Birth and Evolution of the University of Nevada's Seismological Laboratory and Center for Neotectonic Studies

Steven G. Wesnousky

Introduction

I've served on the faculty of the University of Nevada at Reno more than 30 years, all that time as Director of the Center for Neotectonic Studies and more recently as a member of the UNR Seismological Laboratory (herein also referred to as the Seismology Lab, Seismo Lab, or simply the Lab as folks around here tend to do). The focus of my time has been on education and earthquake research, and significantly less on administration. This last year I was asked to serve on an interim basis as Director of the Seismology Lab while we searched for a new one to lead the Lab. The appointment got me thinking about the origin of the Laboratory. My investigations revealed a good number of historical summaries of the University as a whole, but none devoted to the Seismological Laboratory[1-3]. So I decided to put some time into investigating the origins and evolution of the Lab and the Center for Neotectonic Studies. What follows is my history, certainly unofficial, of the Lab and Center learnt largely by examination of regional newspapers, UNR newsletters, and conversations with a number of past faculty and students[4].

The discipline of seismology is perhaps known to most as the study of seismic waves recorded at seismograph stations, with the general aims of learning about the locations, sizes, and processes responsible for the occurrence of earthquakes. Less familiar is maybe the role of geology in studying earthquakes, wherein geologists examine deformations of the ground that occur during earthquakes with these same aims in mind. The geological study of earthquakes is often referred to as neotectonics or simply earthquake geology. These points bear mention as both geological and seismological study of earthquakes take place within the Lab today, and each is critical to the history leading up to the Lab's formalization.

In fits and starts, with the aspirations and talent of individuals, the dynamics of groups, the advance of new technologies, and changing political landscapes, institutions are borne and evolve. The story is no different for the Seismological Laboratory. UNR seismographs have been recording Nevada shocks continuously for well over 100 years. The history rightfully allows the Laboratory to boast the longest continuously operating scientific laboratory on the UNR campus. The story of the lab traces back to the 1870s and the curiosity of a Carson City, Nevada merchant Charles William Friend[5-10]


CHARLES W. FRIEND,

CARSON CITY, NEAVDA,

DEALER IN FINE JEWELRY.

Watches, Clocks and Jewelry carefully repaired and warranted.

The Choicest of Silverware!
The Finest and Fairest of Jewelry!
The Best and Most Elegant Watches!
All selected especially for this market.

Always on hand,
Fine Imported Havana Cigars and First Class Tobaccos.

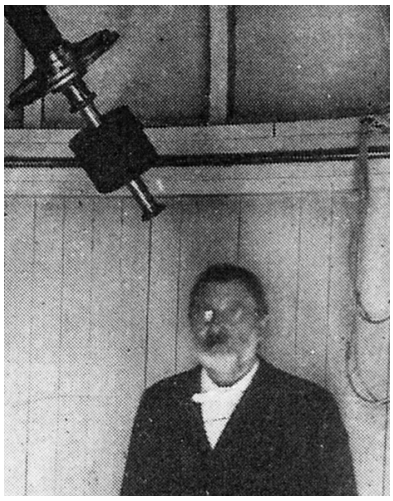
CHARLES W. FRIEND,
One door north of Willis' Drug Store.

Carson City Daily Appeal circa 1877.

The Era of Friend

A dealer in fine jewelry, watches, clocks, fine imported Havana Cigars and leader of the Carson City Brass Band[11,12], the passions of this son of a Prussian immigrant to the California Gold Rush apparently rested in the natural sciences[6]. He constructed largely with his own monies Nevada's first astronomical and weather observatory in Carson City[12], and soon thereafter, a seismometer in the basement of the Nevada State Capitol building in Carson City[13-15].

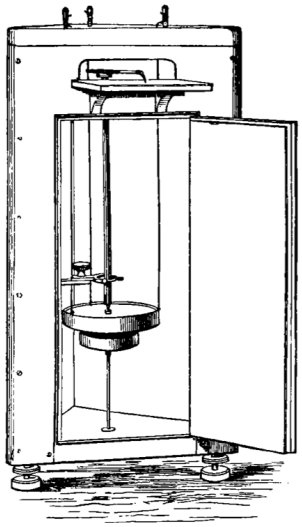
The public-spirited Friend entertained high-school and university students at his laboratory and supplied weather reports to local farmers and the U. S. Signal Service[16-18]. These



Friend in his observatory 1877 (Western Nevada Historic Photo Collection)

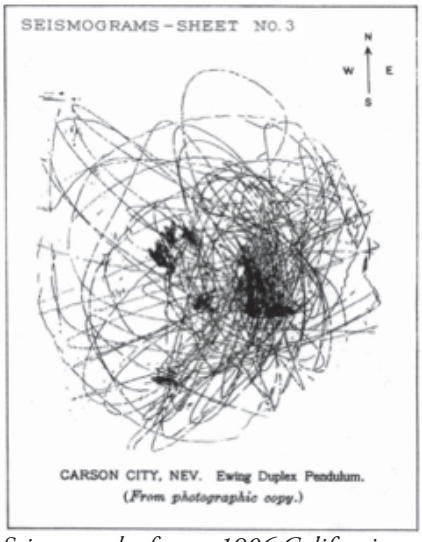
contributions to the community caught the attention of then Governor Charles Stevenson and led to his appointment as first Director of the just established Nevada State Weather Service in 1887[5,8]. It is apt that his description of his seismometer appears first in an early issue of the American Meteorological Society's Monthly Weather Review[19].

Friend's seismometer was a 'duplex pendulum instrument' of the type originally designed by Scottish physiscist and engineer James Ewing while stationed in Japan[20-22]. The first of these instruments in the United States arrived from the Cambridge Scientific Instrument Company in England and was placed at California's



Friend's sketch of duplex-pendulum seismograph for horizontal motion published in Weather Review.

Lick Observatory under the directorship of Edward S Holden[23]. With a vision that better learning about the 'the mode of action' of earthquakes would arise with a 'coordinated group of stations' emplaced across the region[24,25], Holden arranged that a 'cheap form' of the instrument be copied and constructed for sale at an electrical shop in San Francisco [23]. In what seems half a minute less than no time it appears C. W. Friend purchased one of these copies, installed it in Carson City Courthouse, and it became by 1888 an integral part of the first seismic network in the west reaching from California to Nevada[26], with all stations reporting their observations to Lick Observatory[25] . Seismograph recordings sent by Friend to Lick Observatory appear as early as 1889[27], and reports of ground shaking from lesser events yet earlier. Most notably, his instrument's recording of the great 1906 California earthquake is preserved in the California State Earthquake Investigation Commission grand compendium of studies that document the quake[28]. Regrettably, C. W. Friend died in 1907[29,30] and along with it the attentive care and operation of his prized instrument. But the story doesn't end there. It's really the beginning. The instrument was offered a new life with an act of the state legislature that led to purchase of the dormant instrument and a home within the Department of Geology in 1909[31-33].



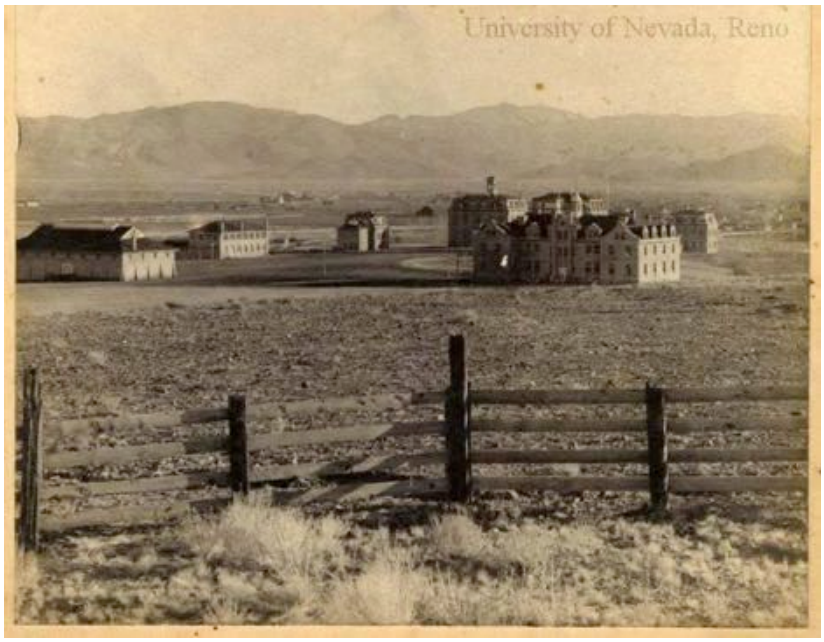
Seismograph of great 1906 California earthquake recorded by Friend's Duplex Pendulum instrument.

A new home for the seismometer and the future academic home of UNR's Seismology Lab

The placement of Friend's instrument within the Department of Geology is likely the reason that Seismology Lab faculty continue to hold appointments in the Department of Geological Science today. The University of Nevada was originally created as the Nevada State University in 1874. The creation followed shortly after Lincoln's Civil War administration championed Nevada's 1864 admittance to the union of the United States. It was ensured in Nevada's new constitution that the State 'provide for establishment of a State University embracing 'departments for agriculture, mechanic arts, and mining, and overseen by a Board of Regents'[1]. Construction of the campus was supported with funds from the Morrill Land-Grant Act of 1862. Political expediency led to placement of the campus in Elko, yet because of dwindling enrollment and desire for a more successful University, the Board of Regents voted in 1885 to move the campus to Reno[1,3].

The cornerstone of Morrill Hall (then the 'Main Building') that graces the south end of the campus quad was laid that same year.[1].

Opening its doors in 1886, a time of no electric lights, no telephones, and horses as the main mode of personal transport, the Reno campus began with 2 professors and 56 students 14 to 21 years old [1]. The University soon hosted a School of Liberal Arts, a School of Agriculture, the State Normal (High) School, a School of Mechanic Arts, a Business Department, and a School of Mining. The University's School of Mines was in 1888 formalized under the Directorship of Robert D. Jackson[3]. A formal program of Geology was in 1903 established within by Professor George D. Louderback[34], then a recent graduate of the University of California.[1] Before that there was simply a mining department. Louderback left Reno a few years later to continue his career as a distinguished Professor at his alma mater where he also served as president of the Seismological Society of America in 1914. Subsequent organizational changes placed the School of Mines beneath the umbrella of a newly created College of Engineering in 1906[3].



View to southeast circa 1900 shows Morrill Hall with cupola near center and the dormitory Lincoln Hall in right foreground. Each remain in use today. (Western Nevada Historic Photo Collection https://wnhpc.com)

George D. Louderback established UNR's program of geology, later to become academic home to faculty in Seismology Lab.

The legislature in 1905 gave the first substantial appropriation to requisition equipment for the Mining Department. That same year also began the now quite famous and often-told story of Clarence Mackay and his wife bequeathing funds to construct a School of Mines building in honor of his father John Mackay. By 1908 the moniker Nevada State University had been cancelled, the University of Nevada came to be, and Nevada's School of Mines formally became the Mackay School of Mines[2]. The Mackay School of Mines building graced by a statue of John Mackay at its front remains standing today at the north end of the University quad, and was to host the Geology program for decades.

View northward along Lake Street to Morrill Hall circa 1900 (The Western Nevada Historic Photo Collection https://wnhpc.com)

Mackay School of Mines circa 1911 (University Libraries)

Geology Jones – UNR's first earthquake scientist

And so with this history C. W. Friend's seismograph came under the care of geology Professor J. Claude Jones. Installation in the basement of the Mackay School of Mines building was just in time to record the ground shaking produced by the largest earthquake in Nevada history. An image of the seismogram is preserved in the first scientific account of the 1915 M 7.2 Pleasant Valley earthquake and authored by J. Claude Jones. With but a brief two days in the field in the week subsequent to the earthquake and influenced by studies of earlier geologic greats [35-37], Jones made observations that are of continued and major importance in the study of earthquakes. Among those, Jones associated the earthquake with development of the basins and ranges across Nevada; recognized that the movement that caused the earthquake resulted in an easterly extension of the earth's surface; that the fault trace extended more than 20 miles; that morphology preserved both in bedrock and alluvium showed that earthquakes had previously occurred on the fault; and that repeated offsets along the fault are largely responsible for the elevation of the Sonoma Range above Pleasant Valley. From this, he induced "that movement has

J. Claude 'Geology' Jones. Professor of Geology. Image from p.15 1 Larson (1954)

not entirely ceased along the faults that bound the range on one or both sides" and, in so doing, articulated the foundation of today's seismic-hazard analysis: that earthquakes occur repeatedly on pre-existing faults. It took this author years to understand these things. Quite humbling that Jones did so in two days.

The duplex-pendulum instrument reimplemented and overseen by Jones only measured the horizontal directions of ground motion and was accompanied by no timing device to measure either the beginning or duration of earthquake induced ground motions. To record a subsequent shock it was necessary to change the circular smoked glass plate on which the motions were etched. Jones and colleagues in California understood the lack of a timing device precluded contributing accurately to locating earthquake epicenters also being recorded on seismometers in California. Such began lobbying for purchase of a more modern instrument[31] ultimately ordered in the middle of 1914[38]. Unfortunately, World War I delayed shipment and it did not arrive until December of 1915, just missing the Pleasant Valley earthquake of Oct 02 that year.

Finishing his field study of the 1915 Pleasant Valley earthquake, Professor Jones turned his attention to assembling the newly arrived instrument. Stories indicate that at best he was aided by instructions only in German and at worst by no instructions at all, they having been lost or destroyed in their near two year transit from Germany[39]. The new Weichert instrument also recorded only horizontal ground motions but now had a clock device that automatically allowed determination of the beginning and duration of ground shaking[38]. Now with sister seismographs in Santa Clara and Berkeley in California, the location of earthquake shocks could be computed from disturbances recorded on all the seismographs[38]. The instrument was also placed in the basement of the

NEVADA STATE JOURNAL

REAL SEISMOGRAPH FOR THE UNIVERSITY

Delicate Instrument Arrives Direct From Germany and Will Be Installed at Once

A consignment of delicate instruments direct from battle-scarred Germany has arrived at the University of Nevada and will be divided between the physics and geological laboratories. Most important of the consignment is a modern seismograph for which Professor J. C. Jones has waited with more or less patience for the last two years. The new instrument is modern in every respect and records vertical as well as horizontal tremors, thereby recording the direction of vibration of tremblors. A clock device is connected with the instrument which will record automatically the period of vibration

With the seismographs located at Santa Clara, Berkeley and Reno a perfect equilateral is formed by which mathmaticians can accurately compute the source of seismic disturbances that are recorded on the instruments.

That the scientific instruments reached this country safely after a year and a half of combat in all countries through which they traveled, is considered remarkable.

Newspaper Dec 17, 1915

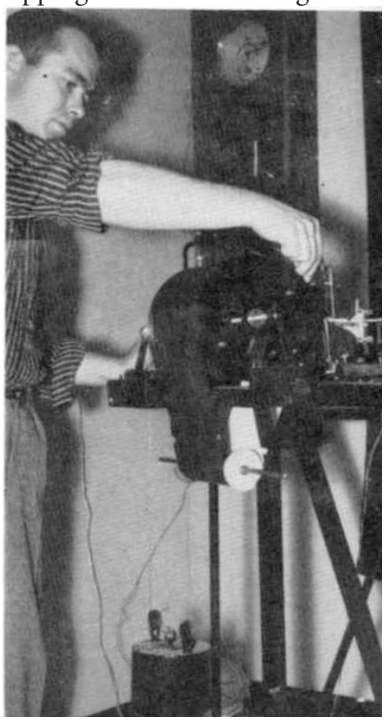
Mackay School of Mines building[3,39]. Jones continued to oversee the seismic station until his death in 1932[2], the result of a blood clot after a surgery for an old athletic injury sustained while a student at UNR. Stories tell of Jones's enthusiasm for geology being contagious[2] such that many around him respectfully gave him the moniker 'Geology' Jones. He may well be considered UNR's first seismologist. He just did a lot of other things too.

Vincent P. Gianella – Another geologist becomes seismologist

Professor Vincent P. Gianella took over operation of the seismic station in 1925, maintaining it until he retired in 1952, the year this author was born. The Weichert instrument installed by Jones ran continuously from 1916[40] until 1954 when mechanical difficulties arose to take it out of action until 1957, when graduate student and seismology lab assistant Robert B. Collagan refurbished the 77 kilogram seismograph[39,41] to operate at least until 1958[41].

Vincent P. Gianella. Professor of Geology and Metallurgy. Image from Larson memoirs (1974)

Much as Claude Jones's life as a geology professor was interrupted by a large earthquake, so too in 1932 was Vincent Gianella's. And like Jones, he with his colleague Eugene 'Pat' Callaghan[42-44], produced observations and insights that continue to influence earthquake studies today. The M 7.2 Cedar Mountain earthquake occurred in a sparsely populated region just east of Mina, Nevada, devoid of many roads, and cold and snow-covered at the time. Their mapping showed something different



Robert B. Collaghan and the refurbished Weichert Seismometer in 1957.

and unexpected for shocks in the high desert of Nevada and Utah. Rather than being focused along a range front like the earlier 1915 Pleasant Valley earthquake, surface faulting was discontinuous, distributed, and formed a distinct left-stepping en echelon pattern in a zone "38 miles long and 4 to 9 miles wide" in a valley between bounding mountain ranges. The en echelon pattern and offsets of sediment by the earthquake faults revealed to the authors that the earthquake produced right-lateral motion, much like what had been reported in California's earthquake of 1872 along the eastern boundary of the Sierra Nevada[45] and the San Andreas fault in California[46]. With that, the idea of the Walker Lane was coined, wherein "the underlying causes of movement in at least the western part of the Basin and Range may be related to those in California, and that horizontal movements must be considered in future studies of the Basin and Range structure". Seismologists now take this for granted.

