not within the immediate covered area of the University of Utah Seismograph Stations (UUSS), southeastern Idaho is of interest to UUSS and the United States Geological Survey (USGS) Earthquake Hazards Program.

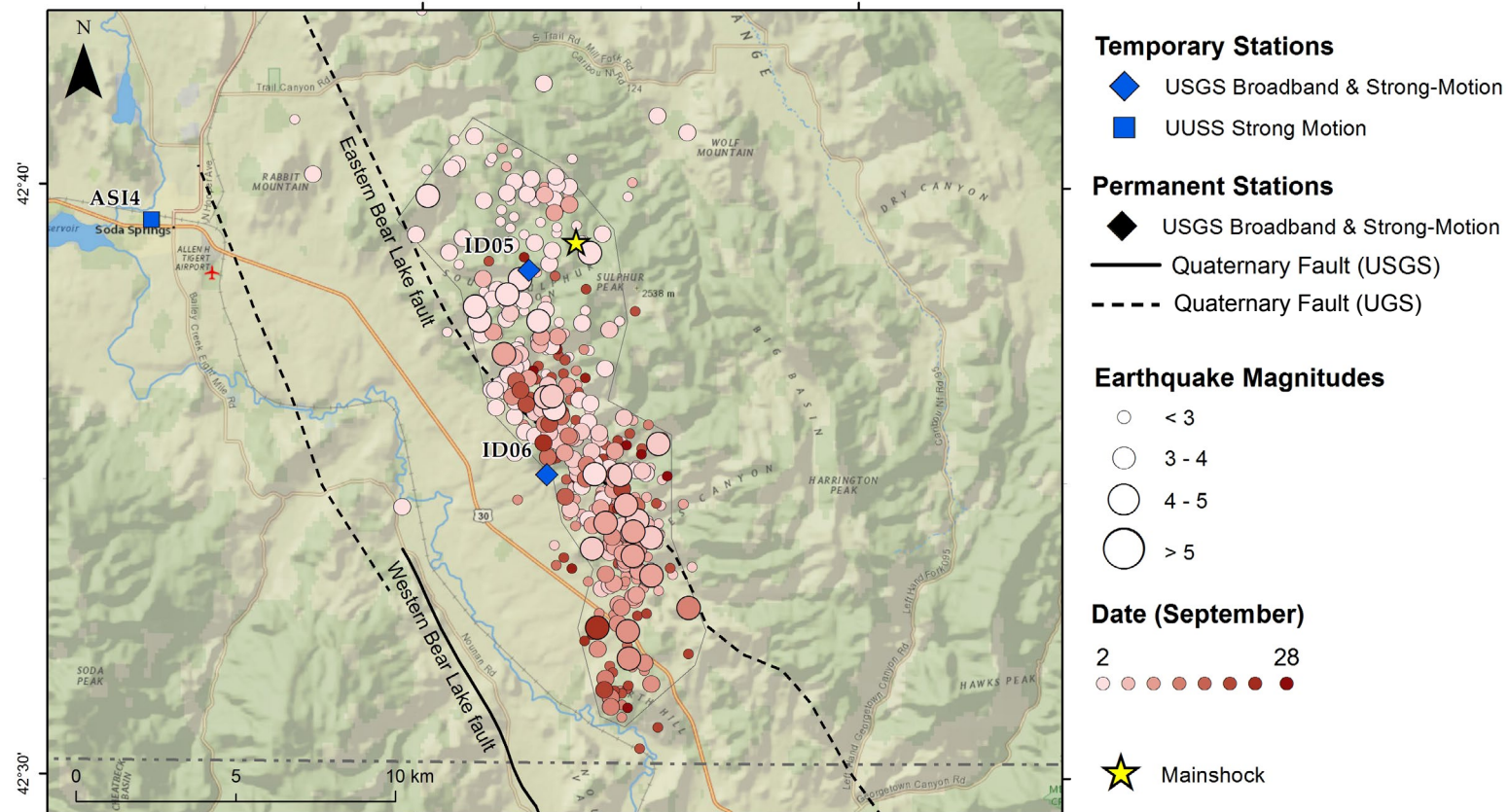
UUSS and USGS collaboratively installed a local network of eight temporary seismic stations during Sept. 5–12. The goals of the temporary deployment were to enable better locations, especially focal depths, for the mainshock, foreshocks, early aftershocks, and ongoing aftershocks. Additionally, the stations were designed to capture strong ground motion from any large aftershocks. The strong ground motion recordings will help to predict large, damaging shaking

from future moderate-to-large earthquakes.

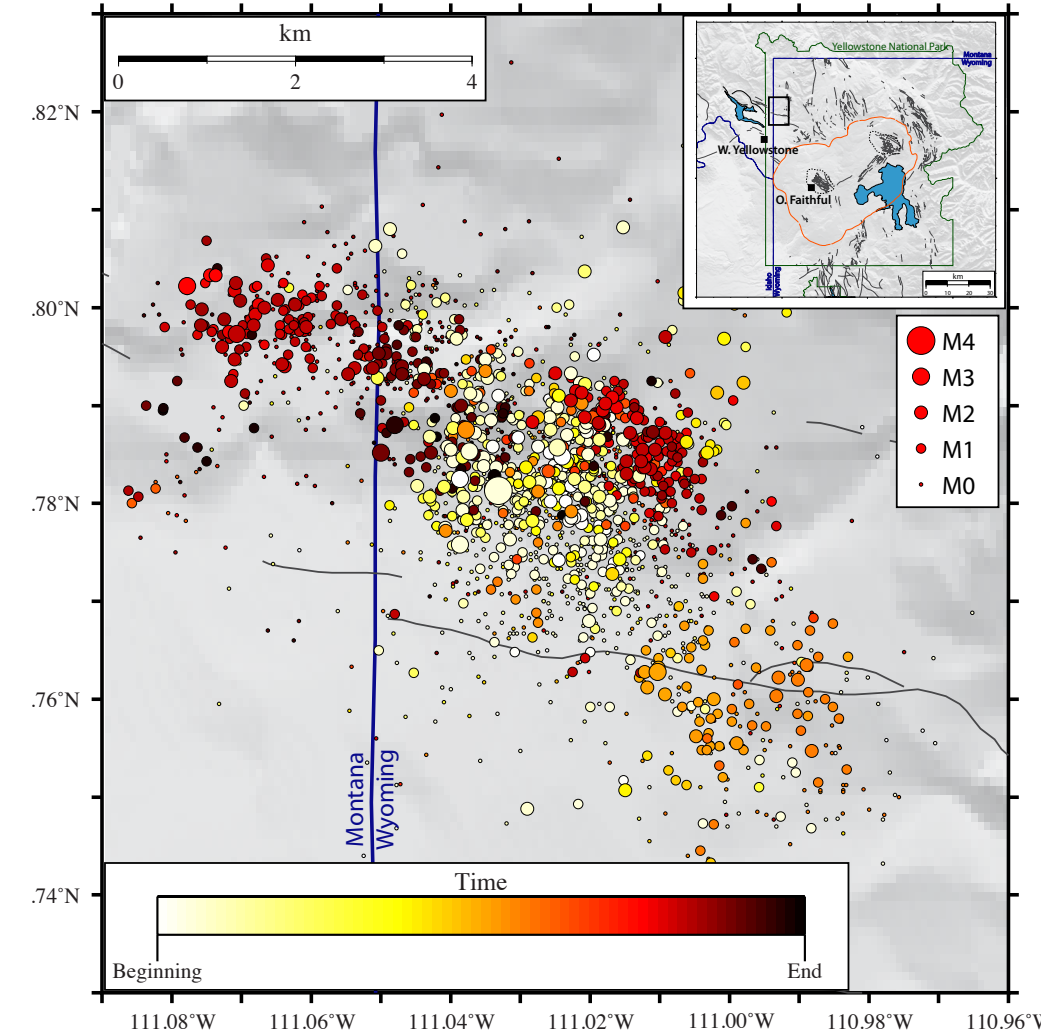
In the 34 minutes prior to the  $M_w$  5.3 mainshock, UUSS detected nine foreshocks of magnitude 1.3 to 4.1. The aftershock sequence was very energetic, consisting of more than 1,900 locatable events. From Sept. 2–28, the aftershocks included 26 of magnitude 4.0 or greater and 147 in the magnitude range 3.0–3.9. The largest aftershock was an  $M_w$  5.0 on Sept. 10, which was reported felt by nearly 200 people.

The  $M_w$  5.3 Sulphur Peak earthquake sequence is not attributed to any known fault. The closest Quaternary faults to the activity are the west-dipping East Bear Lake fault and the east-dipping West Bear Lake fault. The aftershocks of the Sulphur Peak earthquake span the mapped surface trace of the Eastern Bear Lake fault; however, it appears that the aftershocks lie beneath the west-dipping surface of the East Bear Lake fault on an unmapped, buried fault within the Aspen Range.

## EARTHQUAKE EPICENTERS FROM THE UUSS CATALOG (September 2–28)



## RECORD BREAKING SWARM IN YELLOWSTONE



In 2017, Yellowstone experienced the second largest earthquake swarm ever recorded in the park. The Maple Creek swarm began on June 12, 2017, and lasted until late September with sporadic activity continuing in the area throughout the rest of the year.