Trace of Cedar Mountain earthquake fault in 2023 as it traverses remote desert floor in this northward view towards Cedar Mountain.

A few years later, 1948, one finds Gianella proud to be overseeing installation of yet another seismograph, this time in the sub-basement of the Mackay Science Building[47,48]. The seismograph built by the Sprengnether Instrument Company of St. Louis in Missouri[49] drew deserved excitement at the time, by all means modern. The new instrument recorded 3 components of short-period earth motions rather than just the two monitored by the old Weichert instrument. And rather than recording earth motions by scratchings of a pen on a cumbersome smoked piece of glass, electromagnetic principles and beams of light aimed at a revolving cylinder covered with light-sensitive paper, yielded a sensitivity to earth motions some 4000 times that of the Weichert Instrument. The seismograph, loaned by the University of California to UNR on a cooperative basis, was mounted on a 15 ton concrete block in a specially prepared vault beneath the Mackay Science building. Plans were to keep the older Weichert in operation 'since an earthquake record could be obtained without the development of photographic paper'[47,48]. As of 1958 the two instruments were still in operation[41]. To view Vincent Gianella as UNR's 2nd seismologist in this context seems warranted. He retired from his positions of Professor and Chairman in 1952.

Old Seismograph At University To Be Replaced

Another Machine To Record Quakes Being Installed

Installation of a new seismograph for recording earthquakes is now underway at the University of Nevada, said Dr. Vincent P. Gianella, chairman of the university's geology department.

A specially prepared vault beneath the Mackay hall of science will house the new photo-electric machine. The seismograph is being installed on a cooperative basis with the University of California which owns the device. The University of Nevada will operate it.

Mackay school of mines has had a seismograph machine for many years, but it is an older type and fails to record properly under some conditions. The earthquake felt in Reno recently had such a strong vertical motion that the recording needles were lifted from their tracks and left no legible record, Dr. Gianella said.

The new machine has an absolute minimum of levers and friction points that might affect its operation. It can make separate records showing the intensity of east-west, north-south and vertical motion of the earth. When the earth moves, an infinitesimal electric current is generated which moves a reflecting mirror and projects a beam of light onto a revolving drum. The drum is covered with light-sensitive paper which records the motion.

The machine is mounted on a 15-ton concrete block which rests on the ground under the vault. Flexible material between the building's floor and the mounting block prevents stray vibrations from affecting the instrument.

Professor Gianella said that at least one man, and probably two, will be needed to service the new instrument. He will be looking for men who are interested in learning more about interpretation of the earth's movements and the instruments that are used.

Nevada Gazette Journal, Nov 30, 1948

And where did the old seismometers go?

The reasonably curious will ask what became of these old seismometers. They are a part of the Lab's history. I have had no success in finding Friend's instrument. The story told is that a student took it to show off at a professional meeting in San Francisco and in some way lost it. It was like losing a friend, so to speak, for many in the Lab. Related to the instrument, I have been told by some faculty of sitings of the original glass plate on which Friend's instrument recorded the 1915 Pleasant Valley, Nevada earthquake. To my reckonings it disappeared during the transition period between two future Directors of the Seismology Lab, Dr. John G. Anderson and Dr. Graham M. Kent. The more modern Weichert instrument that was constructed in Reno shortly after the 1915 Pleasant Valley earthquake can still be seen in the Mackay

School of Mines building, where it is stored in somewhat unceremonious fashion in Mackay Museum curator Garret Barmore's office. I learned from a past graduate student that the Sprengnether instrument so highly valued by Gianella was dispensed to the garbage by the first Director of the Seismology Lab, as were several co-located Wood-Anderson seismographs. As is usual, things that are getting old are not so valued as things that are old, and so in this way history has a way of disappearing.

1915 vintage Weichert Seismgraph.

Politics set the stage for a UNR Seismological Laboratory

World War II was not far in the rearview mirror when Gianella retired as Chairman of the Geology program. Nuclear bombs had in 1945 been unleashed on Japan, Russia had subsequently developed nuclear capability in 1949, and though at peace, there existed an extreme unease between the United States and Russia as testing and stockpiles of nuclear weapons began to increase[50,51]. It was under this political climate in 1950 that the Nevada Proving Grounds, now the Nevada National Security Site (NNSS) and historically referred to as the Nevada Test Site (NTS), was established by President Harry S. Truman about 65 km northwest of Las Vegas, where upwards of 1000 announced nuclear bombs were exploded during the ensuing years[52,53]. This political framework and the presence of the Nevada Test Site were critical elements in the mix of events leading to development of the Seismological Laboratory as a distinct entity in the University, and as we'll see continues to be a major influence today.

Events pivotal to the creation and future home of UNR seismological laboratory were also taking place within the University. The Mackay School of Mines and its Geology program were at the time academically situated within the University's College of Engineering. This changed in 1951. The Board of Regents voted to partition Mackay School of Mines from the College of Engineering and establish it as an independent College with a Dean[3], and the Department of Geology came with it. Dr. Vernon Scheid assumed the position of Dean that same Spring, a position he kept until his retirement in 1972. His history of contributions to the growth of the Mackay School of Mines are legacy[2,3,54]. But for those in the Seismological Laboratory today, among his first and most important actions was hiring Dr. Burt Slemmons to the Mackay geology faculty [55].

THE MACKAY MINER Page Two April 1, 1951

M. S. of M.---Separate College

On February 1, 1951, a separate college of the University of Nevada, to be known as the Mackay School of Mines, was created by the Board of Regents. The new College contains the departments of Geology, Metallurgy, and Mining, and the Public Service Divisions—The State Bureau of Mines and The State Analytical Laboratory. At the start of the spring semester, Dr. Vernon E. Scheid assumed the duties of the new Dean of the College. Dr. Jay A. Carpenter retains the chairmanship of the Mining Department until his retirement in June.

Among the programs included in the Board of Regents' recommendations for the reorganization of the mining school is the establishment of graduate study courses in the mineral industries leading to an advanced degree. This plan will be put into effect as soon as facilities and staff are available.

Also part of the plan for reorganization is the possibility of occupying the building now being used by the U. S. Bureau of Mines which would provide additional classroom and laboratory facilities. Congress has recently passed a bill authorizing the construction of a new $750,000 building to house the Bureau at a new location on the campus.

Mackay School of Mines separates from College of Engineering.

David B. 'Burt' Slemmons

Scheid didn't know it at the time, nor I'm quite certain did Dr. Slemmons, but history makes clear Slemmons was to be the right guy in the right place at the right time for his role in establishing the Seismology Laboratory at UNR as it exists today. Completing his thesis from UC Berkeley in 1953, his expertise lay in the petrology of feldspars in Sierra Nevada granites, a field of study most distant from seismology. Indeed, Slemmons in his career garnered widespread attention for his accomplishments in feldspar research[55,56]. But he was also at the time charged with assuming oversight of Gianella's seismic stations still operating in the basements of the Mackay School of Mines and Mackay Science Building[39] , and by default like his predecessor became the geology departments 'expert' in seismology. Burt never considered that his career would veer to emphasize earthquake studies. But two large earthquakes in December of 1954 just east of Fallon, Nevada changed that. The two earthquakes were so large that the faults producing the earthquakes could be traced upwards of ~100 km along the edges of Fairview Peak and Dixie Valley. Numerous distinguished seismologists came over from California to take a look. As Burt told me, there he was, out there surrounded for some

Burt Slemmons on 1954 fault scarp.

time by all of these excited and interested seismology experts[57], then they all just got up and departed leaving him all alone in the desert the next day with the realization that they left him with all the work to do! And he did indeed. After several years of field study, he published his observations and maps of the earthquake ruptures. The breadth and completeness of his study immediately made him one of, if not the, country's preeminent expert on the geological manifestation of earthquake ruptures, and thus began his departure from the study of feldspars in Sierran Granites.

Fault scarps just 100 miles east of Reno mark the trace of two large earthquakes that occurred 1954. The Project Shoal 12 kiloton nuclear test explosion of 1963 was detonated in the adjacent Sand Springs Range.

Slemmons' Fairview Peak - Dixie Valley study coincided with the continued testing of nuclear bombs above ground and below, and the Soviet Union's launching of Sputnik, the first satellite to successfully orbit the earth. In direct response to the launch, the specter of nuclear attacks, and fear of losing technological superiority to the Soviets, the administration of Dwight D. Eisenhower established the Defense Advanced Research Projects Agency (DARPA, originally just ARPA) on February 7, 1958[58,59]. DARPA remains today a research and development program of the United States Department of Defense that partners with academia, industry, and government laboratories to 'expand the frontiers of technology and science, often beyond U.S. military requirements[60,61]. A principal charge of the agency in these early days was development of technologies to monitor nuclear tests. The need for monitoring was yet further enhanced with the Soviet Union's and U.S.'s signing of a Limited Test Ban Treaty that went into effect on Oct 10, 1963 and banned nuclear weapons testing in the atmosphere, in outer space and under water[62]. Darpa's Vela Project was tasked with the assignment of treaty verification, initially developing the first 'Vela' satellite sensors to monitor for signatures of nuclear explosions in the atmosphere and shortly thereafter development of the World Wide Standardized Seismograph Network (WWSSN) to monitor the seismic signals produced by underground explosions[63]. Attention in this latter effort was placed toward assessing the minimum size of explosion that could be detected from the global seismograph network and learning if seismic signals from explosions might be distinguished from those of earthquakes (fortunately they are).

Nevada's first seismic network

The Vela Project designed an underground nuclear test to take place within the Sand Springs Range, about 30 miles southeast of Fallon, Nevada[64]. The range resides in the same seismic belt that produced the 1954 earthquake ruptures, and was selected because the earthquake activity afforded a location to compare the seismic signals from earthquakes to nuclear explosions. The Project Shoal 12 kiloton nuclear explosion took place on Oct 26, 1963. It seems no coincidence with this nexus of events and Slemmons' expertise that the Vela Project reached out and awarded him and James Gimlett a $94k grant (~$1m in 2024 dollars) to establish a Seismology Laboratory at UNR[65], assist in a long-range seismological investigation in the Basin and Range and, presumably, the seismic vibrations produced by Project Shoal. Gimlett, a recent graduate of Stanford University, instructor in geophysics and geomorphology, and Assistant Professor of Geophysics in the Nevada Bureau of Mines at UNR between 1959 and 1964[66,67] soon departed to a distinguished professional career in Pasadena culminating as a Chief Scientist at Boeing[68].


KENO EVENING GAZETTE

PROJECT SHOAL BLAST FIRED

16 Stories, and a New Era in Nevada Banking

First National Bank Building Dedicated

LOUD ROAR FOLLOWS LIGHT FLASH

Project Shoal blast catches attention of the public.

Distribution of existing and planned seismic stations with initial funding for a UNR Seismological Laboratory.

The initial funding allowed installation and continued operation of two then-modern seismographic stations located to the north and south of the Project Shoal test site, at Tonapah and between Battle Mountain and Winnemucca. Each station was equipped with both long-period and short period seismometers[65]. The two stations combined with the one in Reno formed the needed triangle to locate earthquakes within. Prior to this effort, there existed only 3 other seismographic stations in Nevada: the

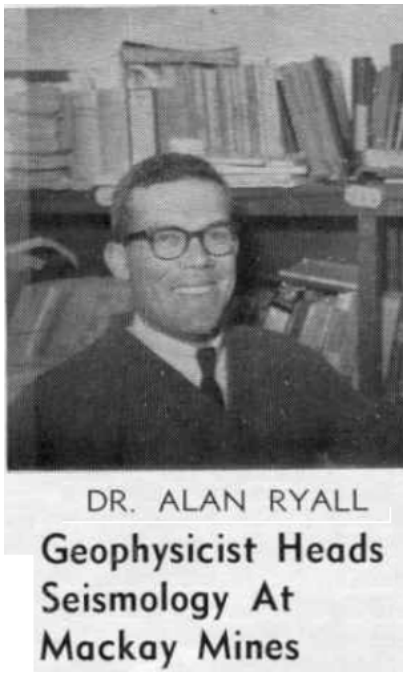
U. S. Coast and Geodetic Survey stations at Eureka and Boulder, Nevada and an additional station operated by Cal Tech in Ely, Nevada. While important, the locations of these latter stations were not favorably situated to locate earthquakes in the vicinity of Project Shoal.

First Director of the Seismology Laboratory – Alan Ryall

Burt Slemmons' personal notes in the University Archives show that dollars for research were generally provided by Geology department funds and measured in the hundreds of dollars, not the 10s and hundreds of thousands of dollars provided by the Vela program. Dollars provided to universities from government agencies are referred to as 'external funds' by academics. This infusion of external funds was new to the geology program at UNR and by 1969 was approaching $400,000[69], sufficient to gain the attention of major newspapers[66,70]and Nevada's public. The University was also apparently taking note of the potential of such funds to support the growth of the geology program and University as a whole. Presumably in response, the University allotted a new faculty position to the geology department. The position was filled by Dr. Alan Ryall, a recent 1962 Ph.D. in geophysics from U C Berkeley[71] who had studied under the guidance of Dr. Perry Byerly. Ryall arrived at UNR in 1964 after a couple of post-doctoral years conducting research at the USGS observatory on Kilauea Volcano in Hawaii. His initial appointments were assistant professor and assistant research seismologist at the Mackay School of Mines[71]. Burt Slemmons was the originator of the Seismological Laboratory though never assumed the title of Director. The title of Director was accorded for the first time to Dr. Ryall[66,71]. The singular seismographic station had now evolved to a full-fledged research laboratory hosted in the Department of Geology (with a very small seismic network).

Seismic Networks are *a distribution of seismometers on the earth's surface that record the seismic waves emanating from earthquakes. The seismic waves from any particular earthquake will generally arrive to the various stations at different times ('arrival times'), later for stations far from the earthquake and sooner for those closer. Measures of the difference in arrival times gives ability to the seismologist to locate the source of the earthquake. Likewise, it is the variations in the size and frequency of seismic motions at stations across a network that allow calculation of the earthquake magnitude. Locating earthquakes cannot be done with a single station or even two. At least three are needed, and with yet more closely spaced stations earthquake locations are determined with increasing exactness. Having just a single station, say in Reno, is of limited utility. Development of seismic networks that either span the globe or with a more regional focus on the scale of Nevada are better developing an understanding of earthquakes and the hazard they pose to the public.*

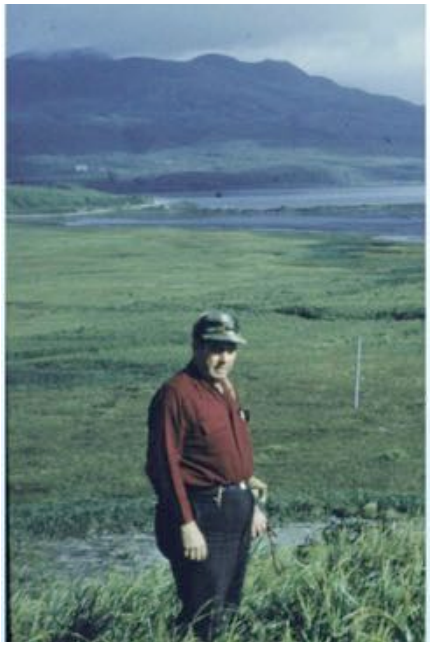
Ryall Years 1964 – 1986



Mackay Newsletter June 1964.

Staff: The first years

The Lab's research and technical staff was small at inception and housed in the Mackay School of Mines Building. Aside from Slemmons, Ryall, and graduate students studying with them, there was seismograph development technician Richard F. Houvicka and Research Associate Austin E. Jones[66]. Jones served for 15 years between 1962 and 1977, at which time he retired emeritus. It seems he was the first research scientist brought onboard when Burt Slemmons received funding to start a seismological laboratory. From where he came and why Slemmons hired him is somewhat lost in history. Immediately upon arrival he teamed with Ryall to develop one of the first computer programs to locate epicenters of earthquakes[72]. The program worked on the University IBM 1620 and, for those who remember, seismic data was entered on computer punch cards, revolutionary for the time, enabling automatic location of earthquakes across Nevada. Soon thereafter he teamed with Slemmons and Gimlett to assimilate Nevada's observations with those from other sources and use the computer program to create a first catalog and map of Nevada earthquakes for the period 1812 – 1960[73]. Later studies find him being a principal contributor to aftershock analyses and earthquakes related to nuclear explosions[74]. He also published what must have taken a herculean effort "Recording of Earthquakes at Reno, 1916-1951" wherein he single-handedly examined and produced a catalog of all earthquakes recorded on the Lab's horizontal, two component 1916 Weichert seismograph described earlier[75].

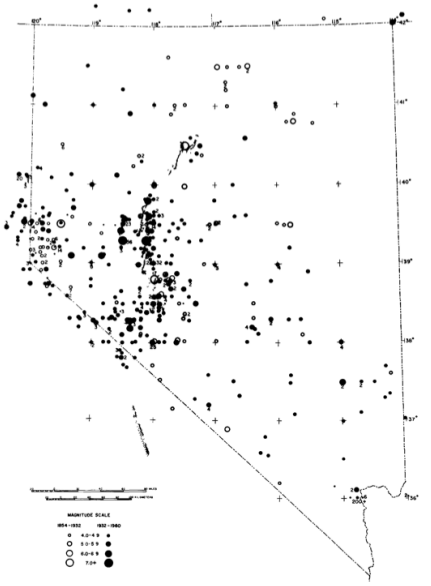


Nary a photo of Austin E. Jones during his 15 year career (1962 – 1967) with the Seismology Lab seems to exist. This USGS archive photo show Jones on Adak Island in the early 1950 (courtesy of John Fournelle).

***Austin E. Jones** was the first research associate hired in the Seismological Laboratory. His history before the Lab is a bit of a mystery. Investigating I discovered to my surprise a 1999 article by John Fournelle of the University of Wisconsin in Seismological Research Letters, 'Seeking information about Austin Emory Jones (1898-1987)'. Someone else had apparently encountered the same stumbling block. It is from a brief personal communication with the author I learned of Jones's most interesting career prior to arriving at UNR, and why most likely he was hired as a Research Associate. His undergraduate degree in Physics at UC-Berkeley shows he was a bright kid, and while there he served as assistant to Professor Byerly, a well-known professor of seismology. Burt Slemmons via his experience with the 1954 earthquake, as well as also being a graduate of Berkeley, was a colleague of Byerly at the time of Seismology Lab's creation. I surmise it was in part this relationship that led to Burt bringing Jones onboard the Lab in 1962. More than that though, Jones had by then accumulated a long history of experience in seismology. He worked as a seismologist at Lassen Volcano Observatory in 1927, and then hired on in 1929 as an Assistant Seismologist at the Hawaiian Volcano Observatory. There he was in charge of operating seismographs, the measurement of seismograms, the preparation of earthquake bulletins, and earned his graduate M.S. degree in 1938. Shortly thereafter he published in Scientific American instructions for 'building and operating in the owner's cellar… a seismograph… which will record quakes from the most distant parts of the earth'. What appears to be his probable future path to more graduate studies was perhaps interrupted by the great Depression. Nonetheless, the years 1949 – 1962 find him hired by the USGS and Coast and Geodetic Survey to operate seismometers and other related geophysical instruments in Hawaii and the Aleutians, He apparently was a well respected and liked fellow, referred to as 'Jonesy' by his Alaskan colleagues. His landing in the Seismo Lab follows naturally from this background in seismology and instrumentation.*

New Homes for the Lab

The technical, operations, and research staff of the Lab was to grow significantly in the ensuing years. With expansion of geology, mining, and seismology programs, things had by 1963 become quite cramped for all in the Mackay School of Mines Building. Fortunately completion of the new Scrugham Engineering-Mines building, then the largest public building in Nevada, on the northeast corner of the campus Quad was to allow the expansion[56]. The Seismology Lab in 1964 moved its center of operations to the 3rd floor of the new building[76]. Here the Lab offices, repair shop, and equipment room were located in and adjacent to Rm 315 near the west end of the building. Lab operations remained there for the next 20 years until dedication of the new Paul Laxalt Mineral Engineering (LME) building on April 27, 1983[77]. Lab operations moved to the 3rd floor of LME shortly after.



Nevada's first seismicity map, 1852-1960, constructed by Slemmons and colleagues in 1965.

Machinations of a Seismology Laboratory

The workings of a Seismology Laboratory may be viewed as three parts, each complimentary and vital, though most often in daily activities occurring separately. Prominent are the *seismic network technical staff*. They deal with the maintenance and development of the seismic instruments that record seismic waves, and the manner in which the seismic records are delivered to the lab for analysis. The instruments are generally deployed in either temporary or more

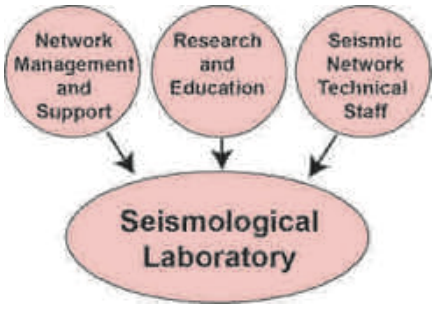
New Engineering-Mines Building Open For Fall Term

By the beginning of the fall semester this year, the new Engineering-Mines Building will be ready for business. Construction is completed and equipment is being installed.

The handsome new structure, largest public building in Nevada, was designed by the firm of De Longchamps and O'Brien. Fred De Longchamps, a graduate of the MSM and well-known in Nevada mining cir-

Mines wing of new James G. Scrugham Engineering-Mines Building.

Mackay Newsletter June 1963



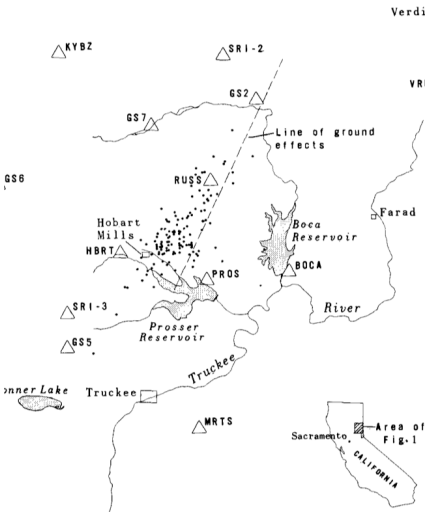
General Organization of a Seismological Laboratory,

permanent networks. The deployment of relatively widely spaced instruments over a broad region for long periods of time are permanent seismic networks. Portable instruments are used to construct temporary and more closely spaced temporary networks to gain higher resolution pictures of earthquake activity in a particular region, or in response to a large earthquake, where deployment is designed to record the many smaller aftershocks that typically occur in the following weeks or months. Activities focused on maintaining the financial health of the seismic network, decisions concerning the design of the seismic network, first assessing the location and size of earthquakes recorded by the networks, and organizing an earthquake catalog accessible to researchers and informative to the public, fall under the umbrella of *network management and support.* Finally, there are academic and research faculty within the lab focused on *education, and research* to understand where, why, and how earthquakes occur and the hazard they pose to the human environment. Some of these faculty are supported permanently by the University, while others are supported by external research grants such as those provided by Vela program. And of course decisions within each group are informed and influenced by those in the others.

The seismic network – permanent components

The Lab's regional network was in 1964 still limited to seismometers at four locations. Recordings of the seismometers at each place were on photographic paper (and/or magnetic tape). The records were transported to Reno daily (or weekly?). The limitations of the Lab's network was quickly brought to the forefront when a magnitude 6.0 to 6.5 in earthquake occurred near Truckee to give Reno a good shake in 1966. Damage from the earthquake wasn't much, though strong enough to throw a crane operator out of his machine's window atop the 22-story Arlington Towers in downtown Reno[78]. The story is perhaps of amusing interest because this seismologist currently owns a condominium on the 19th floor of that same building. More to the point, the wide spacing between the network stations was insufficient to accurately locate the main shock of the earthquake, and the earthquake provided Director Ryall a pulpit to educate the public about the earthquake and seismic hazards in general, all no doubt giving reinforcement to the need of a seismological laboratory in Reno[79].

With the need for a better seismic network to serve the State emphasized by the recent earthquake, Ryall continued sequestering funds and technical assistance for the task[69,70]. Technical assistance showed up in 1966 in the form of Walter 'Wally' F. Nicks. Nicks had been identified while in the military to have a natural aptitude in things technical and therein trained as an aviation electronics technician. Upon discharge in 1962 (honorable we presume) he had moved to San Francisco and used his training as an employee for Lynch Communications. He there noticed an advertisement for a technician in the Seismology Lab, and with relatives in the Reno area, he anxiously applied. Surprised by the phone early one morning, Dr. Ryall offered him the position. Asking Ryall when he would like him to start, Ryall responded 'tomorrow would be great'. Nicks was in Reno within the week, not to retire until 40 years later,



Location of 1966 earthquake near Boca reservoirs outlined by small aftershocks, later located with deployment of portable instruments by graduate student Roger Greensfelder (1964).

Safe from a Dangerous Perch

Crane Operator Saves Himself

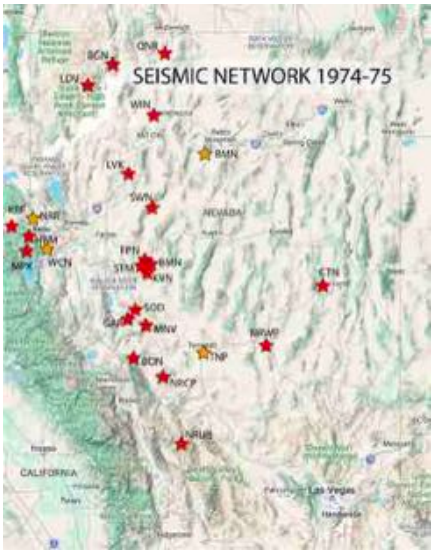
Reno Evening Gazette, Sept 12, 1966

Wally Nicks (2006)

and largely responsible for design and development of the Lab's seismic network during that time. Nicks of course had help. Eric Broten (1972-1980?) , Greg Klemesrud (1983-1984), Erwin McPherson (1971-1975), and Dave Wilson were among network technicians that worked in the Lab during Nicks' first years.

Thus began in 1969, with the aid of more contracts and grants and surplus equipment from the Air Force Office of Scientific Research and the Atomic Energy Commission, the construction of a statewide seismic telemetry network[80]. Soon the network was transmitting continuous seismic signals to the Seismology Lab across leased telephone circuits from a total of nine stations spanning Nevada and California. And plans were in place for yet more radio-linked stations in the vicinity of the Dixie Valley – Fairview Peak earthquakes of 1954[80]. By 1975 the network had expanded to more than 30 seismographic stations and accordingly more radio links employed to get the seismic signals to telephone lines[81]. Added to the network were also strain meters emplaced deep in mine tunnels at Mina and Round Mountain[82], and at Kaiserville though it apparently never operated. Up to 1978 network design and installation was accomplished by Nicks, part-time technicians, and graduate students. Ryall was away from Reno on sabbatical leave in 1976-7 conducting research for the Nuclear Test Ban Treaty in Washington, and James Douglas 'Doug' VanWormer was the acting Director. VanWormer hired Austin Wilson to work with Nicks in the development and expansion of the network. These two up until Nick's retirement in 2006 were the principal forces in technical development and implementation of the Lab's seismic network. Wilson kept on for a couple of more years, then retired, though for another 10 years one could find him around the lab still assisting on projects. Wilson and Nick's still live in Reno today.

Distribution (Network) of seismometers circa 1969 – 1970.



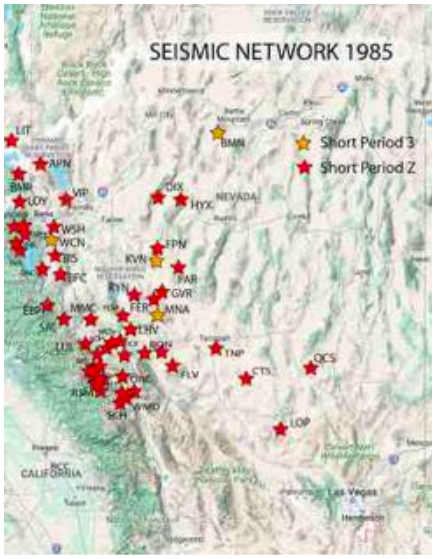
Distribution (Network) of seismometers circa 1974-75

Doug Van Wormer. Graduate of Seismo Lab served as Research Associate and at times Associate Director (1973-1979). Image 1975 issue Mackay Miner.

Wilson kindly took the time to describe the workings of the network to me. The network upon Wilson's arrival in 1978 consisted of about 30 permanent short period analog stations around western Nevada. Most were single-component vertical instruments using L-4 seismometers complimented by a number of 3-component sets of 1-second period Benioff seismometers. The 3-component instruments were located in abandoned mines near Battle Mountain, Tonopah, Washoe City, Kaiserville, and Mina. Because frequencies of seismic signals are too low to modulate a radio signal directly, seismometers were then typically coupled to a voltage control oscillator (VCO) to produce an audio tone that varies in frequency proportionaly to the seismic signal. Seismic station signals in this manner were being telemetered via radio links to 5 mountain top sites: TV Hill west of Reno, Peavine Mountain, Verdi Peak, Fairview Peak and a ridge adjacent to Slide Mountain. Signals were then conveyed to the Lab via voice-grade phone lines or, if close to Reno, directly to an antenna mounted on the roof of the Scrugham Engineering and Mines Building.

By the end of Ryall's tenure the network grew to over 50 permanent seismic stations[83] distributed along the Nevada-eastern California border[81]. The network was dependent on the leasing of private telephone lines. At this time the AT&T telephone sys-

Austin Wilson in 2006.



Seismic stations operating near the end of Ryall's tenure now numbered well more than 50.

tem was a monopoly. The U.S. government broke up the monopoly in 1982 to form numerous smaller 'Baby Bell' companies that went into operation in 1984. An unintended immediate consequence was that the annual cost of leasing phone lines for the Lab increased by thousands of dollars. With that, Nicks and Wilson decided they could build 'our own' system and began planning a microwave link between Slide Mountain and the roof of UNR. This marked the beginning of a fundamental change in the transmission of seismic signals to the Lab that would in ensuing years take place across the entire network. This time also marked the beginnings and development of a computer based recording system that provides on-line digitization of signals[83,84].

The seismic network – portable components

Issues related to crustal strain and earthquake prediction[85], the source properties and aftershocks of moderate earthquakes[86-89], and the relationship of seismicity to active faults[90] were among the topics addressed with deployments of portable instruments during Ryall's years. The portable instruments were first based on the design of a backpack seismograph designed and furnished to Nicks by Dan Hunt, a graduate student in the Electrical Engineering Department[91]. Nicks would lay out, build, and test proposed circuits boards and help with the hardware, soon to result in a system of six short-period portable analog stations that were contained in a covered two-wheeled trailer, and another contained in large wooden boxes suitably sized to fit in the back of a pickup truck[85]. Each used L-4 seismometers. The trailer and box each also contained a 7-track reel-to-reel recorder powered by air-cell batteries that allowed 15 days of continuous recording before the tapes filled and the batteries depleted. Later, Nicks also designed and developed a three-component portable seismograph system with digital event recorders. Other portable equipment in the lab included four small solid-state amplifier heliocorders that were used either with ink or smoked paper to record the seismic signals. The truck system was perhaps most notably deployed just before the magnitude 6 earthquakes at Mammoth Lakes on May 25, 1980[92]. A subsequent portable system employing some dozen S13, 1-second seismometers was deployed to monitor geothermal exploration in Dixie Valley.

***Seismometers are** not all the same. Some are 'short period' and tuned to listen to the highest frequency ground motions and others are 'long period', tuned longer period motions. Longer period motions may be viewed as akin to the sounds of a big bass drum and those of higher frequency to the chatter of school children on a school ground. The long period sounds of the drum may be heard at much farther distances from the playground than the higher frequency children's voices. Short period seismometers are thus most efficient at recording small earthquakes at relatively close distances while long-period seismometers able to hear the deep rumblings of larger earthquakes from around the globe. Technology today has managed to combine the capabilities of these seismometers into single 'broad-band' instruments. And a final note to bring context to the characteristics of seismic networks, some instruments record only a single direction of ground motion while others record 3-components of ground motion, providing the added capability of examining seismic vibrations in 3 dimensions.*

Austin Wilson installing portable seismograph with the Lab trailer in background. Circa 1980. Photo from Mackay Miner 1983.

Network operations

The organization and measuring of seismograms to determine the magnitudes and locations of earthquakes and the cataloging of the seismograms fell largely on the shoulders of analysts Gloria Smith (1968-1982, Floriana Ryall (1975-1986), and in the earliest years of the network Roberta Allen (1970-2) and Marie Simerenko (1969-1970). Their lab or space was generally referred to as the record reading room. Floriana was the wife of the Director and Gloria

Smith interestingly was sister in law of once-Nevada governor Paul Laxalt. Smith left Reno when her husband, a press-spokesman for Nevada Bell got relocated after the AT&T Telephone breakup. Operations in the record reading room evolved at a rapid pace during their time.

Seismic records were delivered by courier as paper recordings during the earliest days of the Lab. Measuring the arrival times of seismic waves took place manually with records spread across desks and light tables and the staff using pencils, rulers, and straight edges to mark and record the times. With the development of the telemetered network, data was transmitted back to Reno and recorded on analog tape recorders in the back of SEM 315. The tape recorders were 7-track machines that used 14-inch reels of ½ inch magnetic tape. The speed of the recorders was such that each reel would fill with data each 28 hours, requiring they be changed out every day. Everyone on the staff took a turn at changing the reels and cleaning the recording heads, including weekends and holidays. Nicks also designed the recording system to include a bank of rotating drum recorders ('helicorders') on which the record of 6 selected instruments was written in real time on black paper covered by white wax with a hot stylus that melted the wax to produce a black trace. Like the magnetic tapes, the helicorders recorded only ~24 hours and needed to be changed by the staff every day. These real time recordings of stations appropriately spaced across the network served to announce to the record reading room that an earthquake had occurred.

The year 1984, with the advance of digital recording and improving computers, marked the beginning of the end of recording seismograms on paper records and magnetic tapes. Here Wally Nicks is examining seismograms on heliocorders around 1979. https://www.unr.edu/nevada-today/news/2019/mackay-history.

Members if the Seismology Lab circa 1985. Bottom three left to right are Flori Ryall, Gloria Smith, and Ute Vetter. Above from left to right are Bill Peppin, Greg Klemsrud, Ed Corbett, Ron Sheen, Alan Ryall, Austin Wilson and Wally Nicks. Mackay Miner, 1985.

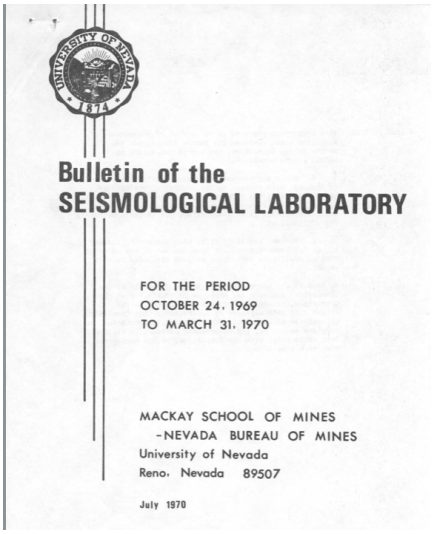
The record readers would also visually record the seismic wave arrival times on the helicorders to provide a rough estimation of the time and location of earthquakes that particular day. Then they would manually search (spin) the analog magnetic tape that day to find the 14 stations nearest the event (i.e. those that also recorded the seismic signals close to the same time), and play back all of the seismograms on to a visual chart recorder, allowing a more accurate measure of seismic wave arrival times, the information needed to locate the earthquake. All were tedious and laborious tasks, particularly noting that thousands of earthquakes occur across the network on average each year. All in all it is a testament to the patience and diligence of Gloria Smith, Floriana Ryall, and the graduate students that assisted.