In total, there were over 2,400 earthquakes in the Maple Creek swarm located around 13 km (~8 miles) north-northeast of West Yellowstone, Montana in Yellowstone National Park. The largest event of the swarm was a magnitude 4.4 earthquake that occurred on June 15, 2017, at 6:48 pm local time (00:48 June 16 UTC). The M4.4 earthquake was reported felt by over 120 people in Yellowstone National Park and the surrounding communities, including West Yellowstone, MT. In addition to the M4.4 earthquake, the swarm produced 11 earthquakes in the M3 range, 186 earthquakes in the M2 range, 784 earthquakes in the

M1 range, and over 1,400 earthquakes with magnitudes of M0 or less. In total, the swarm contained 17 earthquakes that were reported felt by people in and around Yellowstone National Park and accounted for over 70 percent of the total seismicity in and around Yellowstone for 2017.

Earthquake swarms are common in Yellowstone and account for roughly 50 percent of the total seismicity in any given year on average. Most swarms are small and contain 10–30 earthquakes and last for 1–5 days. However, occasionally we have larger swarms like the 2017 Maple Creek swarm. During large swarms like these, UUSS seismologists are in frequent contact with colleagues at Yellowstone National Park and the U.S. Geological Survey to make sure information is being communicated to the public about the increased seismic activity.



# FORGE PROGRESS

In 2017, the University of Utah continued as a front-runner for the permanent home of the Frontier Observatory for Research in Geothermal Energy (FORGE) project. The project, sponsored by the U. S. Department of Energy (DOE), entered Phase 2 (see infographic at right) in determining the location to implement their Enhanced Geothermal System (EGS) technologies facility. Sandia National Laboratory (Fallon, Nevada) and the University of Utah (Milford, Utah) were the top two contenders to host the FORGE project.



The University of Utah Seismograph Stations (UUSS) participated by leading the seismic mitigation and monitoring efforts for the Milford, Utah, site. Prof. Kristine L. Pankow and her team published their local seismic monitoring findings—a key aspect to the Induced Seismic Mitigation Plan necessary for Phase 2B. Pankow's report used four levels of seismic mon-

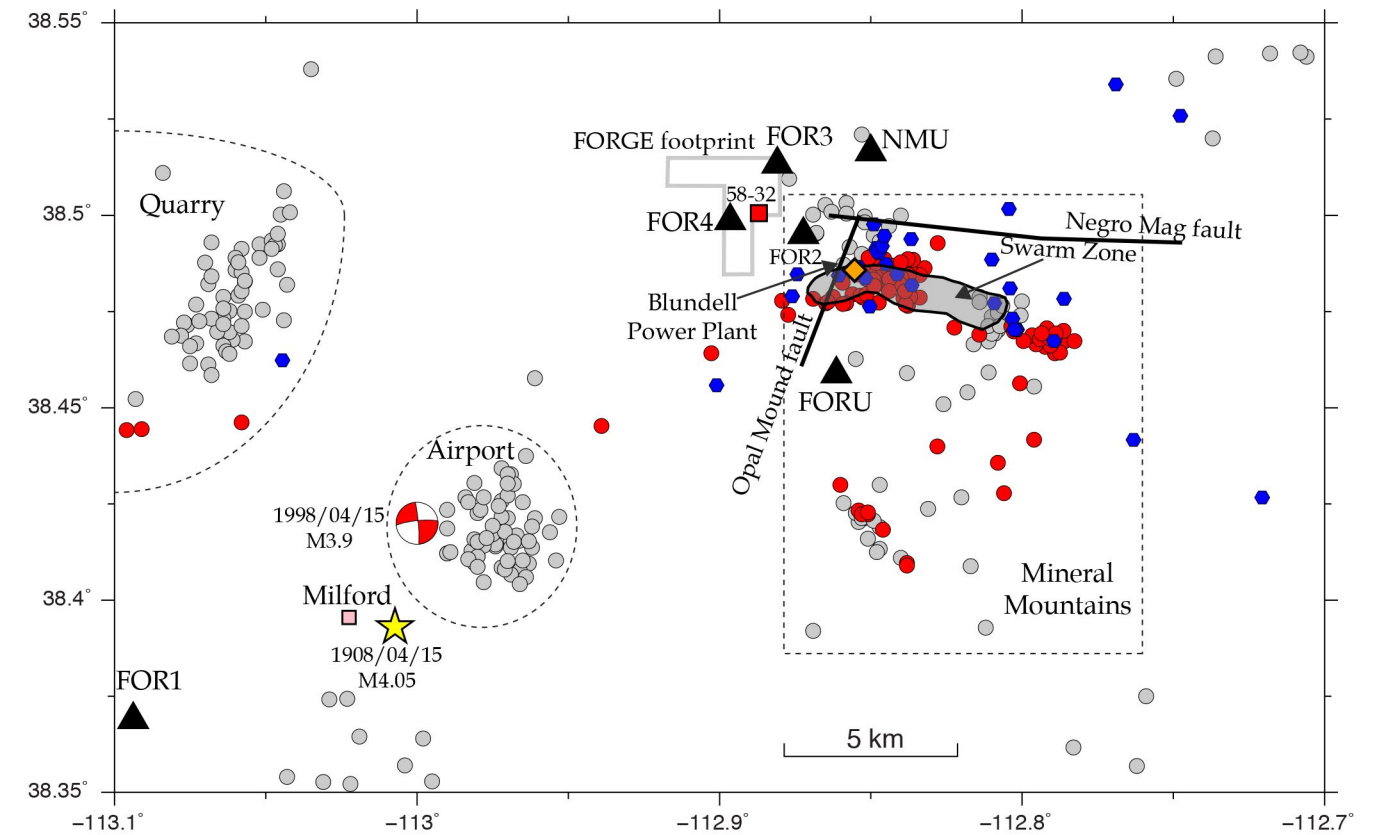
itoring to characterize seismicity around the Utah FORGE site.

The first level of seismic monitoring simply used the historic UUSS seismic catalog to define the main concentrations of regional seismic activity. Analyzing the catalog from 1981 to 2016, Pankow's team found that earthquakes near the Utah FORGE site occurred in three main areas: a quarry, the Milford airport, and the Mineral Mountains (see map at right). The quarry was removed from further analysis after it was determined the seismicity was related to human activity.

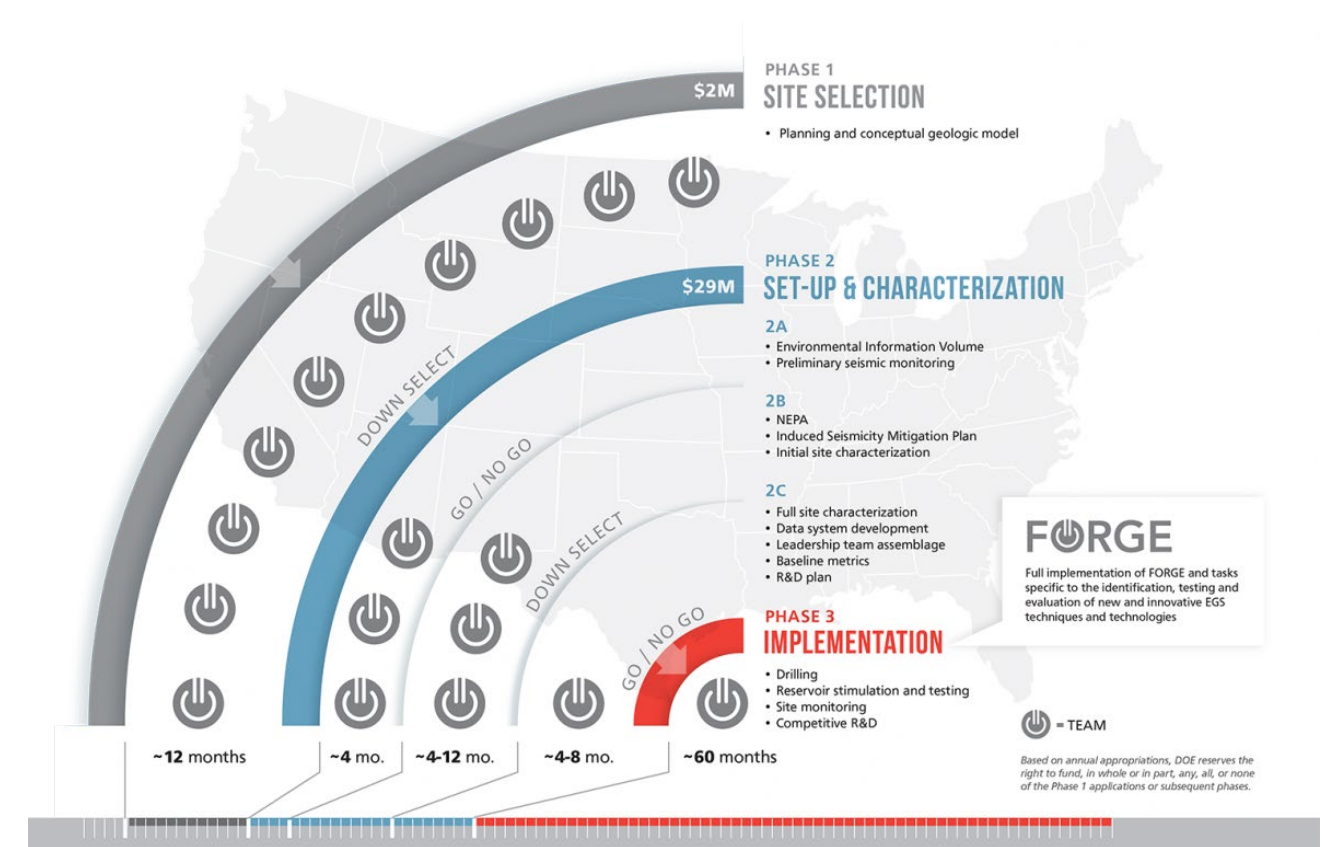
The second level of monitoring used seismic waveform matching with regional seismic network data to generate an enhanced earthquake catalog. This form of matched filter analysis showed 110 new events in the airport area and 153 new events in the Mineral Mountains area. These data helped push magnitude completeness levels closer to zero and showed that the current seismic activity around the Utah FORGE site was minimal and likely non-threatening.