The Lab in 1984 began in earnest to use computers to assist in earthquake processing[83,84]. A computer was employed to continuously analyze the incoming seismic signals, assess when an earthquake had occurred, and then activate a digital tape recorder to record just the time interval containing the seismic event. These digital tapes were then analyzed on a second computer using programs developed by Stephen Malone, a former and first Ph.D. student of Alan Ryall. With the program record readers could dispense with the now rapidly accumulating paper seismograms and manually pick the times that seismic waves reached each station on a computer terminal. The process had alleviated much of the drudgery and reduced the errors associated with locating earthquakes. With this more and smaller earthquakes could be regularly located. More than 3500 were located and cataloged that first year. This approach for the most part continues to be used today.

A primary mission and output of the record readers is a catalog of earthquakes recording the location and size for each earthquake that occurs, and the information used to determine those parameters. Today and since 1984 these catalogs are generally preserved on computers and offered for analysis on the internet. Prior to that time the Lab produced paper bulletins that describe seismicity over the period of 1970 to 1984[93-102]. They are an important archive and testimony to the hours of work and effort in the record room.

Early Research and Instruction

These early years of the Seismological Laboratory were a uniquely exciting time for seismology, not just at Reno but around the globe. The global patterns of seismicity being delineated by seismologists were to be a critical element in development of the then new and revolutionary theory of Plate Tectonics. The role of seismology for nuclear test discrimination had become clear. And the hazard imposed by earthquakes to newly planned nuclear plants, major pipelines, highways, and urban environments was increasingly demanding the attention of seismologists and earthquake geologists. Seismologists were seriously motivated to predict earthquakes and collect observations they hoped would allow them to. With this backdrop, Ryall and colleagues introduced for the first time to the curriculum courses titled Earthquake Engineering, Elementary Seismology, Advanced Seismometry, and the Theory of Waves in an Elastic Medium, and focused research in the lab on ‘ 1) earthquake distributions and mechanisms, 2) possibility that large underground explosions may influence seismic activity, 3) strain measurements in the Nevada region, and 4) structure of the crust and upper mantle in this region[80]. And these issues indeed became the principal subjects of graduate theses and research publications during Ryall’s tenure.



Cover of one of early paper catalogs of seismicity issued quarterly and annually by the Seismological Laboratory.

The First Graduate Degrees

The number of students completing graduate degrees under the advisement of faculty in Seismology today numbers more than a hundred. Their contributions are partially documented with the list of theses provided in ensuing sections. A detailed discussion or description of all is well beyond the scope of the task assumed. Some of the first though deserve some mention. They established a tradition that continues today of graduate students addressing topics of the time, moving on to important societally relevant professional positions, and expanding the national and global expertise in earthquake science.

The first degrees granted under the tutelage of Slemmons and Ryall in the Seismo Lab were Masters of Science (M.S.) degrees. This is natural because of the shorter duration required for completion than a doctoral degree. Roger W. Greensfelder (1964) seems to be the first. His study aimed at determining the depth of earthquakes in Nevada led to a research position at the United States Geological Survey and later his role as California’s State Seismologist. Larry D. Gedney’s (1967) experience studying focal mechanisms, a new approach at the time, of Nevada quakes led to a career

Graduate Degrees are *generally accorded at the Master of Science (M.S.) and Doctoral (Ph.D.) levels. Master’s degrees are generally awarded with an additional ~2 years of course work beyond a Bachelors degree, and the writing of a thesis about a well-defined project. In this manner, they demonstrate they have ‘mastered’ a particular set of tools and approaches to addressing scientific or technical problems. Ph.D. degrees require a more rigorous and extended effort that generally address yet unsolved problems in the particular scientific discipline. These generally take a longer 4 to 5 years to complete. The UNR geology program awarded only M.S. degrees until 1964[28], after the Geology department in 1959 lobbied and was approved by the University to grant Doctoral degrees.*

at the Geophysical Institute of Alaska in Fairbanks as an associate professor of Seismology. He died in 1992[103]. Also in 1967 James VanWormer matriculated with his M.S. entitled Solid Earth Tides as a Triggering Mechanism for Earthquakes. So well liked and respected around the Lab, he was not long thereafter serving as Associate Director. A sad story though, struck by cancer, he died at the young age of 36 in 1979[104]. And on the geological side Gary Carver completed an M.S. thesis in 1969 describing surface faulting associated with the Great 1872 California earthquake in Owens Valley[105]. He moved on to later be awarded a Ph.D. at the University of Washington, become a Professor at Humboldt State University where he instructed numerous students in earthquake geology (many of whom moved here for graduate studies), and gain notoriety for his consultant role in designing the Alaska oil pipeline to withstand displacements of the great 1964 Alaska earthquake.

Gary Carver (circa 2009)

The first Ph.D. degrees soon followed, all under the mentorship of Dr. Ryall. Stephen D. Malone led the pack, completing his study of Earth strain measurements in Nevada and possible effects on seismicity due to solid earth tides in 1972. He moved on to a distinguished career as a Professor at University of Washington and served as Director of the seismic network there. Two years later in 1974 Keith F. Priestley followed with his study of Earth Strain Observations in the Western Great Basin. Preistly was therein hired as an Assistant Professor in the Seismology Laboratory. With a brief interlude in New Zealand, he served until 1990 when as a Full Professor he decided to move on to University of Cambridge, where he presently resides as Emeritus Professor. And yet another two years later William U. 'Woody' Savage completed his study of earthquake probability models: Recurrence Curves, Aftershocks, and Clusters. Woody then spent a career working on seismic hazard assessments for major dams, nuclear power plants, nuclear waste storage, and electric and gas transmission facilities, as Manager of William Savage Consulting, LLC and research scientist in the U.S. Geological Survey. Regrettably, Savage died this last November[106].

The first three Ph.D.'s in the Seismological Laboratory later attending a Seismological Society of America meeting. From left to right: Keith Priestley, Woody Savage, and Stephen Malone.

Lab Research and Investigators

Ryall increased the research imprint with use of the Air Force funding, augmented with support from the United States Geological Survey, the National Science Foundation, and the University to recruit and hire a half dozen young research faculty during his time as Director. The Lab's research productivity increased with each. Some also taught classes and guided graduate theses.

Dr. Gary Boucher was the first. He joined the Lab as an Assistant Professor in 1968 soon after completing his Ph.D. at Columbia University's Lamont Doherty Geological Observatory[107]. Boucher with Ryall introduced the first seismology class in wave propagation to the Geology curriculum. Boucher, for reasons unknown to me, decided to leave the Lab in 1972, but not before quite im-

Gary Boucher retired long after time at the Lab.

pressively publishing a half dozen professional papers exploring the association of earthquakes and underground nuclear explosions[74,108-111]. He moved on to the United States Geological Survey in Alaska and various other positions. Story has it that his greatest satisfaction lay in his wide ranging volunteer work.[112]

Indra N. Gupta followed in 1972, joining the Seismology Lab as an Assistant Professor, following his 1964 Ph.D. from St. Louis University and a post-doctoral stint at the University of Kentucky. His expertise prior to arrival included radiation of body waves from near surface explosions was relevant to the Lab's interest in discrimination[113]. With then current excitement about the possibility of earthquake prediction, he spent his time at the lab investigating and publishing significant papers addressing changes in seismic wave propagation that may occur prior to large earthquakes[114,115]. He left the Seismology Lab after a brief few years in 1975 to continue his career in the private sector with geotechnical firms Dames & Moore and Teledyne Geotech. He is recently deceased[116]

Indra Narayan Gupta

The subsequent new additions to the faculty were previously mentioned James VanWormer and Keith Priestley in 1976. Each were homegrown investigators. Alan Ryall was the thesis advisor to each. Van Wormer during his short time in the Lab for the most part collaborated with Ryall and Slemmons designing studies to understand recent crustal movements, the distribution of seismicity, and seismic hazard along the Sierra-Nevada Great-Basin boundary, what we more typically today call the Walker Lane [87,89,117-120]. Priestley's career began as a graduate student with Ryall, evolving to a research seismologist position in 1973, then leaving briefly for positions at Cambridge and New Zealand, until his return to UNR and an Assistant Professorship in 1976. This fellow, always graced by a bushy beard and an underlying smile, authored nearly two dozen professional publications using observations in and near Nevada to address significant topics in seismology, among them the structure of crust and mantle beneath Nevada[121-123], source properties of the 1980 Mammoth earthquake sequence[124], and the relationship of seismicity to variations in crustal strain[125,126]. All the while he simultaneously mentored more than a half-dozen students to their graduate degrees. Two of these, Diane DePolo and Ken Smith, were in later years to become integral to the operations of the Lab.

Young, athletic, and an avid backcountry skier, William Peppin arrived in 1975[127] with a freshly minted doctoral degree from U.C. Berkeley. He was a whirlwind during his 13 years about the lab, introducing classes to the curriculum, frequently the source of newsletter articles bringing attention to UNR of the Lab's activites[88,128], conducting research aimed at discriminating nuclear explosions from earthquakes[129,130], the characteristics of earthquakes, seismic waves, and a possible magma body in and near the Long Valley caldera[86,131,132]. He at the same time was behind the scenes implementing and writing software to expedite digital analysis of the increasingly greater number of analog seismic signals arriving to the Lab[133]. I am told that today's analysis system still shows pieces of code written by Peppin. Indeed, Larry Larson the Geology Department Chair at the time described him 'as busier than a one-legged seismologist in an earthquake'[134].

New Faculty William A. Peppin (Mackay Miner, 1975)

Malcolm Somerville (AEES)

Malcolm R. Somerville joined the faculty for a short time in 1980. An Australian, he in 1977 had, like Peppin, recently completed his Ph.D. at the University of California. He studied with Bruce Bolt and followed with a post doctoral position at Cal Tech, and then a turn at Blume Earthquake Engineering Center at Stanford before arriving at the Seismo Lab. His entrance coincided with a large 1980 sequence of earthquakes near Mammoth, California, and he like many seismologists and geologists soon converged on the source area, presumably assisting in deployment of UNR portable seismometers amidst speaking to the press[135]. During his brief stint, he also worked with Ryall on his USGS project "Seismic Hazard Evaluation of Large Known and Suspected Active Faults in Western Nevada"[136] and expeditiously published an analysis of a sequence of small earthquakes

at the south end of Carson Valley. He returned to consulting in the San Francisco Bay area and later to a well respected career in the Australian Geological Survey (now GA, Geoscience Australia), regrettably curtailed in 1999 when he died in a house fire[137]. He is fraternal twin to Paul Somerville, also an eminent long term earthquake engineer and member of the Seismological Society of America.

Ute Vetter at a university event.

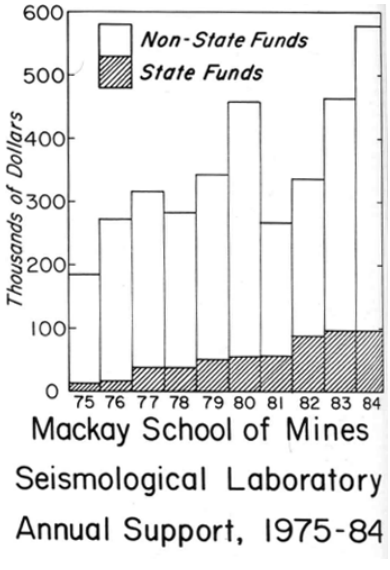
Ute Vetter arrived in fall of 1981 at the request of Ryall. Vetter had recently completed her Ph.D. from Christian Albrechts University, Kiel, Germany, a 14 month stay conducting research at Cal Tech, and a short stay at the Hawiian Institute of Geophysics. A member of the faculty for 9 years, she lectured, conducted research, and played a primary role in publication of the Lab's Bulletins[101,102]. Her class lectures in geophysics were designed to compliment those being provided in seismology by Ryall. Her research employed primarily focal mechanism analysis. She authored numerous papers contributing to today's understanding of the regional stresses responsible for earthquakes and crustal deformation in the western Great Basin[138-141]. Vetter left the Lab in 1988 for a term at the California Geological Survey and then to work on seismic safety of dams and reservoirs for the U. S. Bureau of Reclamation in Denver from which she retired in 2001.

The last addition to Ryall's lab was Ed Corbett in 1984, with a newly minted Ph.D. from Cal Tech. His four years at the lab were apparently divided between operations and research, and traces of his activities are few. He edited of one of the Lab's Bulletins documenting seismicity in 1982[101]. To that may be added his contribution to a study of the magnitude 6.4 1986 Chalfant Valley earthquake near Bishop, California[142], wherein ~1000 of the aftershocks were located to delineate the geometry of the causative fault. He departed the lab in 1988 and apparently shifted gears to become a computer science professional.

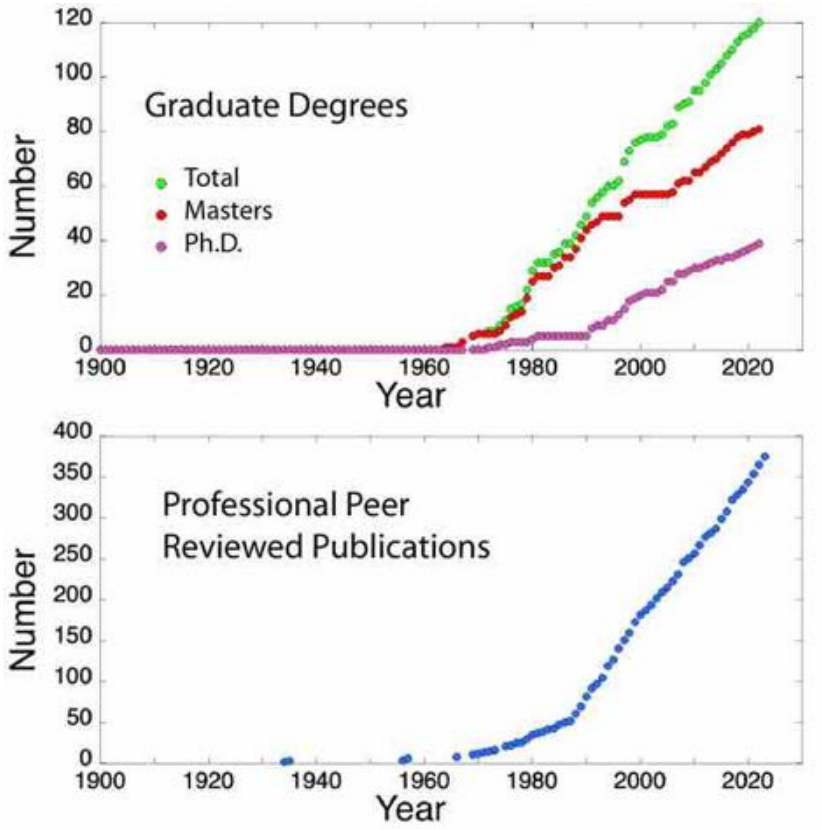
Ryall introduced, guided and promoted the major themes of research being investigated around the Lab. He as well was also active conducting his own research on issues that were drawing the attention of seismologists those days, and for the most part still do. He was the first to construct from seismicity observations the distribution and rates of crustal strain across the Basin and Range[143], and further assess those patterns with earthquake statistics to characterize seismic hazard and the likely location of future large earthquakes in Nevada and surrounding regions[117,126,144-146]. Earthquake prediction was during his time in Nevada a central and optimisitic focus of much seismological research around the world[147]. To this he contributed his[85] and students[125] research on the possibility of crustal strains produced by earth tides triggering earthquakes, and the possibility that observations of S-wave splitting might be a tool to predict earthquakes in Nevada[148]. Discrimination of nuclear blasts from earthquakes of course also gained his attention[108,149]. Visits of prominent scientists from around the globe attest to the global recognition being gained by research in the Seismology Lab[150-153]. Ryall's election as President of the Seismological Society of America in 1981 puts a fitting exclamation mark on the respect he and his Lab's efforts had gained in the professional community.

End of the Ryall Era – Formal Recognition of the Seismology Laboratory

Alan Ryall resigned from the Seismology Lab in 1986. He briefly returned to DARPA to continue his research to improve nuclear test ban treaty verification. His later retirement led him to yet another distinguished career as author of maritime history[154] and award-winning artist and painter[155]. All of the above faculty moved on around the time of Ryall's retirement from UNR. They can all deservingly boast of their contributions to creating an organization valued both within and outside the University. Indeed, if graduate theses, publications, and external funding are a currency by which academic research institutions are valued, the Seismology Lab's worth skyrocketed under Ryall's leadership. This was not lost on the University administration. On Feb 15, 1974, the Board of Regents voted without dissent to establish 'that the Seismological Laboratory be established as a separate research laboratory under organized research (Statewide Programs, UNR) with its Director reporting to the Dean of the Mackay School of Mines[156-158]. Prior to this time it was in fact a self-organized group within



External funding brought to the UNR for Seismo Lab research during just the years of 1975-1984. Mackay Miner, 1984. $330,000 in 1984 is equivalent to about $1 million today.