The third level of monitoring involved the installation of new seismometers. In mid-November 2016, UUSS installed a five-station broadband telemetered seismic network near the Utah FORGE site. Using these new data, Pankow's team identified 32 earthquakes ranging from M-0.74 to M1.15 between November 2016 and May 2017. These data indicated that the ongoing seismic activity beneath the Mineral Mountains is below the detection threshold of the UUSS regional seismic network. Minimal seismic activity around the proposed Utah FORGE site was found. The final level of analysis included a temporary deployment of 93 three-component Nodal seismometers from Dec. 13, 2016, through Jan. 15, 2017. This method identified 57 earthquakes near the Opal Mound fault (see map at right).

Pankow concluded that earthquakes occurring in the vicinity of the Utah FORGE site happened in two zones and were characterized by low earthquake rates and low magnitudes. It was also concluded there was no source of activity directly beneath the Utah FORGE site. This report helped qualify the Milford, Utah, site as the top pick for the FORGE project.



ABOVE: Map identifying three main areas of seismic activity near the Utah FORGE site. BELOW: FORGE phase infographic (<https://www.energy.gov/eere/forge/downloads/forge-phase-infographic>).

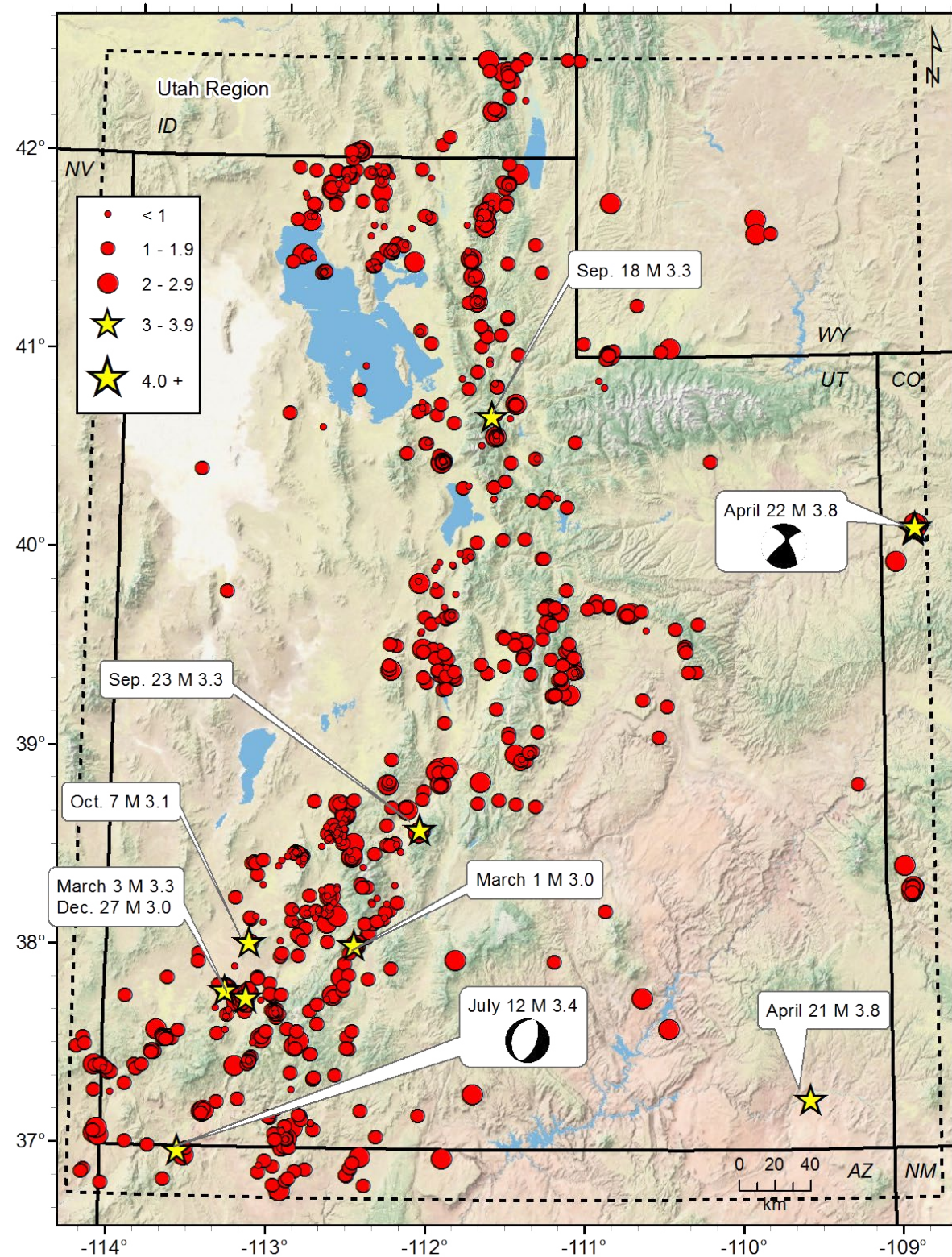




## SEISMICITY IN THE UTAH REGION

During the 12 month period Jan. 1, 2017, through Dec. 31, 2017, the University of Utah Seismograph Stations (UUSS) located 1,002 earthquakes within the Utah region. The total includes zero earthquakes in

the magnitude 4 range, 11 earthquakes in the magnitude 3 range, and 102 earthquakes in the magnitude 2 range. Earthquakes of magnitude 3.0 or larger occurring in 2017 are plotted as stars (see map below).

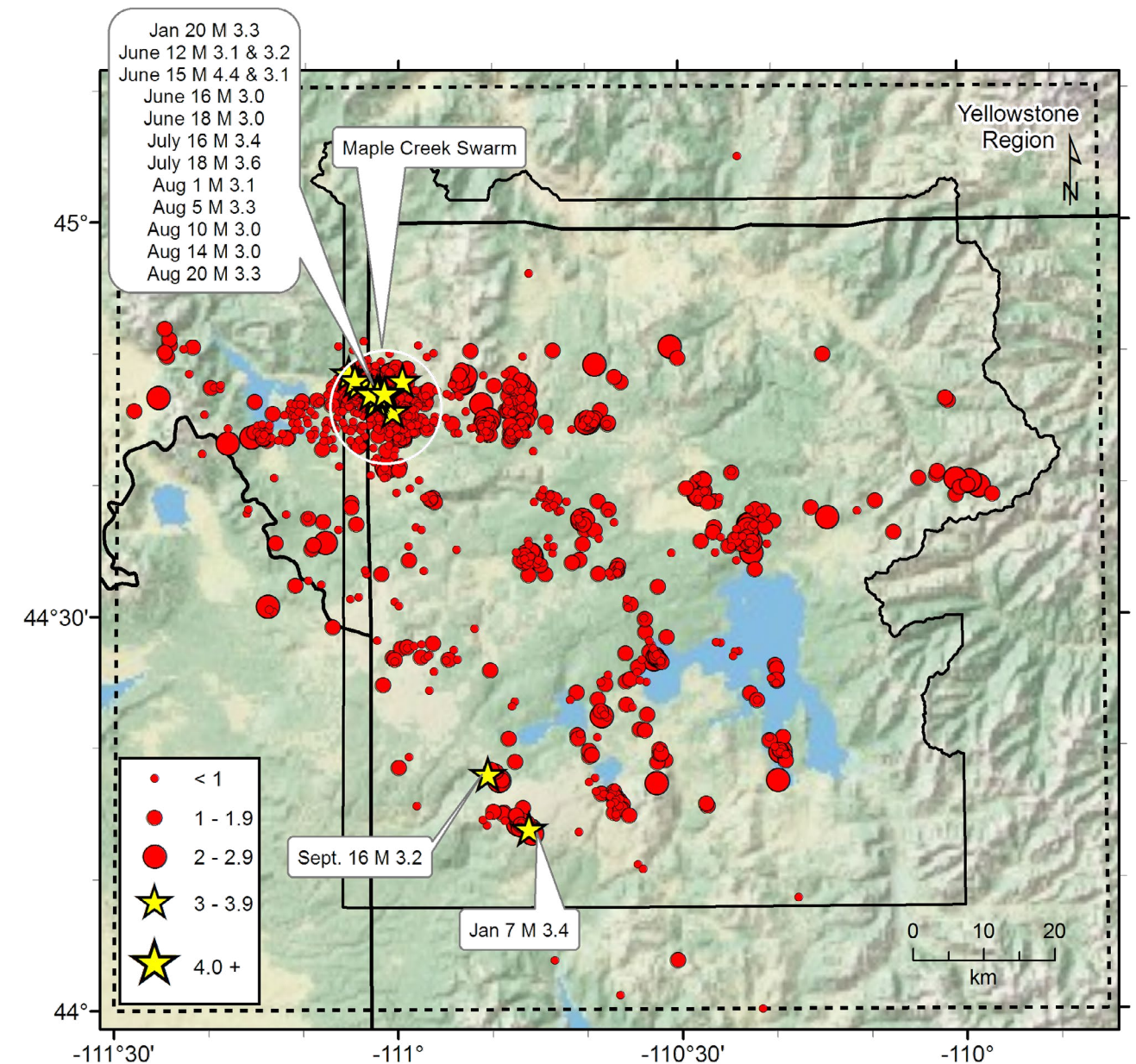


## SEISMICITY OF THE YELLOWSTONE NATIONAL PARK REGION

During the 12 month period Jan. 1, 2017, through Dec. 31, 2017, the University of Utah Seismograph Stations (UUSS) located 3,427 earthquakes within the Yellowstone National Park region — which reflects a relatively high rate of earthquakes for the area. The total includes one earthquake in the magnitude 4 range, 15 in the magnitude 3 range, and 245 earthquakes in the magnitude 2 range. Earthquakes of magnitude 3.0 or larger occurring in 2017 are plotted as stars (see map below).