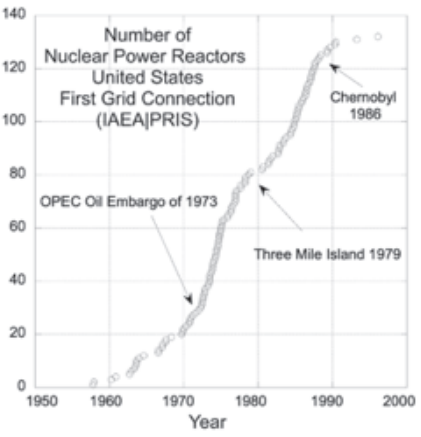


The sudden and rapid rise of graduate degrees and publications in seismology observed in 1960's coincides with Ryall assuming Directorship of the Lab.

the Department of Geology. That was 50 years ago, reason for this digression into the Lab's history and maybe a little celebration.

Politics of Atom Expands Influence on Seismology Lab Activities

Nuclear test discrimination played a central role in Lab activities during Ryall's years and continues to do so. Scientists and engineers soon began considering peaceful uses of atomic energy after World War II, particularly as a potentially cheap and limitless source of electrical energy [159]. Nuclear reactors came to be viewed as commercially viable sources of electricity, and electric utilities began rapidly placing orders for reactors. The rate increased yet more rapidly when the Organization of Petroleum Exporting Countries (OPEC) ceased deliveries to the U. S. in 1973-74 [160]. Various events were simultaneously conspiring to raise public awareness to the risks posed by potential failures of nuclear power plants. Prominent among them was the malfunctions and meltdowns of the nuclear reactors at 3 Mile Island in Pennsylvania and Chernobyl [159,161]. Commercial reactors coming online slowed after each of these events. Nonetheless, leading up to Ryall's retirement the number of operating commercial nuclear power plants grew at a rapid pace, reaching to more than 120 in 1986, with a hundred more in planning [162].



The Atomic Energy Commission (AEC) was created in 1946 to manage and develop nuclear energy for military and civilian applications. The Atomic Energy Act of 1954 made possible the development of a civilian nuclear industry [163] and removed the military's responsibility to reviewing and licensing commercial power plants. The civilian AEC was charged with the task, and so assigned to it the potentially competing responsibilities of promoting commercial uses of nuclear power and insuring their safety to the public. Geotechnical reviews once conducted externally by the United States Geological Survey (USGS) and U.S. Army Corps of Engineers became in-house functions of the AEC. The burgeoning of licensing applications soon surpassed the capabilities of the AEC staff alone.

The AEC was replaced by the Energy Research and Development Agency (ERDA) in 1954 which, in


RENO EVENING GAZETTE

Oil noose tightens; Arabs hold rope

RENO EVENING GAZETTE

Nuclear plant leak triggers new protests

Soviet nuclear accident

States brace for fallout

Monitoring effort stepped up; no danger expected

Likely path of radioactive fallout

USA

USSR

Greenland

Making headlines in Reno Gazette Journal. Major events impacting development of nuclear power included (top) the 1973 Organization of Oil Producing States Oil Embargo, (middle) the nuclear plant leak of 1979 at 3 Mile Island, Pennsylvania, and (lower) the 1989 meltdown of nuclear reactors at Chernobyl in the former Soviet Union.

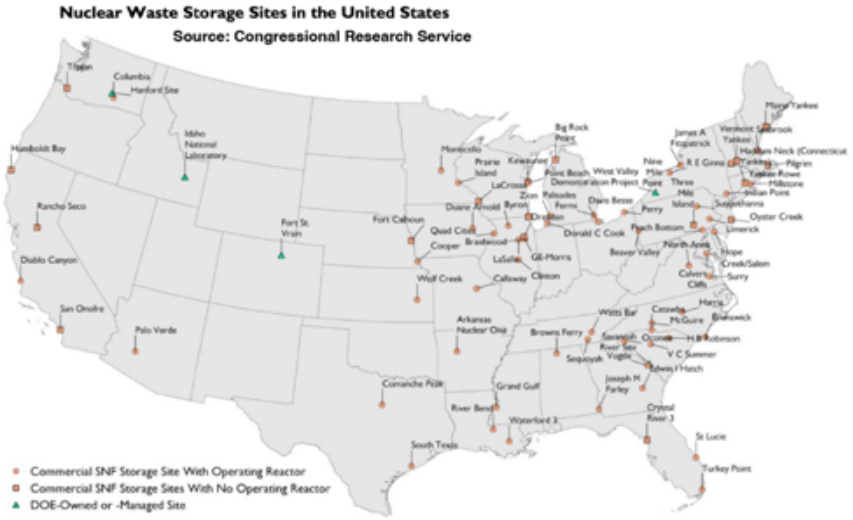
turn, was in 1977 consolidated into what we know today as the Department of Energy (DOE). In response to the increasing number of license applications and the desire to separate the potentially conflicting tasks of promoting nuclear energy and protecting the public, an independent Nuclear Regulatory Commission (NRC) was established in 1974. Thereafter the geological and seismological data needed for licensing was codified in Federal law[164,165] and standardized Safety Analysis Reports required for license applications. Because such reports rely heavily on geological and seismological information, electric utilities seeking licenses began hiring geotechnical consultants from the private sector and scientists from universities to provide the needed information [162].

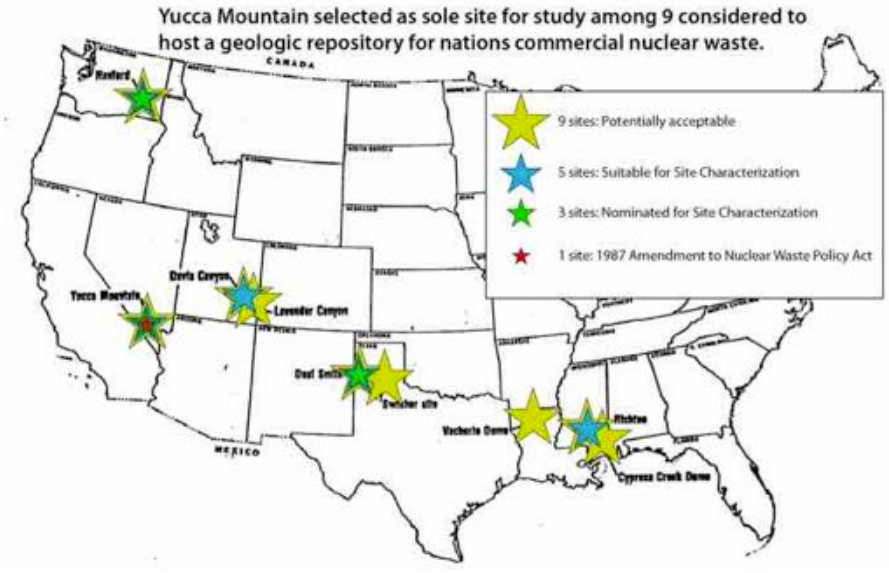
Over time reactor fuel becomes incapable of economically producing power and must be replaced. The fuel is a low-enriched uranium oxide fabricated in rods. The radioactivity in the used or 'spent' rods remains nevertheless at levels dangerous to human life and ultimately requires safe disposal [166]. With the exception of a 1957 National Research Council report concluding that underground disposal of waste produced by nuclear reactors was 'seemingly' the most promising approach [167], the issue of waste disposal did not receive much attention from the public in the early years of the flourishing commercial reactor industry [168].

DOE though announced in 1977 that it would accept and take title to commercial reactors' spent nuclear fuel (SNF)[169,170]. Then, with the USGS, it prepared Earth Science Technical Plans (ESTPs) that specifically addressed the earth-science research tasks needed to license a geologic repository for waste resulting from nuclear generation of electrical energy [171-173]. The reports proved timely with the subsequent enactment of the Nuclear Waste Policy Act of 1982 [174], which assigned the DOE responsibility to site, build, and operate two deep geologic repositories. The Act also established the taxation of commercially operating nuclear generating plants to create a Nuclear Waste Fund to support the activities.

DOE's initial intent was to put forth nine potentially acceptable sites and recommend not less than three to the President to begin site characterization activities [175]. The DOE did indeed recommend three sites in December of 1984, located in Washington, Texas, and Nevada[176], and President Reagan approved the recommendations in May 1986 [177]. The politics of 'not in my backyard' ensued, joined as well by representatives of other states that intended to avoid becoming host for the nation's nuclear waste [169]. Add to this that the Speaker of the House of Representatives and Senate Majority Leader were at the time from Texas and Washington, respectively, it is not surprising that legislation ensued to eliminate Texas and Washington from consideration, codified with 1987 Amendment to the Nuclear Waste Policy Act of 1982, leaving Yucca Mountain, Nevada to be the only site to be considered and characterized. The political maneuvering eliminated a potentially fair selection process, and the 1987 amendments became known to many in Nevada as the 'Screw Nevada' bill [168].

Nevada's reaction to these developments was prompt. The Governor in 1983 established by executive order an Agency of Nuclear Projects to oversee and give the governor guidance concerning federal high-level waste





activities in the State. The Legislature formally established the Agency in 1985 and gave it the additional moniker of Nuclear Wastes Project Office (NWPO). Because the 1987 amendment designated Yucca Mountain to be the sole site considered for characterization, Nevada was entitled to request funds from the DOE to independently assess the viability of the site and potential economic and environmental impacts attendant to its potential development (42 U.S.C. 10136(c)(3)(B)). Nevada did this, and so it came to be that NWPO with allegiance to a State Government adamantly opposed to the idea of Yucca Mountain came to be funded by Nuclear Waste Fund money channeled through the DOE's Office of Civilian Radioactive waste management, the very agency motivated to license the project. Congress began allocating Nevada on average $5 million per year for oversight activities, albeit they asked for much more [169].

Politics made it such that the Nuclear Wastes Projects Office, DOE, and related commercial interests would soon begin to draw upon and fund the interests of earth scientists across the University and, of course, the Seismological Laboratory.

Slemmons 1986: Originator and First Director of the Center for Neotectonic Studies

The preceding events played large in Burt Slemmons' research, development of students, and organization of earthquake science around the Lab during the years immediately following Ryall's departure. The Pacific Gas and Electric Company (PG&E) in May of 1985 had successfully licensed and commenced operation of a nuclear reactor at Diablo Canyon, CA., with another to follow in March of 1987[178]. The licensing process was meanwhile meeting significant public resistance[179]. The 1979 Three Mile Island Accident, a large earthquake at Morgan Hill along the San Andreas fault in 1984, and then the 1986

Chernobyl incident all raised public concern. Furthermore a section of the Hosgri fault was located within ~3 km of the plant. Knowledge that the fault had produced a M7 event in 1927, underscored the potential hazard earthquakes posed to the power plant. These events did not lead the Nuclear Regulatory Commission (NRC) to further review or revoke the plant's licenses[180]. They were nevertheless motivated to reevaluate the seismic hazard posed to Diablo Canyon by the Hosgri and other possible faults nearby. The NRC in that circumstance funded in 1985 a new project spearheaded by Slemmons to conduct a three-year study of the "Earthquake Potential and Maximum Credible Earthquake for Diablo Canyon Nuclear Power Plant"[181]. Slemmons also at this time received additional support from the NRC to address the hazard posed to nuclear generators in the eastern United States, with a focused analysis of the Meers fault in Oklahoma[182,183]. Slemmons fittingly began using the funds to support graduates students' earthquake geology studies in and around the power plant and Oklahoma, ultimately leading to Master's degrees for each[184-188]. The activity and funds led Slemmons in July of 1986 to informally establish a Center for Neotectonic Studies (CNS) as a research component of the Mackay School of Mines[189].

Those of you in Nevada may have noted the particular beauty of the desert in the evening sun as shadows accentuate the hillslopes. Slemmons in years preceding his establishment of the Center noted this phenomenon and cleverly applied it to recognizing and studying earthquake fault scarps as they course across the landscape[190,191]. He in fact convinced a pilot-friend to cut a hole in the bottom his small plane to mount a camera expressly for the purpose of collecting these low-sun-angle photographs along earthquake faults. His trove of

1986 Mackay Miner announcement of new Center accompanied by Slemmons' low-sun angle photo of faults produced by 1968 Project Faultless underground nuclear test.

such photos was to continue to grow, housed in the Center, and formed the basis for many of his students graduate studies.

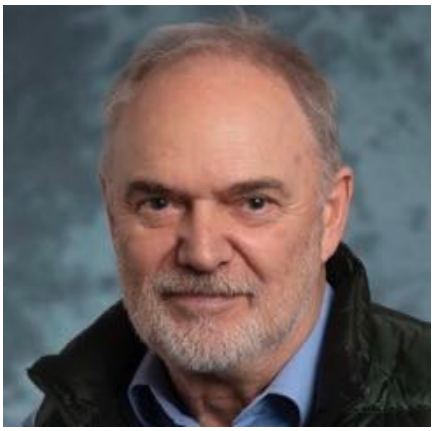
At this same time the Nuclear Wastes Projects Office (NWPO) was seeking earth scientists in Mackay to initiate geological, seismological, tectonic, and geochemical reviews for oversight of DOE's activities directed to licensing of the proposed waste site at Yucca Mountain. Slemmons with Dean James V. Taranik took the opportunity in late 1986 to proffer a proposal soon accepted by NWPO that poised CNS, with Burt Slemmons as Director, to coordinate numerous studies to be conducted by individual investigators in the Mackay School of Mines [192]. Slemmons' Center received 1.5 million dollars from NWPO for the calendar year 1987[193]. It was anticipated funding of projects through the Center would in the future average ~$2-3 million annually, a very large sum for the University at the time[194,195]. The CNS lab was to receive a small fraction of the funds to provide a single liason to NWPO, eliminating the need to contract individually with all of the principal investigators involved. The NWPO monies provided Slemmons' graduate students support to conduct earthquake geology studies for their M.S. degrees in southern Nevada[196-199].

Board of Regents recognizes Center

With the vigor of activity, the large amount of funds, and likely assumption that the Yucca Mountain evaluation process would continue for a long time[195], the Board of Regents on Nov 17, 1988 formally recognized the Center for Neotectonic Studies to "administer basic scientific studies and review technical information related to the Yucca Mountain nuclear waste research project and other neotectonic studies". The Center was to be non-degree granting and "financial support for salaries and any future equipment needs … be provided by research grants and contracts"[200].

Slemmons had just greeted the first post-doctoral researchers to the Center for Neotectonic Studies. Dr. Peizhen Zhang (1987-1991) arrived with a new Ph.D. from Massachusetts Institute of Technology and Dr. Michael Ellis (1987-1990) similarly from Washington State University after brief stops as visiting Professor at Universities in Pennsylvania and Minnesota. These two teamed together and with others funded through the Center to publish several papers addressing factors controlling the size and rate of earthquakes and fault slip along the Panamint Valley fault zone[201-203]. Each regrettably departed when funds from NWPO supporting their positions abruptly diminished, moved on to most successful careers, and still today remain active. Dr. Zhang is currently Professor at School of Earth Sciences and Engineering at Sun Yat-sen University and Dr. Ellis serves as Head of Catchment Science and Observatories, British Geological Survey. Fortunately the two continued collaborations with the Center investigators over the years[204-207]. As well, a number of doctoral students working with Dr. Zhang visited in later years to study with Center investigators[208-210].

Peizhen Zhang (1987-1991)



Michael Ellis (1987-1990)

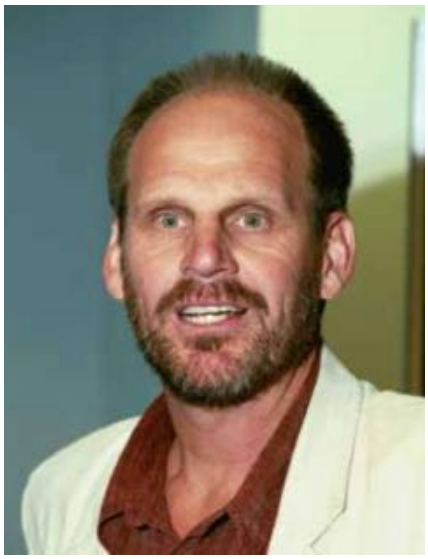
1989 – Slemmons Retires, Center For Neotectonic Studies Gets New Director, and Budget Cuts

Burt Slemmons after 38 years, mentoring dozens of students, influencing many, and originating both the Seismo Lab and Center for Neotectonic studies, and creating a legacy-to-last in neotectonics and seismic risk evaluation, decided to retire from UNR at the age of 67, and with that also retire his Directorship of the Center for Neotectonic Studies in 1989. The University advertised widely for his replacement. I at the time had finished in 1982 my Ph.D. at Columbia University followed by a several year post-doctoral stint at Cal Tech, with research at each focused on methods and issues related to integrating geology and seismology for seismic hazard analysis[211-213]. That evolved into a research faculty position at the Tennessee Center for Earthquake Research and Information (now CERI at Memphis State University) where my interests and practice were evolving to paleoseismology and the seismological and structural evolution of earthquake faults. Seeing the advertisement for Slemmons' position, I didn't apply. Surely they were looking for someone 'important'.

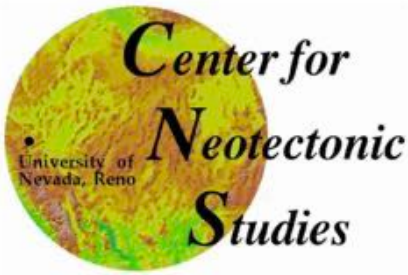
A chance meeting

As I recall it, I was presenting some research at UCLA in spring of 1989 and found myself having breakfast with Jim Brune and John Anderson who were also attending the meeting. It had been a year since the advertisement was posted and I assumed they had by then hired someone. So it was natural to ask them who?, to which they then looked at each other and replied 'nobody, would

you like to and, if so, give Burt a call'. So I did. Burt instructed me to send him a letter of interest, back date it a couple of weeks, and a few weeks later I met Burt for the first time in of all places Dixie Valley, where I was coincidentally then participating in a field trip across the Basin and Range. He told me about the position, shortly after I received an offer letter from Mackay School of Mines' Dean Dick Bradt, and in August of 1989 Steven G. Wesnousky officially took over the reigns as the Center's Director.



Steven G. Wesnousky.