The most significant swarm in 2017 was the Maple Creek swarm (indicated by the oval on map below). This swarm is the second largest swarm to ever be recorded in Yellowstone, after the October 1985 swarm which occurred nearby (see p. 2 for more information).

Overall, there were 15 swarms identified in 2017 which accounted for ~78 percent of the total seismicity during the year. On average, swarm seismicity accounts for around 50 percent of total seismicity in Yellowstone.





## PRESENTATIONS

### SEISMOLOGICAL SOCIETY OF AMERICA ANNUAL MEETING | APRIL 18–20, 2017, DENVER, CO:

- Arrowsmith, S.J., C. Young, and K. Pankow (2017). Accessing WCEDS as an alternative pipeline processing system.
- Farrell, J., F.-C. Lin, S.-M. Wu, R.B. Smith, and M. Karplus (2017). Using dense geophone arrays to image subsurface hydrothermal structure in the Upper Geyser Basin, Yellowstone National Park.
- Kilb, D.L., A. Yang, N. Garrett, V. Hilke, K. Pankow, J. Rubinstein, and L.M. Linville (2017). Tilt Trivia: A multi-player app teaching induced seismicity concepts.
- Linville, L.M., K. Pankow, D. Kilb, and J. Rubinstein (2017). Identifying new earthquake templates adds valuable information to induced seismicity sequences.
- Marcillo, O.E., G.G. Euler, and K.D. Koper (2017). On the application of super-resolution array processing methods for characterizing Earth's short-period seismic noise field.
- Potter, S., K. Pankow, J. Moore, and R. Allis (2017). Seismicity in the Mineral Mountains, Utah and the possible association with the Roosevelt Hot Springs geothermal system.
- Trow, A., L.M. Linville, K. Pankow, and P. Wannamaker (2017). Detecting seismicity in a prospective geothermal play, using a 48 geophone array.
- Wang, N., D. Roten, K.B. Olsen, and J. Pechmann (2017). Rupture direction, basin, and distance effects on ground motions from M7 earthquakes on the Salt Lake City segment of the Wasatch fault, Utah.
- Wong, I., W. Lund, C.B. DuRoss, P. Thomas, W. Arabasz, A. Crone, M.D. Hylland, N. Luco, S. Olig, J. Pechmann, S.F. Personius, M.D. Petersen, D.P. Schwartz, and R. Smith (2017). Forecasting large earthquakes along the Wasatch Front, Utah: Final results from the Working Group on Utah Earthquake Probabilities.
- Zhang, H., K.D. Koper, K.L. Pankow, and Z. Ge (2017). Imaging the 2016  $M_w$  7.8 Kaikoura, New Zealand earthquake with teleseismic P waves: A cascading rupture across multiple faults.

### EUROPEAN GEOSCIENCES UNION GALILEO CONF. | JUNE 6–9, 2017, OHLSTADT, GERMANY

Koper, K.D., R. Burlacu, and Y. Xu (2017). Lakes as a source of short-period (0.5–2 sec) microseisms, EGU Galileo conference. From process to signal—advancing environmental seismology.

### OBSERVATORY FOR RESEARCH IN GEOTHERMAL ENERGY | JULY 30 – AUG. 4, 2017, KOBE, JAPAN

Pankow, K.L., S. Potter, H. Zhang, F. Lin, and J. Moore (2017). Developing an induced seismic mitigation plan for the proposed Utah Frontier.

### GEOTHERMAL RESOURCE COUNCIL | OCTOBER 1–4, 2017, SALT LAKE CITY, UT

Moore, J., R. Allis, K.L. Pankow, S. Simmons, J. McLennan, and P. Wannamaker (2017). Overview of the Utah FORGE Project, Geothermal Resources Council, v. 41.

### AMERICAN GEOPHYSICAL UNION FALL MEETING | DECEMBER 11–15, 2017, NEW ORLEANS, LA

- Arrowsmith, S., K.L. Pankow, R. Brogan, and C.J. Young (2017). Evaluating the waveform correlation event detection system (WCEDS) through comparison with an analyst catalog.
- Cormier, V.F., J. Attanayake, C. Thomas, K.D. Koper, and M.S. Miller (2017). Inferences on the Physical Nature of Earth's Inner Core Boundary Region from Observations of Antipodal PKIKP and PKIKP Waves.
- Koper, K.D., Y. Xu, and R. Burlacu (2017). Lakes as a source of short-period (0.5–2 sec) microseisms.
- Linville, L., T. Draelos, K.L. Pankow, C.J. Young, and S. Alvarez (2017). Leveraging long-term seismic catalogs for automated real-time event classification.
- Mokhdhari, A.A.M., K.D. Koper and, R. Burlacu (2017). Lake generated microseisms at Yellowstone Lake as a record of ice phenology.
- Pang, G., J.M. Hale, J. Farrell, R. Burlacu, K.D. Koper, and R.B. Smith (2017). The 2017 Maple Creek seismic swarm in Yellowstone National Park.
- Tibi, R., C.Y. Young, K.D. Koper, and K.L. Pankow (2017). Discrimination of man-made events and tectonic earthquakes in Utah using data recorded at local distances.
- Trow, A., K.L. Pankow, P.E. Wannamaker, F.-C. Lin, and K.M. Ward (2017). Seismic imaging of a prospective geothermal play, using a dense geophone array.
- Xu, Y., K.D. Koper, and R. Burlacu (2017). Microseismic properties of typhoons in the Western Pacific.
- Zhang, H., M. Brudzinski, K.D. Koper, and K.L. Pankow (2017). Imaging the 2017  $M_w$  8.2 Tehuantepec intermediate-depth earthquake using teleseismic P waves.

### ADDITIONAL PRESENTATIONS

- Dinter, D.A., and J.C. Pechmann (2017). "Great Salt Lake fault zone," Field Review for the Geologic Map of the Tooele 30' x 60' Quadrangle, Tooele, Salt Lake, and Davis Counties, Utah, May 9, 2017.
- Farrell, J., and R.B. Smith (2017). The Yellowstone crustal magmatic system: Our current understanding and what's next, IAVCEI 2017 Scientific Assembly, Portland, Oregon, August 14–18, 2017.
- Farrell, J., S.-M. Wu, R.B. Smith (2017). Seismic imaging of the Yellowstone Upper Geyser Basin using a dense seismic array, Swiss Federal Institute of Technology, Zurich, Switzerland, September 14, 2017.

Pechmann, J.C., Y. Zeng, P.A. Thomas, and M.D. Petersen (2017). "Comparison of geodetic and geological/seismological moment rates for the Wasatch Front Region, Utah," Utah Quaternary Fault Parameters Working Group Meeting, Salt Lake City, Utah, February 8, 2017.

## PUBLICATIONS

### PEER REVIEWED JOURNAL PAPERS

- Gal, M., A.M. Reading, S.P. Ellingsen, K.D. Koper, and R. Burlacu (2017). Full wavefield decomposition of high frequency secondary microseisms reveals distinct arrival azimuths for Rayleigh and Love waves, *J. Geophys. Res. Solid Earth*, 122, 4660–4675, doi:10.1002/2017JB014141.
- Filson, J.R., and W.J. Arabasz (2017). Origins of a National Seismic System in the United States: Seismological Research Letters, 88, 131–143, doi:10.1785/0220160039.
- Lay, T., L. Ye, K.D. Koper, and H. Kanamori (2017). Assessment of teleseismically-determined source parameters for the April 25, 2015  $M_w$  7.9 Gorkha, Nepal earthquake and the May 12, 2015  $M_w$  7.2 aftershock, *Tectonophysics*, 714–715, 4–20, doi:10.1016/j.tecto.2016.05.023.
- Moore, J.R., K.L. Pankow, S.R. Ford, K.D. Koper, J.M. Hale, J. Aaron, and C.F. Larsen (2017). Dynamics of the Bingham Canyon rock avalanches (Utah, USA) resolved from topographic, seismic, and infrasound data, *J. Geophys. Res. Earth Surf.*, 122, 615–640, doi:10.1002/2016JF004036.
- Pankow, K.L., S. Potter, H. Zhang, J. Moore (2017). Local Seismic Monitoring at the Milford, Utah FORGE Site, *GRC Transactions* 41, 304–312.
- Wang, Y., F.-C. Lin, B. Schmandt, and J. Farrell (2017). Ambient noise tomography across Mount St. Helens using a dense seismic array, *J. Geophys. Res.*, 122, doi:10.1002/2016JB013769.
- Workman, E., F.-C. Lin, and K.D. Koper (2017). Determination of Rayleigh wave ellipticity across the Earthscope Transportable Array using single-station and array-based processing of ambient seismic noise, *Geophys. J. Inter.*, 208, 234–245, doi:10.1093/gji/ggw381.
- Wu, S.-M., K.M. Ward, J. Farrell, F.-C. Lin, M. Karplus, and R.B. Smith (2017). Anatomy of Old Faithful from subsurface seismic imaging of the Yellowstone Upper Geyser Basin, *Geophys. Res. Lett.*, doi:10.1002/2017GL075255.
- Xu, Y., K.D. Koper, and R. Burlacu (2017). Lakes as a source of short-period (0.5–2 s) microseisms, *J. Geophys. Res. Solid Earth*, 122, 8241–8246
- Zhang, H. (2017). Imaging the Rupture Processes of Earthquakes Using the Relative Back-Projection Method: Theory and Applications, Springer 2017.
- Zhang, H., K.D. Koper, K. Pankow, and Z. Ge (2017). Imaging the 2016  $M_w$  7.8 Kaikoura, New Zealand earthquake with teleseismic P waves: A cascading rupture across multiple faults, *Geophys. Res. Lett.*, 44, 4790–4798, doi:10.1002/2017GL073801.

Zhang, H., and Z. Ge (2017). Stepped rupture of the 2014  $M_w$  7.0 Yutian, Xinjiang earthquake, *Bull. Seismol. Soc. Am.*, 107 (2), 581–591

### REPORTS

- Burlacu, R., P.M. Roberson, J.M. Hale, J. Stanley, A. Parapuzha, K.D. Koper, J.C. Pechmann, and K.L. Pankow (2017). Earthquake Activity in the Utah Region Preliminary Epicenters October 1 – December 31, 2016, Quarterly Report, University of Utah Seismograph Stations, Salt Lake City, Utah, 32 pp.
- Burlacu, R., P.M. Roberson, J.M. Hale, J. Stanley, A. Parapuzha, K.D. Koper, J.C. Pechmann, and K.L. Pankow (2017). Earthquake Activity in the Utah Region Preliminary Epicenters January 1 – March 31, 2017, Quarterly Report, University of Utah Seismograph Stations, Salt Lake City, Utah, 30 pp.
- Burlacu, R., P.M. Roberson, J.M. Hale, J. Stanley, A. Parapuzha, K.D. Koper, J.C. Pechmann, and K.L. Pankow (2017). Earthquake Activity in the Utah Region Preliminary Epicenters April 1 – June 30, 2017, Quarterly Report, University of Utah Seismograph Stations, Salt Lake City, Utah, 30 pp.
- Burlacu, R., P.M. Roberson, J.M. Hale, J. Stanley, A. Parapuzha, N. Forbes, K.D. Koper, J.C. Pechmann, and K.L. Pankow (2017). Earthquake Activity in the Utah Region Preliminary Epicenters July 1 – September 30, 2017, Quarterly Report, University of Utah Seismograph Stations, Salt Lake City, Utah, 32 pp.
- Wang, N., D. Roten, K.B. Olsen, and J.C. Pechmann (2017). Rupture direction, hanging wall, basin, and distance effects on ground motions from large normal-faulting earthquakes, Final Technical Rept., U.S. Geol. Surv. Award Nos. G14AP00044 and G14AP00045, 44 pp., [https://earthquake.usgs.gov/cfusion/external\\_grants/reports/G14AP00044.pdf](https://earthquake.usgs.gov/cfusion/external_grants/reports/G14AP00044.pdf) .t.

### OTHER SCIENTIFIC PUBLICATIONS

- Arabasz, W.J., R. Burlacu, and J.C. Pechmann (2017). Earthquake database for Utah Geological Survey Map 277: Utah earthquakes (1850–2016) and Quaternary faults: Utah Geological Survey Open-File Report 667, 12 p. plus 4 electronic supplements. [https://ugspub.nr.utah.gov/publications/open\\_file\\_reports/ofr-667/ofr-667.pdf](https://ugspub.nr.utah.gov/publications/open_file_reports/ofr-667/ofr-667.pdf) .
- Bowman, S.D., and W.J. Arabasz (2017). Utah earthquakes (1850–2016) and Quaternary faults: Utah Geological Survey Map 277, 1 plate, scale 1:500,000.
- Wong, I., W. Lund, C. DuRoss, P. Thomas, W. Arabasz, A. Crone, M. Hylland, N. Luco, S. Olig, J. Pechmann, S. Personius, M. Petersen, D. Schwartz, R. Smith, and S. Bowman (2017). Estimating the probabilities of future large earthquakes along the Wasatch Front, in *Geology and Resources of the Wasatch: Back to Front*, W. R. Lund, S. H. Emerman, W. Wang, and A. Zanazzi (Editors), Utah Geological Association Publication 46, CD, 277–294.



## MARTHA KNOWLTON RETIRES

Martha Knowlton retired from the USSS at the end of 2016 after more than 14 years of service, initially as Administrative Assistant and later as Administrative Manager. Martha was deeply committed to helping the USSS “shine,” typified by her signature achievement—the celebration on June 29, 2007, commemorating the centennial of the installation of the first seismographs in Utah by Dr. James E. Talmage and celebrating 100 years of earthquake recording at the University of Utah. Due in great measure to Martha’s heroic efforts, the event was a resounding success, rewarded by enthusiastic comments from Talmage family members, university officials, and other attendees. (Then) Vice President David W. Pershing wrote a congratulatory note calling the event “a huge success” and “one of the best events of its type that I have ever attended.”

Martha’s outstanding professionalism, graciousness, and constant willingness to give more than expected were hallmarks of her years of service as a dedicated administrative assistant, a meticulous accountant, and an efficient office manager. Her refined nature and skills reflected a varied educational background that included two undergraduate degrees (B.A., French, College of William and Mary; B.A., Russian, University of Utah) and two graduate degrees (M.A., Russian, University of Utah; M.B.A., University of Utah). The theatre is one of Martha’s loves. A mainstay of her calendar is her annual travel to the Utah Shakespeare Festival in Cedar City. She also serves as a volunteer usher for theatre and concert events at the Pioneer Memorial Theatre.

The time frame of Martha’s work for the USSS coincided with a period of dramatic growth in funding and network expansion, the move from the Browning Building into new facilities in the Sutton Building, and another celebration of note—the 50th anniversary in April 2016 of the formal founding of the USSS, with an event honoring the memory of Dr. Kenneth L. Cook as its first director. Without diminishing Martha’s role, shared credit for many of the accomplishments during much of her time with the USSS goes to Sheryl



Martha Knowlton, University of Utah Seismograph Stations Administrative Manager.

Peterson (see next page). Martha and Sheryl, in their time, were an extraordinary team in the USSS administrative office. Each was basically quiet in nature but remarkably effective—bringing to mind a Mark Twain quote: “Thunder is good, thunder is impressive; but it is lightning that does the work.” Praised be for Martha, for Sheryl, and for the lightning.

## IN MEMORY OF GERHARD HENSCHEL

Gerhard Henschel, a native of Germany and former seismograph field technician with the USSS in the early 1990s, died at his home in Salt Lake City on or about May 9, 2017. Through recreational outdoor activities, Gerhard met Ken Whipp, who (in Ken’s words) “brought this puppy home,” involving him in USSS field work. After being hired by the USSS, Gerhard was a mainstay in the buildout of the Jordanelle seismic network in 1992–93. Gerhard later worked and eventually retired as a master electrician at the Delta Center/EnergySolutions Arena.

## VISITING SCHOLAR YAN XU

Dr. Yan Xu, a seismology professor at Yunnan University in Kunming, China, visited USSS for nearly all of 2017. Dr. Xu worked with Keith Koper and Relu Burlacu analyzing data from a large seismic array that had recently been deployed in China. Together, they studied the ambient seismic energy recorded by the array and determined moment tensors for hundreds of small-to-moderate size earthquakes in China.

## SAYING FAREWELL TO SHERYL PETERSON

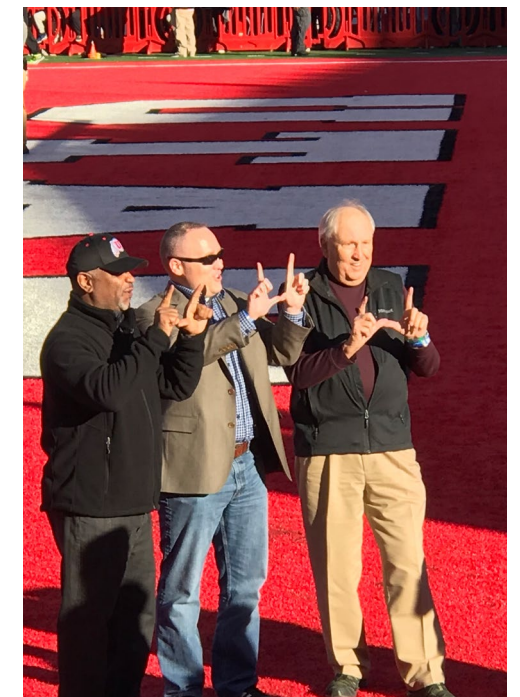
At the end of 2016, Sheryl Peterson moved to Virginia, ending a series of positions with the USSS that spanned decades (1989–1995, 1997, 2004–2016). Her supportive roles evolved from student administrative assistant to communications specialist—after she gained a master’s degree in professional communication. Sheryl used her versatile skills to make wide-ranging contributions to the USSS, chiefly in administrative but also in technical areas. The following list of descriptions tells part of the story (encapsulated by the often-heard refrain, “Thank God for Sheryl”): “one of the most organized and super-efficient workers I’ve ever observed”; “self-starter with great teamwork and interpersonal skills”; “craves challenges and is uncomfortable when underutilized”; “an instinctive and undaunted problem-solver”; “hardworking, conscientious, dependable, and consistently attentive to detail”; “able to innovate and adapt to change.” To which should be added, “A very special person whom we all will miss.” [Note: The design and production of our past USSS annual reports are part of Sheryl’s legacy.]