Politics leads to budget cuts

The good feeling of returning west to oversee a major well-funded research operation didn't last long. NWPO's budget was slashed by DOE[169] only days after I signed on and consequently so too was the CNS budget. The position became rather unpleasant. Being required to inform investigators that they would at best be funded at much lower levels, or not at all, was no way to create a positive research environment. The negativity of the situation was aggravated because the Director position was entirely funded by NWPO, and thus with the smaller budget the Director's salary was taking up a significant fraction of the budget.

Politics continued to hurt. Congress and DOE completely ceased allocating funds to Nevada for Yucca Mountain oversight activities in 1995[169], and accordingly NWPO support for the Center Activities also stopped. My position was fully funded by the NWPO funds. This was a problem. I soon received a letter of termination from the University. Somewhat wisely though, I had required Dick Bradt, the Mackay Dean responsible for my hiring, to rewrite his original offer letter such that UNR would assume my salary in the event the Yucca Mountain program died. This was apparently not known higher in the University administration. So I dug deep into my filing cabinets to find that letter and posted it up to the President's office. The letter consequently set off a scuffle to assess how and where my position was to be supported. My stated preference was to be placed in the Seismology Lab. It seemed natural. My Ph.D. was in seismology and at the time I was President of the Seismological Society of America. Internal squabbles nonetheless led to establishing a tenure track position fully within the Department of Geology. It was more than twenty years later that Dean Thompson converted Wesnousky's position to the Seismology Lab.

'Dick' Bradt MSM Dean (1989-1991)

Jeff Thompson COS Dean (2008-2021)

Lemonade from Lemons

The situation was not all negative. Less time of me was needed for administration of NWPO funds and more could be placed toward garnering support from other sources for graduate students and post-doctoral researchers to follow their interests beyond the footprint of the Nuclear Test Site, and watching them move on to important positions at universities, government labs, and geotechnical companies in the private sector.

Craig Jones was the first post-doctoral researcher to join me at the Center, his presence emphasizing the value of surrounding yourself with smart people. After a brief couple of years, with papers published in Science[214] and Geology[215], and establishing himself as the go to source of knowledge

Craig Jones. CNS (1991-1993)

for all things Sierra Nevada and Basin and Range[216], he moved on to a faculty position at the University of Colorado and remains active there to this day.

Alessandro Michetti arrived soon after with a NATO fellowship from Italy to broaden his knowledge in neotectonics. After mapping active faults along the Santa Rosa Range in northern Nevada he returned to take up his current faculty position at the University of Insubria in Como, Italy.

Alessandro Michetti. CNS (1992-1993)

Mark Petersen joined them with support from the Southern California Earthquake Center and used his time to complete a then most comprehensive survey of fault slip rates in California. With this early career experience he moved upward to his current postion in the USGS as chief of the National Seismic Hazard Model Project.

Mark Petersen. CNS (1993-1994)

Janice Murphy in 1992 was the first to complete her M.S. degree under Wesnousky's guidance. Her study of seismic hazard in the San Francisco area after the 1989 Loma Prieta earthquake led to a research position conducting and assisting with 3-d imaging of the San Andreas fault. She retired in 2011 and if anybody knows of her whereabouts now, let us know.

Janice Murphy M.S. 1992

Yu Guang transferred with me from Memphis State University to complete her 1994 Ph.D. at UNR. Her quick bright smile and mathematical capabilities wowed us at the Lab. She died too young in 2006. Her research had earlier landed her a prestigious post-doctoral position with the Southern California Earthquake Center.

Yu Guang. Ph.D. 1994

John Caskey followed in 1996 with his Ph.D. Aided by the spiritual help of Maria and the Grateful Dead, John took on the herculean task of walking the entire trace of the 1954 Dixie Valley and Fairview Peak ruptures. His efforts established the distribution of slip along the fault's traces, provided insight to the the 3-dimensional geometry of the fault, and gave reason to why the two earthquakes occurred only 4 minutes apart. Since then he has been imparting his knowledge to students lucky to have him as a professor at San Francisco State University.

S. John Caskey. Ph.D. 1996

Ken Adams followed in 1997 with no less effort circumnavigating 1000+ km of pluvial Lake Lahontan shorelines to establish the isostatic rebound signal and, in so doing, becoming the go-to source of all things pluvial in the western Basin and Range and embark-

Ken Adams. Ph.D. 1997

ing on a career of research at the Desert Research Institute in Reno.

Chris (Sierra) Willoughby smiled his way in wonder mapping active faults along the Ruby Mountains to receive his M.S. degree also in 1997. He now uses his earth science background serving as the Supervisory Park Ranger in California's Joshua Tree National Park.

Chris 'Sierra' Willoughby. M.S. 1997

John Oswald's 1999 M.S. mapping of the Saline Valley fault was a work of art and remains the primary reference for the fault today. He established his own geotechnical consulting firm in the Humboldt area for many years and is now a senior engineering geologist for the California Geological Survey.

John Oswald. M.S. 1998

Arriving a tea-drinker and soon converted to coffee, Mark Stirling came to the Center from New Zealand, motivated to become an expert in seismic hazard analysis and take that knowledge back to apply at home. Amidst his passions for art and Burning Man, and with pushes from his wife Jayne, he did so with flying colors. He is currently Professor and Chair of Earthquake Science at the University of Otago in New Zealand.

Mark Stirling Ph.D. 1998

Richard Briggs and Senthil Kumar toiled together at the Center. Briggs' 1994 Ph.D. study of neotectonics and paleoseismology along the Pyramid Lake and Olinghouse fault systems quantified deformation in the Walker Lane near Reno. He bounced from that to a post-doctoral position at Cal Tech studying the great Sumatran earthquake of 2005 and onward to his current research postion in the Earthquake Hazards Program of the USGS in Golden, CO. There he continues to focus his efforts on the geology and seismotectonics of large earthquakes. More than a curiosity, the maps of his thesis quite recently gave Apple reason to relocate buildings housing their Cloud facility along interstate 80 near Wadsworth, NV.

Kumar conducted the first successful paleoseismological studies along the Himalayan Frontal Thrust of India and used that success to gain a prestigious faculty position at India's International Institute of Science in Bangalore. He resigned from that position for family reasons to pursue other interests, an unfortunate loss for Indian science.

Rich Briggs Ph.D. 2004 (l)
Senthil Kumar Ph.D. (2005) (r)

Robert Turner used publication of his M.S. 2006 study deciphering the slip rate and paleoearthquake history of the Honey Lake fault zone to launch a career in the consulting industry. He is now a software engineer at Fugro Land, USA. He designed the Centers first website, perhaps early on showing his true interest resided in computer software

Rob Turner M.S. 2006

With passions in music, photography, motocross, and wizardry in all applications GIS, Andrew Barron found the time to study the paleoseismology of the Osgood Mountains near Winnemucca and collect his M.S. in 2007. Today he continues to follow those appetites and serve as well as a consultant to various geotechnical firms across the west.

Andrew Barron M.S. 2007

Rich Koehler appeared at the Center after numerous years working as a geotechnical consultant and motivated to change directions toward research and education. His efforts leading to his 2009 Ph.D. were prodigious. Conducting paleoseismic and mapping studies along 10 mountain ranges spanning a 450 km long transect across central Nevada, he determined the rate at which the Basin and Range is widening. Alaska soon scooped him up to be their Senior Earthquake Geologist. Fortunately for us, he returned in 2015 to a faculty position in the Nevada Bureau of Mines that provides opportunity for continued research and classroom teaching.

Rich Koehler Ph.D.. 2009

Alexandra C. Sarmiento proved herself to be a smiling bundle of energy (and digger!) during her 2020 M.S. study of paleoseismology along the Carson and Antelope Ranges in the Walker Lane. Between sky dives she is today a Seismic Hazard Analyst for GeoPentech, Inc. and a Project Scientist at the UCLA B. John Garrick Institute for the Risk Sciences.

Alexandra 'Alex' Sarmiento M.S. 2010

With his mild manner and systematic approach, Stephen Angster completed his Ph.D. in 2018 being one of the first to use UAF technology in neotectonic studies and, at the same time, completing a geomorphic study showing the effects of Walker Lane deformation in northeast California. He moved quickly to offer his skill set to the Pacific Northwest, where he currently resides as a research scientist at the Seattle Field Office of the USGS Earthquake Science Center.

Stephen Angster Ph.D.. 2018

Using endurance skills acquired from track and field, Tabor Reedy traversed, mapped, flew drones, and applied cosmogenic dating techniques to quantify the paleoearthquake history and slip rates of faults bounding the Tobin and Stillwater mountain ranges in central Nevada, the same faults that produced the great 1954 Dixie Valley and Fairview Peak earthquakes. His 2018 M.S. was springboard to a career assessing the hazard of active faults. Today he is a geologist with the Bureau of Reclamation in Denver evaluating the hazard posed by active faults to dams in the western United States.

Tabor Reedy M.S. 2018

Sharing offices with Angster and Reedy, Ian K. Pierce used his time at CNS between Burning Man events and building art cars to clarify neotectonic processes in the central Walker Lane. Helping numerous of his fellow students along the way, he culminated things here with his Ph.D. in 2019. The thesis research led to a post-doctoral position at Oxford University in England from which he recently returned. At the moment he is conducting paleoseismic studies of dam sites for the Bureau of Reclamation.

Ian Pierce Ph.D. 2019

The Center has served in the tradition of Ryall, providing opportunity for students and postdoctoral researchers to follow their interests and gain experience toward later careers in societally relevant professional positions. It was a good ride.

1987 – 1998: Second Director of the Seismology Laboratory – James Brune

James Neil Brune was appointed the 2nd Director of the Lab in 1987[217], remaining so until stepping down some 11 years later in 1998, to contribute yet another dozen years of research until his retirement in 2011. His path to UNR makes for an interesting story. Located in the meagerly-populated alpine town of Markleeville about 60 miles south of Reno, Brune was raised in a primitive cabin lacking electricity or indoor plumbing by a father that prospected for gold and local jobs that were available[218]. He attended the 'new' Webster primary school for grades 1 to 8, of local interest because it was designed by the heralded Reno architect Frederic J. DeLonchamps. It is now officially anointed a California Point of Historical Interest (No. P762). Markleeville was too small to warrant a high school of its own, so Brune then began bussing his way[219] 20 miles each day to Douglas High School in Minden, Nevada, where his aptitudes consistently placed him on academic honor rolls[220,221], and there he and 30 classmates graduated in 1952[222]. The effort gained him acceptance to UNR, a chance to again frequent academic honor rolls[223,224], and matriculate with 23 of his peers in 1952 from the geological engineering program[225,226]. Columbia University in New York City recognized his potential and offered him their prestigious Eugene Higgens Fellowship[226] to attend graduate school. He accepted, moved east, came to study under the tutelage of preeminent seismologists of the time[227,228], and was granted his Ph.D. in 1961. For his novel thesis studies bearing on the propagation of seismic

Jim Brune. 2nd Director of Seismological Laboratory's (Mackay Miner 1987)

surface waves[229-231], he was a year later awarded the American Geophysical Union's first James B. Maclewane Award[24,232,233], now considered the highest honor bestowed on young scientists in fields of geophysics. During the ensuing years, he held professorships at Cal Tech and University of California, San Diego, wrote seminal papers linking seismogram observations to geological stresses that produce earthquakes, the spectra of shear waves[234], the use of fault slip rates as input to seismic hazard analysis[235], and the relationship of friction to heat along the San Andreas fault[236], earning him yet more accolades and honors[237]. So it was, with awards and honors in hand and an influencing body of research, the local-boy-made-good came back to Nevada after 35 years to lead the Seismology Lab.

The Lab brimmed with activity during the first years of Brune's tenure. Peppin and Vetter's analyses of the 1980 Mammoth earthquake sequence and regional stress patterns in the Great Basin[86,131,132,140] continued, as did Peppin's efforts to upgrade the Lab's digital data acquisition system[133]. Soon though, aspects of nuclear bomb discrimination and nuclear waste disposal were to dominate Lab activities.

NEVADA Seismological Laboratory

University of Nevada, Reno

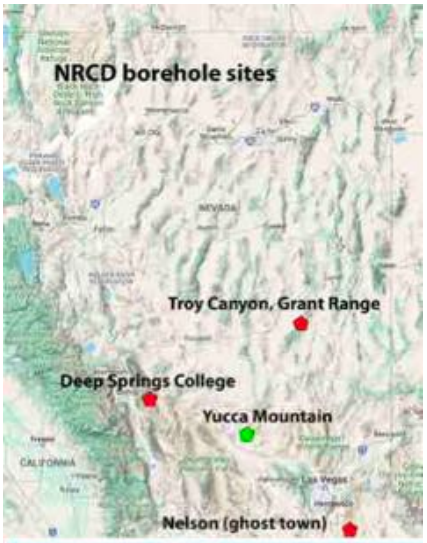
Members of Lab circa 1988. Standing from left: Stephen Horton, Bill Peppin, Chris Archer, Bill Walter, George Randall, Keith Priestley, Uta Vetter, John Anderson, Jim Brune, Austin Wilson, Wally Nicks. Kneeling from left: Raoul Castro, Diane DePolo, Martha Savae. Arturo Aburto.

NRDC project

The Nevada Test Site (NTS) was the largest U.S. source of controlled nuclear detonations upon Brune's arrival. The Soviet Union maintained an analogous site in what was the Kazakh region of the Soviet Union, the Kazakh Test Site (KTS). Development of a nuclear test ban treaty between the Soviets and U.S. were hindered and terminated by the Reagan administration in 1982, They cited concerns that methods of treaty verification were unreliable[238]. In May of 1986, the Academy of Sciences of the USSR entered into a 'seismic' agreement with representatives of the U.S. Natural Resources Defense Council (NRDC), a private environmental group[239]. It was agreed to establish three seismic stations manned jointly by U.S. and Soviet scientists at each of the tests sites, with the goal of perfecting techniques for verification of nuclear detonations or, more pointedly, demonstrate to governments of both countries that very small explosions could be detected by sensitive seismometers even at large distances from the source.

Support both financial and scientific from the U.S. government was welcome but deemed irrelevant to the agreement. On the U.S. side, the NRDC assumed the role of contractor, purchased the needed equipment, and invited seismologists from the University of Colorado, the Scripps Institution of Oceanography, and the University of Nevada to conduct the experiment. Keith Priestley was asked to lead the UNR effort. Brune, originally involved at Scripps, joined him upon becoming Director. With that, Priestley, Brune and other members of the Lab were soon installing seismic stations around the test site and in the Soviet Union[239]. Sensitive 3-component Geotech seismometers were placed in 100 m deep boreholes at each site. Seismic signals were digitized onsite with Reftek digitizers sent to satellite uplinks for transmission to sites of analysis. The resulting observations showed high-frequency signals could easily be detected at distances extending beyond 1000 km and seismic waves produced by nuclear blasts and earthquakes distinguished by their spectral characteristics. It was so shown with this civilian effort that distrust between the Soviets and U.S. governments based on unreliability in seismic verification was unwarranted. The project finished in 1989 and the Seismology Lab can rightfully claim an important role in the United Nations' subsequent adoption of Comprehensive Nuclear-Test-Ban Treaty in 1996, albeit the U.S. and several other nations have yet to ratify the treaty.

Keith Priestley and Jim Brune with fellow Russian and American scientists of the NRDC project.



NRDC project borehole sites. Will Honjas at Troy Canyon installation

Yucca Mountain project

A significant portion of Nevada's Nuclear Wastes Projects Office funding for studies of Yucca Mountain was in 1987 being channeled to the Seismology Lab[195]. This source of funding would contribute in following years to the appearance of many new faces about the lab and expansion of the seismic network, both spatially and technologically. The NRDC stations encompassed an analog seis-

YUCCA MOUNTAIN

Anti-nuke Nevadans tell U.S. to say no

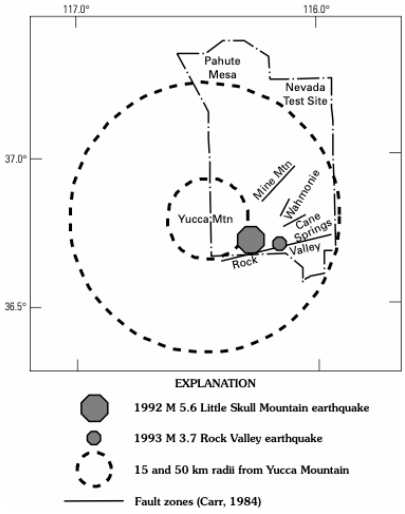
Nevada officials who oppose the proposed nuclear waste dump at Yucca Mountain are making a whistle-stop tour of the U.S. to tell people the nation is at risk if the dump plan is adopted.

Kansas and Missouri could see as much as 40 percent of the nation's spent fuel from nuclear reactors over the next 30 years, some Nevada officials said Tuesday in Kansas City. They oppose the dump proposed for Yucca Mountain, about 100 miles northwest of Las Vegas, and are touring cities along possible disposal routes to criticize the federal plan.

Such shipments would "unleash a Pandora's box of health and safety risks as well as social and economic impacts," said Bob Loux, executive director of the Nevada Nuclear Waste Project Office, a state agency fighting the proposed disposal site.

1993 Reno Gazzette Journal

mic network around Yucca Mountain that at the time was being funded by the DOE and operated by the USGS. Technical inadequacies of the USGS analog seismic network were becoming apparent to the DOE. The inadequacies were underscored with the occurrence of a moderate sized earthquake that occurred on the Test Site in June of 1992: the so-called Little Skull Mountain earthquake.