Sheryl Peterson, University of Utah Seismograph Stations Communications Specialist.

## ROBERT B. SMITH HONORED AT FOOTBALL GAME

Robert B. Smith (pictured right), was honored at a University of Utah football game on Nov. 11, 2017. Smith is a past director (1980–1985) of the University of Utah Seismograph Stations and Professor Emeritus of Geology and Geophysics for the university. He was honored for his service in the United States Air Force.



Robert B. Smith, (far right) honored at a University of Utah football game, Nov. 11, 2017.

## PAUL ROBERSON & JON RUSHO RECEIVE AWARDS

The University of Utah presented service awards to Paul Roberson and Jon Rusho.

Roberson is an Earthquake Information Specialist for the University of Utah Seismograph Stations (USSS) and was presented with a service award for his 15 years at the university.

Jon Rusho is a Seismic Network Engineer and was also awarded for 15 years at the university, 11 of which have been with the USSS.

## WELCOMING BACK CINDI MEIER

2017 marked the first full year back at USSS for administrative officer Cindi Meier. Cindi last worked for USSS in 1997 as an administrative assistant. Cindi’s duties include preparing income statements and reports, maintaining accounts and billings, analyzing and projecting costs, coordinating purchasing, and overseeing departmental record keeping. Cindi was sorely missed during her absence from USSS. Since her return, Cindi’s hard work and professionalism have led to significant productivity gains at USSS.



Cindi Meier (left) new Administrative Manager starting 2017.



## STUDENT AFFILIATES

### 2017 GRADUATES



LISA LINVILLE — 2017 Graduate  
Ph.D. Geophysics

Thesis: Data-Driven Methods in Earthquake Monitoring, Detection, and Catalog Building



STEPHEN POTTER — 2017 Graduate  
MS Geophysics

Thesis: Characterizing Background Seismicity in the Region Surrounding Milford, Utah



MONIQUE SCALES  
Ph.D. Candidate, Geophysics

Monique's research focused on seismic event discrimination for nuclear monitoring purposes. She's interested in being able to distinguish an explosion from an earthquake using seismic data. Currently, she's working on using local magnitude and coda magnitude as a depth discriminant for seismic events at local distances.



GUANNING PANG  
Ph.D. Candidate, Geophysics

Guanning's research focused on the energetic earthquake swarm that began in March 2014 and continued through the present, near Challis, Idaho. This swarm is adjacent to the Lost River Fault which produced the damaging M6.9 Borah Peak earthquake in 1983 and the earlier study indicated that the relocations of more than 100 events in 2014 outlined a NW-SE trend similar to the strike of the Lost River Fault.

ANDY TROW  
MS Geophysics

Andy investigated a potential geothermal play near Milford, Utah. Detecting and locating small seismic events in order to characterize potential seismic swarms in the area. Seismic swarms are clusters of events that occur closely in space and time and exhibit no clear mainshock. Swarm like behavior has been known to be caused by migrating hydrothermal and magmatic fluids in the subsurface.



AINI ASHIQIN BINTI MOHD MOKHDHARI  
Senior—Geoscience-Geophysics

Aini analyzed lake generated microseisms at Yellowstone Lake from 39 seismograph stations around the lake and compared the seismic observations to direct measurements of the date of freezing and melting of the lake as reported by rangers at Yellowstone National Park. The seismic data could be used as a proxy for ice phenology to assess the effects of climate change.



AMY RECORD  
Senior—Geoscience-Geophysics

Amy has assisted in the design, deployment, and collection of remote nodal arrays in Southern Utah in conjunction with the Play Fairway and FORGE projects. She also analyzed the data from these arrays to identify and locate detected earthquakes.



JONATHAN VOYLES  
Senior—Geological Engineering & Geoscience-Geophysics

Jonathan is a second-year undergraduate researcher working on the  $M_L$ - $M_C$  project. His current work involves creating a seismic catalog of events caused by blasting from mining and explosion testing since 2012. This data set will be used to test methods that discriminate between naturally occurring earthquakes and human-induced earthquakes.





## PERSONNEL

### FACULTY

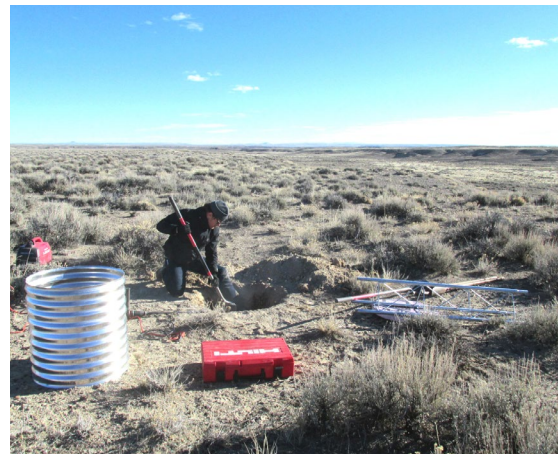
- Dr. Keith D. Koper
- Director
  - Professor of Geology and Geophysics
- Dr. Kristine L. Pankow
- Associate Director
  - Research Associate Professor of Geology and Geophysics
- Dr. James C. Pechmann
- Research Associate Professor of Geology and Geophysics
- Dr. Jamie M. Farrell
- Research Assistant Professor of Geology and Geophysics
- Dr. Walter J. Arabasz
- Research Professor Emeritus of Geology and Geophysics  
[Past UUSS Director, 1985-2010]

### FULL-TIME STAFF

- William Blycker      Systems Administrator
- Valeriu Burlacu      Research Manager
- David Drobeck      Seismograph Technician
- Mark Hale              Earthquake Information Specialist
- Corey Hatch          Seismic Network Engineer
- Cindi Meier            Administrative Officer
- Paul Roberson        Earthquake Information Specialist
- Jon Rusho             Seismic Network Engineer
- Dr. Hao Zhang        Postdoctoral Research Associate in Earthquake Seismology

### PART-TIME STAFF

- Nicholas Forbes      Student Analyst
- Barry Morse          Station Attendant
- Wesley O'Keefe      Field Assistant
- Peter O'Neill         Field Assistant
- Arvind Parapuzha    Student Analyst
- Sheryl Peterson      Communications Specialist
- Julian Stanley        Student Analyst
- Ken Whipp            Electronics Technician



## COMMITTEE SERVICE

### DR. KEITH D. KOPER

- Vice-chair, Utah Seismic Safety Commission, 2010 – present
- Member, US Air Force Seismic Review Panel, 2011 – present
- Member, Editorial Advisory Board, EOS Transactions of the American Geophysical Union, 2010 – present
- Member, Board of Directors, Incorporated Research Institutions for Seismology (IRIS), 2016 – present
- Member, External Review Panel, Geophysics SCEC5, National Science Foundation, 2016
- Member, External Review Panel on Signal Analysis, US Department of Energy: Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), and Sandia National Laboratory (SNL), 2016

### DR. KRISTINE L. PANKOW

- Member, Utah Mine Safety Technical Advisory Council, 2011 – present
- Intermountain West Regional Coordinator for Committee on National Implementation, Committee on Comprehensive Catalog and Advanced National Seismic System (ANSS), 2010 – present

### DR. JAMES PECHMANN

- Member, Utah Quaternary Fault Parameters Working Group, Utah Geological Survey, 2003 – present
- Member, Utah Ground Shaking Working Group, Utah Geological Survey, 2003 – present





# SEISMO TEA — GEOPHYSICS SEMINAR



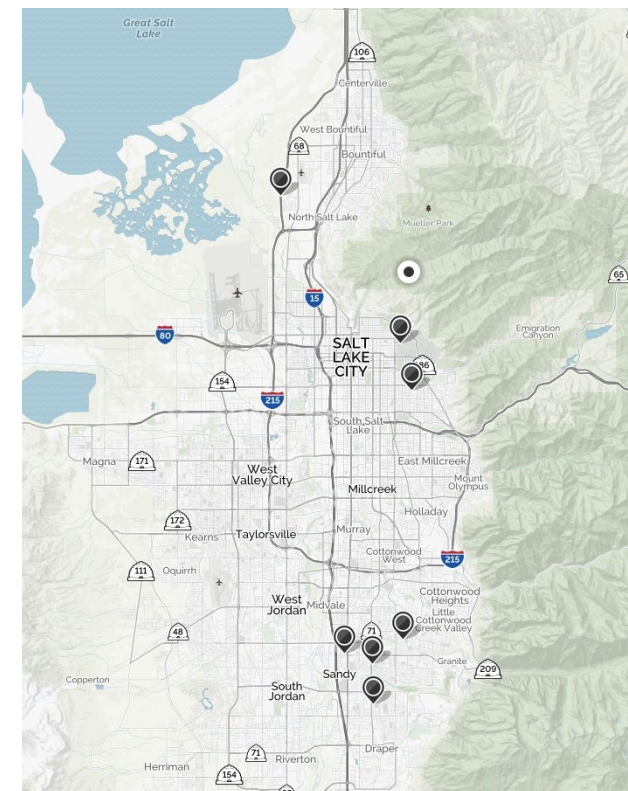
BREWED BY:  
 Elizabeth Berg (Spring)  
 Guanning Pang & Kevin Ward (Fall)

Date	Speaker	Affiliation	Title/Topic
Jan. 13	Keith Koper	University of Utah Seismograph Stations	$M_L - M_C$ : A Possible Depth Discriminant for Small Seismic Events Recorded at Local Distances
Jan. 27	Yan Xu	Yunnan University, China	Himalaya Project, Phase 1 (Yunnan)
Feb. 3	Jim Pechmann	University of Utah Seismograph Stations	Comparison of Geodetic and Geological/Seismological Moment Rates for the Wasatch Front Region, Utah
Feb. 17	Steve Holbrook	University of Wyoming	Multi-Scale, Multi-Method Geophysical Images of Yellowstone's Hydrothermal Plumbing
Feb. 24	Stephen Arrowsmith	Sandia National Laboratories	Forming Infrasound Events on the IMS Infrasound Network (II) WCEDS Approach for Detecting Seismic Events in Utah
March 3	Roice Nelson, Jr.	Dynamic Measurements, L.L.C.	Lightning Analysis: Creating Geo-Frameworks
April 7	Emily Kleber	Utah Geological Survey	Applications of High Resolution Topographic Data to Geologic Hazards in Utah
April 14	Phil Wannamaker	Energy and Geoscience Inst., University of Utah	Play Fairway Analysis for Structurally Controlled Geothermal Systems in the Eastern Great Basin Extensional Regime, Utah
April 24	Huajian Yao	University of Science and Technology of China	Imaging Interface Structures Beneath North China Craton with Teleseismic Receiver Functions and Ambient Noise Interferometry
Sept. 13	Keith Koper	University of Utah Seismograph Stations	The New Nuclear Test in North Korea
Sept. 28	Charles Meertens	UNAVCO, Inc	Update from the Earthscope Plate Boundary Observatory: Hydrologic Loading, Real-Time GPS, and Earthquake Early Warning
Oct. 18	Yadong Wang	University of Utah Geology & Geophysics	Ambient Noise Tomography Across Mount St. Helens Using a Dense Seismic Array
Oct. 25	Amir Allam	University of Utah Geology & Geophysics	The Music of Fault Zone: What Fault Resonance Tells Us About Past and Future Earthquakes
Nov. 1	Monique Scales	University of Utah Geology & Geophysics	A Decade of Induced Seismicity in Venus, Texas
Nov. 15	Hao Zhang	University of Utah Seismograph Stations	Imaging the 2017 $M_w$ 8.2 Tehuantepec Intermediate-Depth Earthquake Using Teleseismic P-Waves: A Rupture Thoroughly Across Double Benioff Zones
Dec. 7	Elizabeth Berg	University of Utah Geology & Geophysics	Ambient Noise Tomography at Regional and Local Scales in Southern California using Rayleigh Wave Phase Dispersion and Ellipticity
Dec. 7	Sin-Mei Wu	University of Utah Geology & Geophysics	Anatomy of Old Faithful Hydrothermal System from Subsurface Seismic Imaging of the Yellowstone Upper Geyser Basin

# EARTHQUAKE EXHIBIT

“Earthquakes in the Intermountain West” is a traveling educational exhibit funded by the State of Utah and maintained and administered by UUSS. The exhibit tells Utah’s earthquake story including the history of earthquakes in the region, the science behind them, and how to prepare for future earthquakes. The list and map below show public schools and other organizations that hosted exhibit displays during the year:

- Silver Mesa Elementary – Sandy
- Rocky Mountain Jr. High School – West Haven
- Dixon Middle School – Provo
- Altara Elementary – Sandy
- Foxboro Elementary – North Salt Lake City
- Altara Elementary – Sandy
- Fort Herriman Middle School – Herriman
- Utah Prepare Conference – Sandy
- Bell View Elementary – Sandy
- Clayton Middle School – Salt Lake City
- Delta Air Lines Safety Fair – Salt Lake City



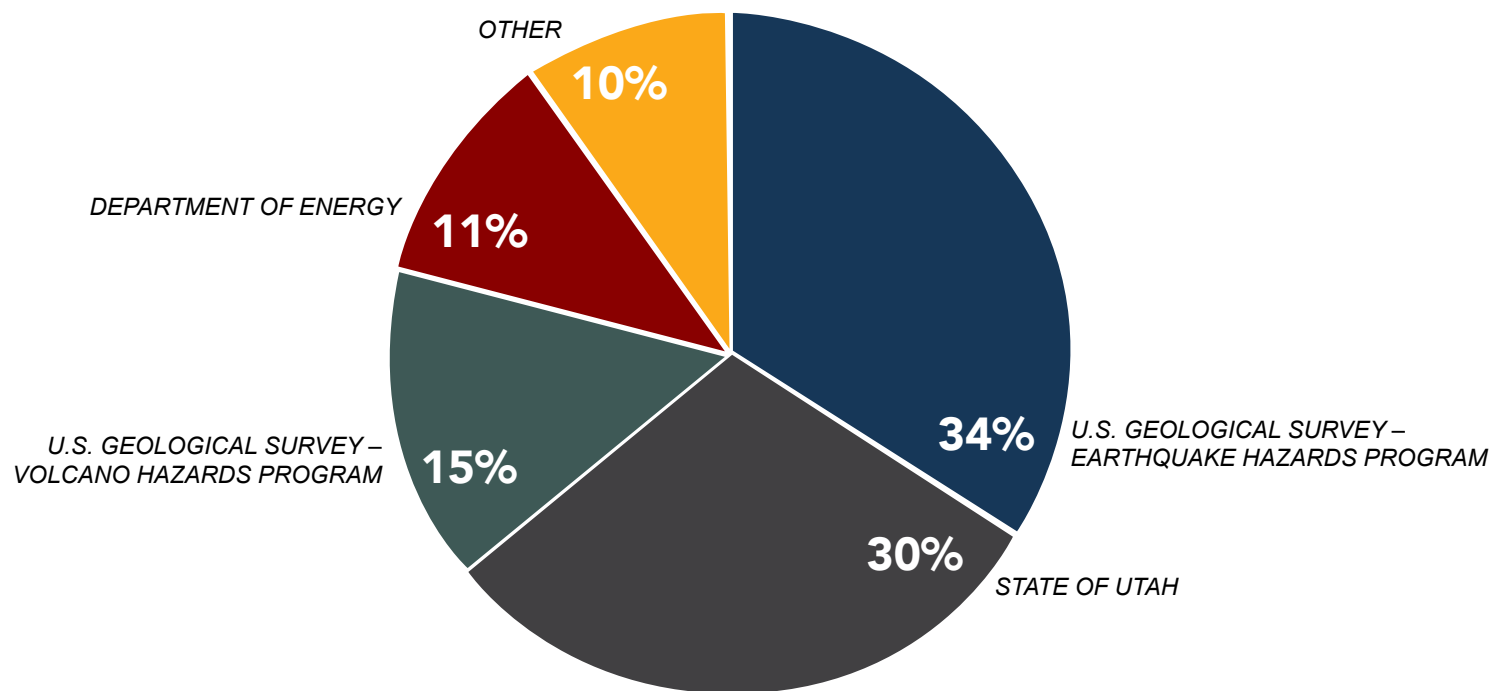
# OUTREACH PRESENTATIONS

Utah’s Earthquake Threat, OSHER Lunch and Learn	January
Highland Park Elementary, Salt Lake City, UT	Feb. 10
Regional Readiness Rendezvous, Eastern Idaho Public Health, Idaho Falls, ID	April 11
Yellowstone Center for Resources training, Mammoth Hot Springs, WY, YNP	August
Yellowstone regional training, Old Faithful, WY, YNP	Sept. 28
Utah Prepare Conference & Expo	Sept. 8–9
Field trip to UUSS for SACNAS Annual Meeting	October
Lecture to MSSST cohort on potential research projects	October
Podcast interview with Jim Dabakis, Utah Earthquake and Yellowstone	October
Indian Hills LDS Ward Emergency Preparedness	Oct. 29

# EARTHQUAKE INFORMATION CENTER TOURS

UUSS provided 15+ tours of the Rio Tinto Earthquake Information Center to groups from various educational institutions and community organizations. Each tour gives an overview of Utah’s earthquake threat as well as UUSS network operations and the role the University of Utah Seismograph Stations play in earthquake response.