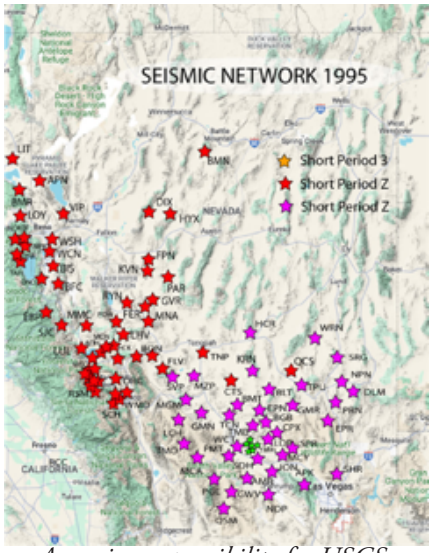
M5.8 Little Skull Mtn and M3.7 Rock Valley earthquake sequences within 15 km of Yucca Mountain (Smith et al., 2000)

The earthquake's seismic signals overwhelmed the telephone lines over which they were transmitted, and the USGS failed to satisfy the DOE and NRC's requirements for monitoring and calibration. The DOE then, frustrated with the situation, inquired if Jim Brune and the Seismology Lab would design and implement a state-of-the-art fully digital network at Yucca Mountain.

The contract offered would support the lab for 10 years at >$1.2 million per annum. Brune was familiar with the potential of digital technology for seismic networks from the NRDC project and his earlier work in California studying the 1972 San Fernando earthquake. That experience and having complete confidence that Wally Nicks could implement the task he took DOE up on the offer, to begin in 1993. The Lab was now receiving funds from both NWPO, an agency dead set against licensing the Yucca repository and DOE, the agency charged with licensing it.

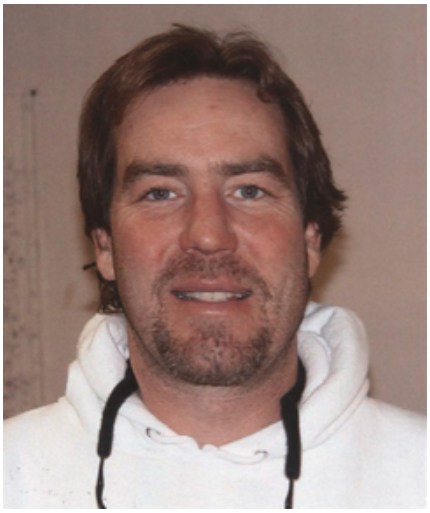
The seismic network – permanent components – major expansion

The demands of the DOE Yucca Mountain project swiftly led to major southward expansion of the Lab's seismic network. NWPOs desire and funding to provide oversight of the site characterization process first led in 1987 to the Seismology Lab telemetering 16 stations of the existing USGS network around Yucca mountain for co-recording in Reno[195]. DOE's request that UNR take over the entire USGS Yucca Mountain seismic network expanded UNR networks footprint yet more. This was the situation when John Torrisi (1993-2019) joined the Lab in 1993.



Assuming responsibility for USGS stations (purple) led to rapid southward expansion of Seismo Lab's recording responsibilities.

Torrisi arrived after twelve years installing seismic networks around the globe to monitor nuclear weapons testing with the Air Forces Technical Applications Center (AFTAC), the center charged with operating and maintaining the U.S. Atomic Energy Detection System. Torrisi began his time with the Lab living in Las Vegas full time because of the demands of the new Yucca Mountain contract. The transition from analog recording and transmission of seismic network signals to a digital process had already begun at AFTAC, so Torrisi would provide immediate technical experience for the Network's goal of developing a network where digital signals from seismometers were sent digitally over a communications network to Reno. His contributions to this task would prove herculean over the next 26 years until his retirement in 2019.



John Torrisi

The USGS Southern Nevada Seismic Network (SNSN) was largely composed of analog seismometers interspersed with a few digital stations. Seismic signals of the network were directed via phone line or radio links to a set of mountain top microwave towers and signals transmitted to Reno, all designed and installed under the guidance of Nicks and Wilson. Microwave links previously established for the Northern Nevada Seismic network and the NRDC project carried the analog seismic signals to Reno, where they were collected on a computer and digitized for analysis[133].

Torrisi's first actions included finding the Lab's 65 or so analog sites in the remote desert, getting them calibrated, and permitting an upcoming 50 plus sites for emplacement of digital seismometers and communication sites. It was a time before cell phones, handheld GPS, and internet commu-

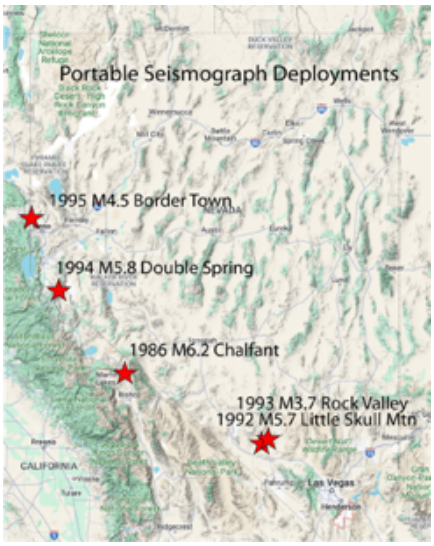
Microwave repeater sites at time of network expansion.

nications made such efforts simple. Aided only with rough sketches and markings on old topographic maps, the task took some 6 months. Because Torrisi had top secret security clearance while at AFTAC, it was relatively easy for him to acquire security clearance to access remote seismic stations on the test site. Such was not so for the Lab's Director and seismologists. Visits to remote seismic stations on the Test Site would invariably require they ask for John's accompaniment.

The seismic network – portable components – aftershock deployments

The Lab's portable seismometers displayed their utility in aftershock studies of numerous moderate earthquakes during and after Brune's transition to Director. The M6.3 Chalfant earthquake occurred in July 1986, making for a particularly exciting time for students and staff at the Lab. Prompted by the occurrence lesser-sized earthquakes in the week before, students and staff were tasked with deploying portable digital event recorders in the area, putting them in place to not just record but also experience the ground shaking first hand [142,240]. The earthquake served to move ground near Bishop California in a strike-slip fashion similar to that observed on the famous San Andreas fault far to the west.

The year 1992 brought the June 29 M5.7 Little Skull Mountain earthquake that occurred on the Test Site, less than 10 miles from the proposed repository[241]. Interest was of course high because of its location, and underscored because it followed only a day later than a much larger event just ~250 kms to the south in the Mojave Desert, the June 28, 1992 M7.3 Landers earthquake. The Lab's deployment of portable instruments recorded nearly 4000 aftershocks, more than sufficient to show slip occurred on a fault confined to depths of about 5-12 km and 10 km length that produced a northwest extension of the underlying crust. The earthquake certainly lent urgency to the Lab's nascent plans to upgrade the USGS's analog network to digital capabilities.



Moderate earthquakes studied with deployments of portable seismometers.

On May 31, 1993, almost exactly a year after the Little Skull Mountain earthquake, another sequence of earthquakes occurred on the Test Site, just a few km to the east of the Little Skull Mountain earthquake, on the Rock Valley fault zone. Interest in these quakes was again large because of their location near the proposed Yucca Mountain repository. Even though the largest earthquake in the sequence was a small M3.7, their occurrence along a previously mapped Rock Valley fault zone reinforced others' conclusion that the fault was active and capable of producing a M7.0 earthquake or larger. UNR deployment of a portable instrument over the mainshock region provided the most convincing evidence of the sequences' most unusual characteristic that all events occurred at depths less than 3 km. So shallow that today efforts are being made to drill down to the hypocenter of the largest shock, set off a blast, and record for comparisons the generated seismic waves to those recorded in 1993. It will be the Seismo Lab's responsibility to record it.

Deployments of portable instruments after the 1994 M5.8 Double Spring and 1995 M4.5 Bordertown earthquakes just to the south of Carson City and north of Reno, respectively, made possible graduate student Gene Ichinose's highly accurate 3-d depictions and source characterizations of faulting responsible for the earthquakes.

Network Operations

The demands of managing the network grew with its rapid expansion, as did opportunities for research. David von Seggern and Ken Smith soon arrived to meet that demand.

David von Seggern (1992-2005). With the expanding demands of Yucca Mountain Project it was recognized that the Lab needed someone to oversee the operational aspects of seismic monitoring, handle adminis-

David Von Seggern

trative aspects of the DOE contract, and report on seismic observations relevant to the site's characterization. Von Seggern joined us as the Network Manager for Yucca Mountain with a Ph.D. from Pennsylvania State University and 15 years of experience as a research seismologist studying underground nuclear tests at Teledyne Geotech and computer program development to support 3-D imaging for oil and gas exploration for Phillips Petroleum. Managing the network can only be described as an arduous task, particularly in light of DOE's requirements of 'Quality Assurance'. Von Seggern, at least from outwards appearances, handled the demands with patience and aplomb, while at the same time remarkably finding the time to lend his expertise and author with colleagues some 15 papers during his tenure, and serve as Treasurer of the Seismological Society of America (1998-2006) where he was instrumental in evolving the Society's Bulletin to electronic publication. He transitioned to a well-earned emeritus status in 2005.

Ken Smith (1992-2023). After a half-dozen years conducting research for his 1991 Ph.D., under the tutelage of Keith Priestley, and personally experiencing the M 6.4 1986 Chalfant Valley earthquake while deploying portable instruments in the epicentral area, Ken Smith was well acquainted with earthquakes and the lab when he returned to UNR in 1992 to mount an aftershock response to the Little Skull Mountain earthquake. With time his roles evolved and expanded to include Coordinator of Projects for the Yucca Mountain network, head of Nevada's seismic network operations to the north, Research Associate Professor and, at times, Associate Director of the Lab. Amidst the constant tugs and pulls associated with managing network operations, his energies found time to support and guide several students to their Ph.D. degrees[242-244], and be an author on nearly 50 publications most frequently addressing the spatio-temporal and geometrical characteristics of seismicity associated with moderate and large earthquakes along the Walker Lane[245-248], at Yucca Mountain, and beneath Lake Tahoe[249]. Though Smith after 21 years at the lab is now emeritus, he remains a frequent presence in the hallways, always anxious to impart advice and perspective on local earthquakes and the machinations of the seismic network.

Ken Smith

While Smith and VonSeggern were managing the overall operations, the need still remained to do the quiet work of measuring the continually arriving seismic signals, locate the earthquakes producing them, and construct a catalog to document their occurrence in a form suitable for research. It was Diane Depolo, Arturo Aburto, and Tom Rennie that inherited the task from their predecessors Gloria Smith and Flori Ryall in the record reading room.

Diane Depolo received her M.S. degree with the guidance of Keith Priestley in 1989 and was hired as the Lab's network seismologist that same year. Her employment in the record reading room actually dates back to 1984 while she was a student working with Ryall and Smith. It was natural that she take the reigns after her degree and their departures. For 25 years she was the face and personality of the record reading room!, until she moved on in 2015. That's a lot of earthquakes. None around the Lab then will forget her ever present positivity nor their birthday cookies.

Diane Depolo

Arturo Aburto came to the Lab in 1985 after earning an M.S. degree from Stanford University. His quiet and steady assistance in the record reading room until 2007 provided continuity to operations for 22 years. Word of his death in 2023 reminded many of his always kind and mellow demeanor about the Lab.

Arturo Aburto

Tom Rennie graduated with his B.S. degree from UNR, decided it best for him not to pursue a graduate degree with Wesnousky, and began working with Diane DePolo in the record reading room in 1992. Still with us today, more than 30 years later, it is he that provides a continuity to operations in the record reading room. With the revolving aid of many

graduate students, Rennie collects the information needed to locate all the earthquakes recorded by the Lab's seismometers.

Tom Rennie

Charlotte Middlebrook for a brief period (1995-1997) served as Computer Systems Manager for the Lab.

Lab Research and Investigators

The NRDC Kazakh project was immediately aided by post-doctoral researcher Joan Gomberg and visiting scholar Paul Bodin. Gomberg had just completed her 1986 Ph.D. at UCSD and transferred to Reno along with Brune. Paul Bodin, who had been a field geologist and seismological field technician at IGPP, came with Joan and Jim from San Diego. Paul was a Ph.D. student of Brune and Slemmons, and worked on scaling relationships of strike-slip earthquakes. Gomberg and Bodin applied cross-spectral methods to calibrate the Kazakh seismic system during their 1998-1998 stay in Reno. The Lab was for each but a brief stop along the way to most notable careers in seismology. Gomberg, now a Research Fellow of the AGU, remains a research geophysicist at the USGS. Bodin is now an emeritus research professor at the University of Washington where he managed the Pacific Northwest Seismic Network.

Joan Gomberg

Paul Bodin

George E. Randall spent 1987-1989 at the Lab as a post-doctoral researcher. Randall arrived to work with Keith Priestley, also on the NRDC-Kazakh project. He employed then relatively new teleseismic receiver analysis to examine crustal structure beneath the Soviet test site[250,251]. His studies at UNR led to a career conducting similar studies at Los Alamos National Lab from where he recently retired.

Upon his arrival to UNR Brune immediately advertised in EOS for a seismologist to run the Lab's seismic network, then funded largely on a USGS contract, and wasted no time in recruiting Martha Savage for the position. Savage's 1987 Ph.D. at the University of Wisconsin, Madison concerning microseismicity in Hawaii made her a natural fit and she remained at the Lab until 1994. While supervising operations and managing contracts of the then 55 station seismic network, she further supported the seismic network, her research, graduate students, and others on the staff with successful proposals to the National Science Foundation and United States Geological Survey. Observations at the heart of much of her research were the separation of seismic waves into components that travel at slightly different speeds ('shear-wave splitting' in seismologists' vernacular). The disparities when observed are correlated to rock fabric and where detected provide clues to the movements of the earth's tectonic plates. Regrettably for the Lab, but great for her, and after authoring some 20 papers, she left her Associate Research Professor position here and moved to Victoria University in Wellington, New Zealand where she remains a professor today. She is now a fellow to both the American Geophysical Union and

Martha Savage

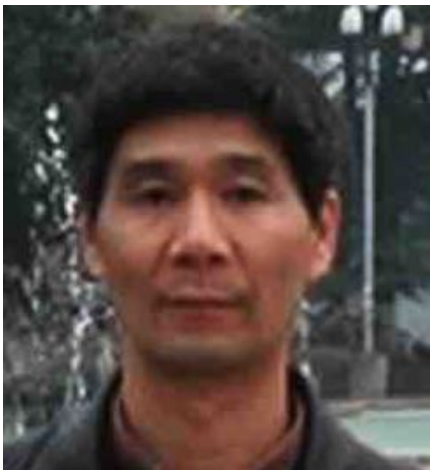
Royal Society of New Zealand and recent recipient of New Zealand Association of Scientists' Marsden Medal for a lifetime of outstanding service to the cause or profession of science.

UNR provided Brune opportunity to hire a new tenure track position to fill upon his arrival. That was John G. Anderson in 1988. Ander-

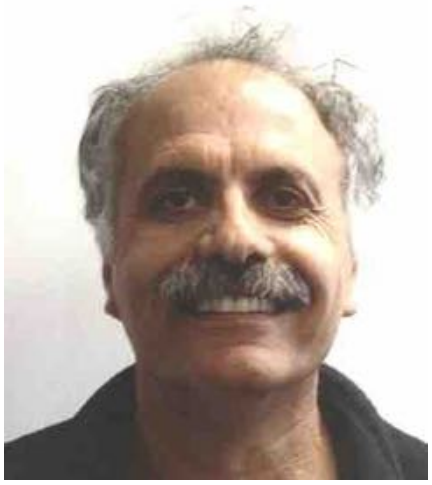
John Anderson

son, like Brune, gained his Ph.D. in Geophysics from Columbia University. Moreover, between graduation and arrival at UNR, Anderson was a research geophysicist and engineer at the University of California at San Diego, alongside Brune. Anderson had quickly established himself as one of the world's experts in strong ground motion seismology, published prolifically, and offered to the seismological community a seminal and still oft-cited paper showing that the spectral shape of seismically induced ground motions may be characterized by a single decay parameter called kappa. It was natural that Brune recruited Anderson to fill the new position. Anderson's focus during these first years at the Lab was on his National Science Foundation project collecting and analyzing ground motion data being gathered with a network designed for purposes of earthquake prediction in the Guerrero Seismic Gap in Mexico[252-254]. Anderson was later to become Director of the Lab, recently retiring in 2022.

Tall and mild mannered Yuehua Zeng came to the lab in 1991, soon after his Ph.D. under the tutelage of K. Aki at the University of Southern California. Earthquake source models, wave propagation, strong ground motion, site effects, seismic hazard estimation, and stress-triggering of earthquakes were among the many interests he pursued during an incredibly productive 10 years as a Research Associate Professor, often working in tandem with Anderson and Brune. He left a legacy of some 30 professional publications before he accepted in 2005 a position as research geophysicist at the U. S. Geological Survey in Golden, CO. He remains there today as a principal player in the development and evaluation of the nations National Seismic Hazard Maps.



Yuehua Zeng



Rasool Anooshehpoor

Abdelrasool (Rassool) Anooshehpoor received his Ph.D. in physics from the University of California, San Diego. His thesis entailed construction of a foam rubber model to examine the effects of topography on the strong ground motions that impaired Pacoima dam during the 1972 San Fernando earthquake in California. Brune was on his thesis committee. It seems natural that in 1992 he arrived at the Seismo Lab for a long career using similar techniques with Brune to study the heat and seismic radiation produced by fault slip[255], dynamics of slip on earthquake fault plains[256], and constraints on ground motions preserved in precariously balanced rocks[257]. His smile and passion for running was missed immediately around the lab upon his departure in 2011 when move on to serve at the Nuclear Regulatory Commission in Washington from which he recently retired.

Anne Sheehan received her Ph.D. from MIT in 1991. The next year she spent here conducting studies related to the the Yucca Mountain Project, before moving on to her current position as a professor educating students and addressing a dizzying array of problems in earthquake seismology, tsunami science, active tectonics, and geophysical imaging of the earth's subsurface at the University of Colorado Boulder. Her collaborations with Martha Savage and Ken Smith led to new characterizations of the 1992 Little Skull Mountain earthquake sequence and shear-wave velocity structure across the Basin and Range.