## U.S. GEOLOGICAL SURVEY – EARTHQUAKE HAZARDS PROGRAM 34%

- Regional and urban seismic monitoring and research along the Wasatch Front urban corridor and Inter-mountain Seismic Belt

## STATE OF UTAH 30%

- Earthquake monitoring, research, education, and outreach in the Utah region

## U.S. GEOLOGICAL SURVEY – VOLCANO HAZARDS PROGRAM 15%

- Earthquake monitoring and research in the Yellowstone National Park region

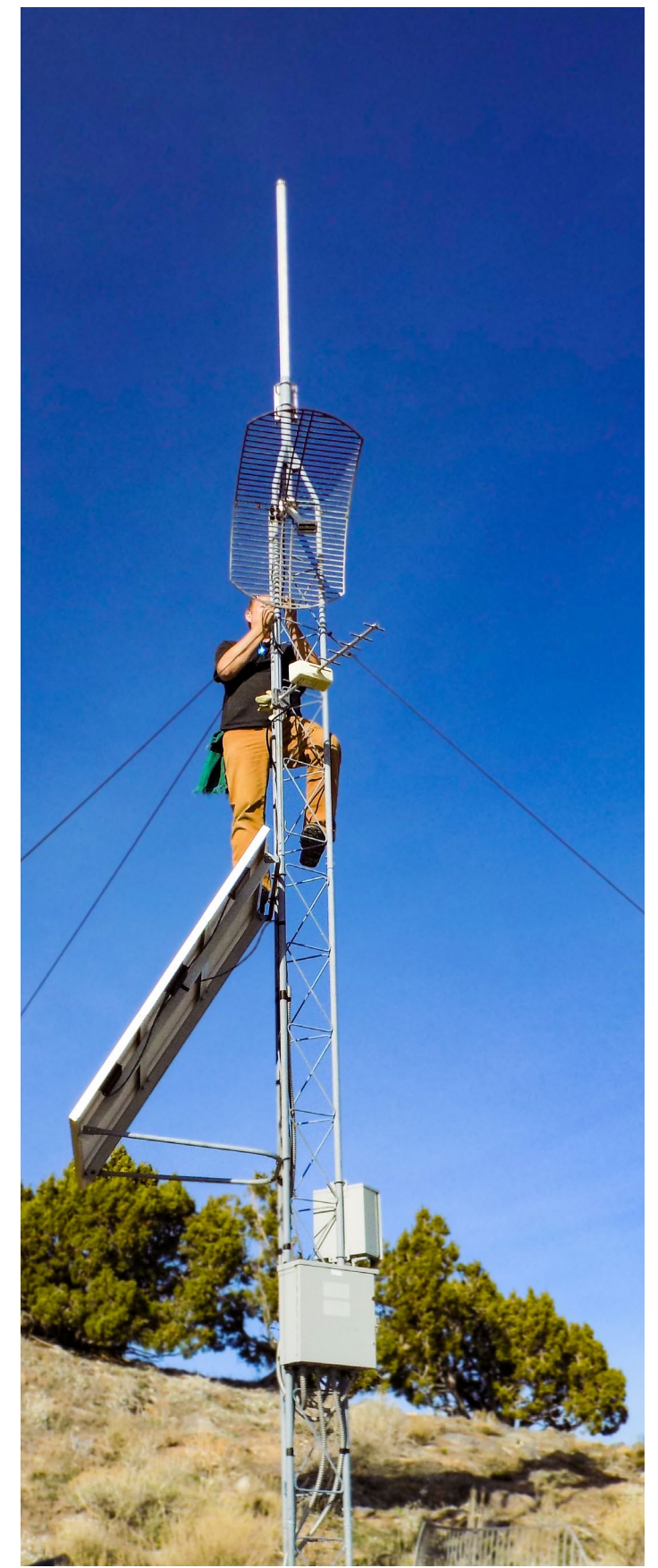
## U.S. DEPARTMENT OF ENERGY 11%

- Frontier Observatory for Research in Geothermal Energy (FORGE)
- Analysis of structurally controlled geothermal systems in the Eastern Great Basin Extensional Regime, UT

## OTHER 10%

- National Science Foundation**
- Capitalizing on EarthScope transportable array data to better characterize induced seismic sequences
  - Mapping fine scale structures in Earth’s inner core with a global array of seismic arrays
  - Origin and propagation of shallow water micro-seisms: a Yellowstone Lake multidisciplinary study
- Utah Department of Public Safety**
- Traveling educational earthquake exhibit

- Air Force Research Lab**
- Evaluation of  $M_L - M_C$  as a Possible Depth Discriminant at Local Distances
- National Institute for Occupational Safety and Health**
- Tools for Improving Mine Ground Control Safety and Health

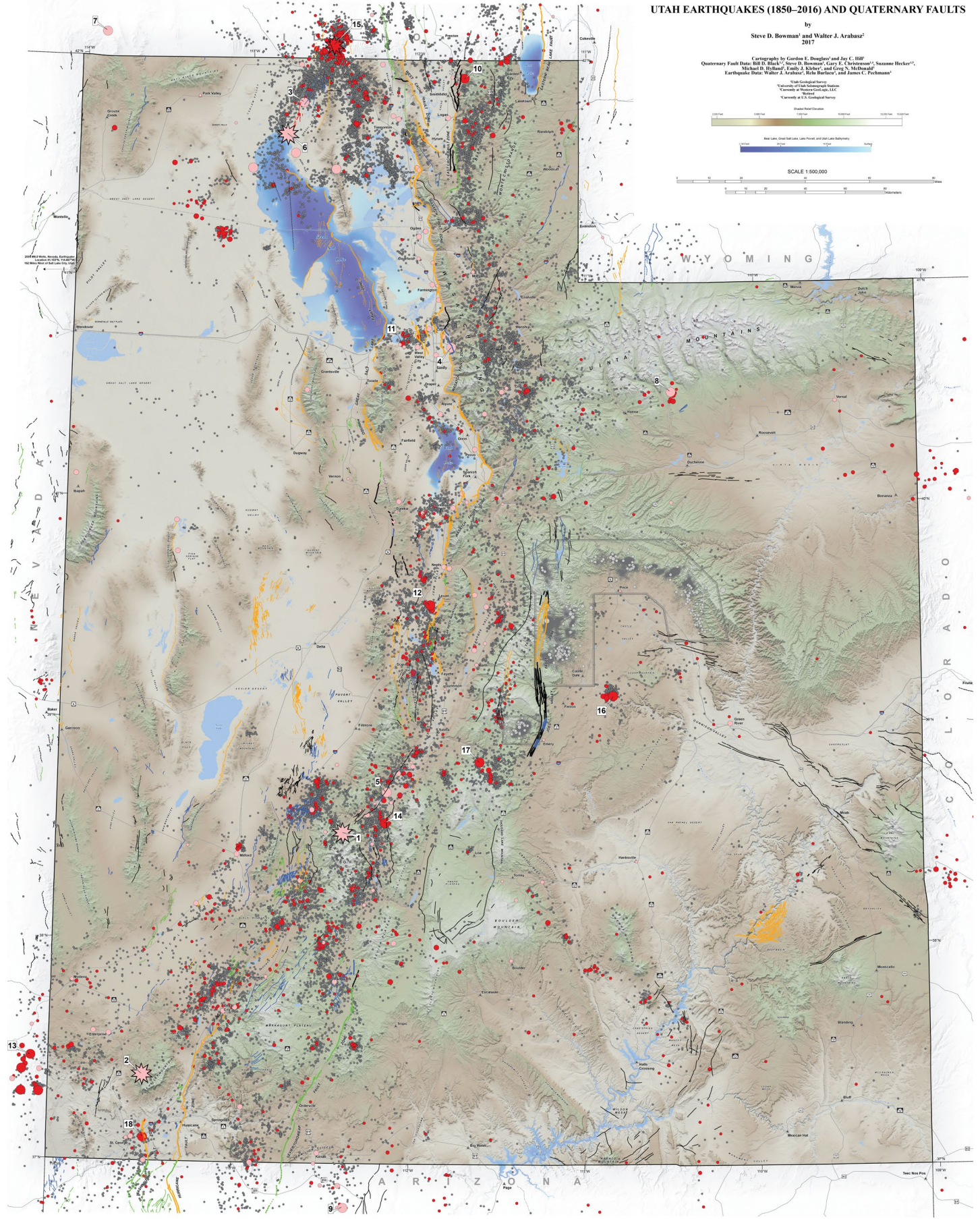
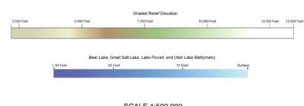




# UTAH EARTHQUAKES (1850-2016) AND QUATERNARY FAULTS

by Steve D. Bowman<sup>1</sup> and Walter J. Arabasz<sup>2</sup>

Cartography by Gordon E. Douglas<sup>3</sup> and Jay C. Hill<sup>4</sup>  
Quaternary Fault Data: Bill D. Black<sup>5</sup>, Steve D. Bowman<sup>1</sup>, Gary E. Christensen<sup>6</sup>, Suzanne Hecker<sup>7</sup>,  
Michael D. Hilland<sup>8</sup>, Emily J. Kibler<sup>9</sup>, and Greg N. McDonald<sup>10</sup>  
Earthquake Data: Walter J. Arabasz<sup>11</sup>, Rich Barkley<sup>12</sup>, and James C. Pechmann<sup>13</sup>



In 2017, UUSS collaborated with the Utah Geological Survey and the Utah Division of Emergency Management to produce UGS Map 277, entitled Utah Earthquakes (1850-2016) and Quaternary Faults. It can be freely downloaded at <https://ugspub.nr.utah.gov/publications/maps/m-277.pdf>.