Anne Sheehan

Upon completing her 1992 Ph.D. at USC studying with Dr. K. Aki and a brief stop with the strong ground motion program of the California Geological Survey, Feng Su accepted her research associate professor position at the Lab in 1993. With her expertise in earthquake source physics, wave propagation, and site amplification of ground motions she collaborated largely with John Anderson to publish

Feng Su

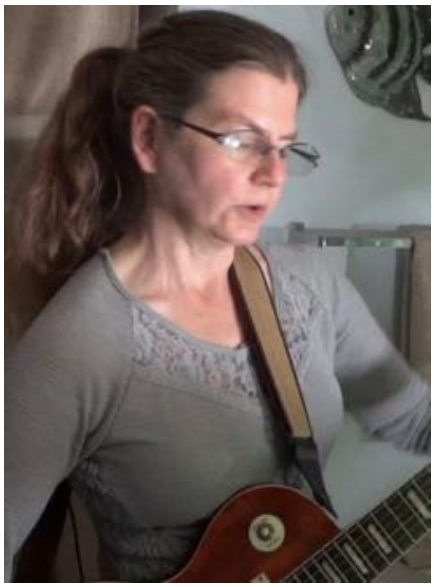
significant articles addressing physical factors that control earthquake strong ground motions[258-260]. Feng Su's productivity and effervescent smile left with her family to Colorado in 2005. There she eventually took the position of senior research geophysicist at the Bureau of Reclamation, from which she just recently retired after 16 years of service.

Glenn Biasi employed P-wave tomography to examine crustal structure and introduced statistical techniques to quantitatively refine calibrated C-14 distributions reported in paleoearthquake studies on his way to a 1994 Ph.D. at the University of Oregon. That same year he joined the Lab as a post-doctoral researcher on the Yucca Mountain project. He continued to expand and deploy methods originating with his thesis research, contributing than 40 papers during his tenure addressing myriad topical issues, among them the time-dependence of seismic hazard on major faults[261], critical evaluation of the nation's seismic hazard maps for site-specific applications (UCERF)[262], controls on rupture propagation posed by fault geometry[263,264], and deep crustal structure beneath the Nevada Test Site. After evolving over his nearly 25 years from post-doc to research associate professor, Biasi retired from UNR and moved to the USGS office in Pasadena where he today remains

Glenn Biasi

contributing to development of the nation's nascent Earthquake Early Warning System. His grasp and willingness to share the nuances of probability calculations was special and now missed at the lab.

The Seismology Lab was a brief post-doctoral stop along the way for Susanna Gross to a long career at University of Colorado and UNAVCO, the non-profit university governed consortium to facilitate research and education in geodesy, from where she just recently retired in 2020. In her brief time here between 1994-1995 she made a clever contribution to nuclear test discrimination, applying her expertise in earthquake statistics to show aftershock sequences of nuclear explosions decay more rapidly and show a form distinct from those produced by most earthquakes.



Susanna Gross

Along with Biasi and Gross, Steven Jaume was one of 3 post-docs first hired on the DOE funded Yucca Mountain project. Indeed, Steve shared offices with each during his time here. Focusing attention on the Yucca Mountain Project his first year, he then took over upon Marth Savage's departure managing the Western Great Basin seismic network. There were some cutbacks in both DOE and USGS funding at the time that led to Jaume's exit to the University of Queensland, Australia to conduct earthquake fault physics and geological site response work, and then on to his current faculty position at the College of Charleston in South Carolina.

Steven Jaume

John Louie (1994-2023). John Louie was on the faculty of Penn State in 1993, after receiving his Ph.D. from Cal Tech in 1987. The geological engineering department at UNR was lacking anybody to teach geophysical methods related to establishing shallow structural and soil conditions at engineering sites. The Department of Geological Sciences and Engineering, the Mackay School of Mines administration, and the Seismo Lab joined forces to create a new position to fill the void, split between geology and seismology. I had known Louie when a graduate student. Familiar with his interests and capabilities in imaging and characterizing subsurface struc-

John Louie

tures, I suggested to him he apply. Long story short, he was hired. Along with Anderson and Brune, there were now three tenure track seismologists with appointments in the Seismology Lab. Mentoring a consistent stream of undergraduates in the Refraction Microtremor (ReMi), seismic reflection, and gravimetric methods to analyse the shallow subsurface, he likewise found time during his 29 years to serve as principal advisor to 29 students seeking graduate degrees, eight of those obtaining advanced Ph.D.'s, and all today filling significant positions in education, government research labs, and the private geotechnical community. Quite the career. John with his new emeritus position continues to remain in close contact with the Lab.

Brune steps down.

Brune stepped down as Director in 1998 to focus on research until his retirement in 2011. With the serendipity of politics and scientific acumen he guided the Lab to exceptional growth. His research brought forth new observations and ideas that guided the research of students and investigators througout the Lab. Seismologists will recall his collaborations with Rasool Anooshehpoor using comically large room-filling foam models to examine the dynamic processes underlying earthquake rupture, in so doing providing possible explanations for many of the most perplexing problems in earthquake science[255]. His early walks on Yucca Mountain introduced PBR's to the seismological community, not as in the abbreviation for Pabst Blue Ribbon beer used by youth of the day, but rather as shorthand for precariously balanced rocks. Those PBRs perched delicately on the land surface for millennia now mark areas in earthquake country where earthquake shaking is particularly infrequent[265]. These topics and related lines of investigation remain relevant today. Brune is now emeritus, still with an office, and still publishing papers[266].

1998 – 2009: Third Director of the Seismological Laboratory – John Anderson

Anderson had in preceding years continued to publish prolifically, lead numerous students to graduate degrees, acquire research funds to support them, and become well-recognized for his contributions to the seismological community. He too had served on occasion as Acting Director in preceding years and was thus well acquainted with the administrative aspects of the lab. Brune had stepped down but not retired and the University was not inclined to create a new position in the Lab. So with the growing influence of his science and experience in lab operations it was natural that Anderson evolved to be the Lab's 3rd director.

John G. Anderson
3rd Director of Seismo Lab

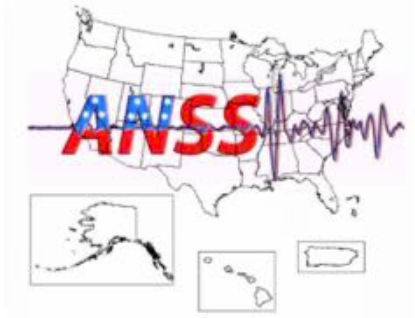
Graduate Degrees 1987-1998 in Seismology.

(1989) M.S. **Lat, C.N**. Seismicity and tectonics of the Garfield Hills area Nevada. 154 (Brune).
(1989) M.S. **Martinelli (de Polo), D.M**. Geophysical investigations of the northern Sierra Nevada-Basin and Range boundary, west-central Nevada and east-central California. 172 (Priestley).
(1990) M.S. **Zhang, J.** Later aftershocks of the March 2, 1987 Edgecumbe, New Zealand, earthquake. 53 (Anderson).
(1991) Ph.D. **Castro Escamilla, R.R**. Source functions, site response and spectral attenuation in the Guerrero, Mexico subduction zone. 127 (Anderson).
(1991) Ph.D. **Smith, K.D.** Earthquake processes: Seismotectonics of the 1984 Round Valley, California, earthquake sequence and radiated energy and the seismic spectrum. 132 pp. (Priestley).
(1991) Ph.D. **Walter, W.R**. High frequency seismic source spectra from earthquakes and explosions. 135 (Priestley).
(1992) Ph.D. **Horton, S.P.** Waveform inversion for the source characteristics of earthquakes. 129 (Anderson).
(1993) M.S. **Honjas, W.** Results of post and pre-stack migrations imaging the Hosgri Fault, offshore Santa Maria Basin, California. 118 (Louie).
(1994) Ph.D. **Pullammanappallil, S.K.** Nonlinear optimization to estimate velocities and image reflectors from multi-offset seismic data. 137 (Louie).
(1994) Ph.D. **Yu, G.** Some aspects of earthquake seismology: Slip partitioning along major convergent plate boundaries; composite source model for estimation of strong motion; and nonlinear soil response modeling. 151 (Anderson & Wesnousky).
(1996) Ph.D. **Ozalaybey, S**. Seismic velocity structure in the western United States from shear-wave splitting and receiver functions of teleseismic earthquakes. 171 (Savage).
(1997) Ph.D. **Chavez-Perez, S**. Enhanced imaging of fault zones in southern California from seismic reflection studies. 130 (Louie).
(1997) M.S. **Hasting, M.A**. Indian Wells Valley earthquakes, August 1995 through June 1996: Their relocation and implication for strain transfer in the eastern California shear zone. 241 (Anderson).
(1997) M.S. **Kanbur, Z.** Seismic reflection study of Upheaval Dome, Canyonlands National Park, Utah. 30 (Louie).
(1997) M.S. **Lee, Y.** Evaluation of attenuation relations in the southern California region. 166 (Anderson).
(1997) M.S. **Mela, K.** Interpretation of stochastic hydrogeologic properties from seismic data. 83 (Louie).
(1998) Ph.D. **Asad, A.M.** Linearized and nonlinear travel time tomography for upper crustal velocity structure of the western Great Basin. 150 (Louie).
(1998) Ph.D. **dePolo, C.M**. A reconnaissance technique for estimating the slip rates of normal-slip faults in the Great Basin, and application to faults in Nevada, United States of America. 381 (Anderson).

The seismic network – permanent components

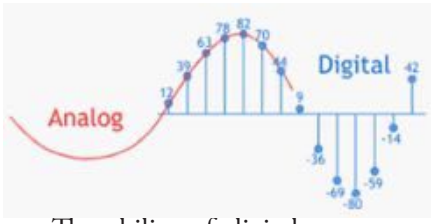
ANSS

Congress in 2000 authorized an Advanced National Seismic System (ANSS), a collaboration of the U. S. Geological Survey (USGS) and regional, state, and academic partners charged with monitoring seismicity across the United States[267]. The authorization, long in planning, was spurred by new funds to earthquake science in response to the famous World Series earthquake, or more formally, the M7 Loma Prieta earthquake of October 17, 1989. The Lab and seismic networks across the country had since Ryall's time received support from the USGS. The support though was more frequently through contracts and grants, annual and sometimes multi-year, focused on research rather than network operations. As an element of the ANSS, the Lab could now expect a steadier source of funding to support lab operations.



Evolution to Digital

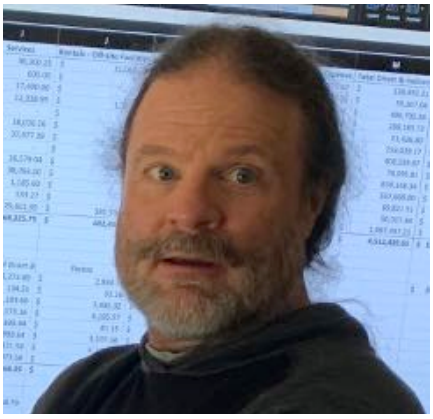
Seismology by now was seeing a rapid shift from primarily analog to digital collection of seismic signals[268,269]. Digital recording instruments offered significant advantages over analog stations. They were more sensitive to the smallest ground motions, capable of accurately recording the larger ground motions, and digital recording allowed for immediate analysis with computers becoming increasingly available to seismologists. A broader range of frequencies could be monitored by the appropriately designed seismometer as well.



The ability of digital computers to communicate with each other was pioneered by the military's Advanced Research Projects Agency (ARPA) during the 1970s and into the 80s. The achievement was accomplished with development of a Transmission Control Protocol and Internet Protocol (TCP/IP)[270] allowing ARPAnet, a network of computers across the U.S. to link and converse. Communication occurs with information at one computer being broken down into small packets, sent over many different routes at the same time, and then reassembled at the receiving computer. TCP is the component that collects and reassembles the packets of data, and IP is that for making sure the packets are sent to the right destination (address). ARPAnet, largely motivated to allow scientists access to the few number of powerful research computers then available to them, evolved to become the World Wide Web (WWW)[271], which relies on this same protocol.

The Lab's network was constructed primarily of short-period analog seismometers when USGS's SCSN network operations were reassigned to the Seismology Lab. Seismic signals too were transmitted analog via microwave towers to Reno. The newly assumed SCSN network included a number of RefTek digital seismometers. The goal soon was to switch out all analog stations and replace them with digital models. It was in this environment that the dreams, desires and obligations of the Lab turned to evolving the seismic network into a fully digital communications system using TCP/IP technology. This was to be a long process.

Glenn Biasi and others in the lab, recognizing they could use some assistance in the effort, began interviewing in 2002 to fill a new position. In the door walked this clean cut Canadian in a nice blue suit with more than a dozen years experience in the telecommunications industry[272]. That was David Slater. Still with the Lab today, hair a bit longer and grayer, he has been instrumental in transitioning the network to the TCP/IP standard. Providing complementary elements of computer programming required for the task was Carol Freinkel (2006-2010).

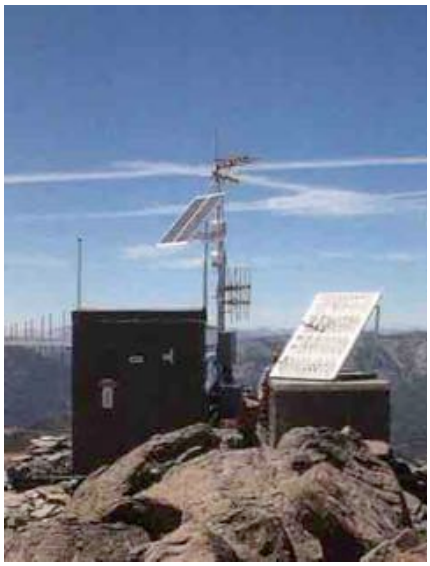


David Slater

Carol Freinkel

The transition did not simply entail implementing changes in computers and software at the Lab. Hardware on all of the mountain top microwave sites required conversion. In many cases new sites on other mountaintops were created to gather and transmit the expanded network's seismic signals. The task was initially accomplished by Wally Nicks, Austin

Wilson, and John Torrisi. Nicks and Wilson retired in 2006 and 2008, respectively, leaving the daunting task to John Torrisi. Torrisi, now filling Nicks shoes, filled their voids with the hire of Development Technicians Nathan Edwards (2006-2011) and Ryan Presser (2008-2018), and these two with Torrisi accomplished the heavy lifting for years to come. Edwards after five years moved back to his native South Dakota where he now manages South Dakota State University's Mesonet, a statewide communications network to convey weather data to the public, emergency management agencies, and scientists. Presser after 10 years of service returned home to California to take a position with the USGS where he his is now the Acting Network Operations Manager. These fellows and Slater set the foundation for development of the digital communications network that is operated by the Lab today.



Installation and modifications of communications stations is challenging prospect on remote mountaintops of Nevada.

Nathan Edwards

Ryan Presser

The seismic network – portable components

A couple of moderate sized earthquakes in this time gained the attention of the public and spurred deployment of the Lab's portable instruments. The M5.0 Mogul earthquake gained particular attention because of its proximity to the Reno urban area and being located directly beneath the Director Anderson's home. While attention was considerable, damages from the earthquake were minimal. Portable instruments proved critical to defining the geometry and stresses about the causative earthquake fault[273,274], and the Ph.D. studies of Christine Ruhl.[243] The rural M6 Wells earthquake near Elko was the largest in the Basin and Range since the M7.3 1983 Borah Peak in Idaho, causing some significant damage, and similarly gaining the attention of a portable deployment. Other than that, the earth beneath Nevada was relatively quiet while Anderson was Director.

Network and Lab operations

Diane DePolo and Tom Rennie remained the pillars of record reading room activities. Administrating grants and travel during Anderson's stint as director were Earl 'Mel' Holzgrafe, Pam Love, Lori McClelland, and Erik Williams. Mel Holzgrafe died suddenly in 2008. Love left the University at about that same time. Rumors suggest Love, an artist at heart, has moved herself to the sunny environs of Baja, California. Lori Mclellan and Erik Williams divided their responisbilities between the needs of the Yucca Mountain project and the northern Nevada seismic network. Each continued long enough before retiring to

Mel Holgrafe

provide continuity in transitioning to a new Director upon Anderson stepping down.

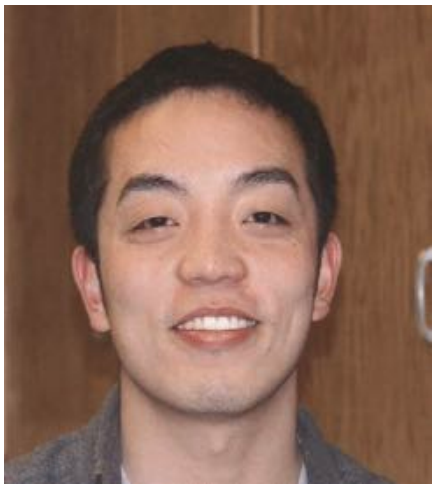
Pam Love

Lori McClelland

Yuichiro Miyata joined the Lab in 2004 to fill a new role of GIS analyst. Miyata completed in 2003 his BS in geography at UNR. He brought his talents in in the relatively young and rapidly evolving field of GIS to the Lab the following year. The young man wasted no time impressing all with his use of GIS to construct unprecedentedly beautiful maps of seismic data, for illustration and research by investigators in the lab. Some still grace the hallways here 15 years after his departure. Today he is a senior GIS analyst for PacifiCorp in Portland, Oregon.

Lab Research and Investigators

The Lab's activities continued to be dominated by the Yucca Mountain project, supplemented by various grants from the National Science Foundation and United States Geological Survey. Anderson, Brune, and Louie remained as the 3 academic faculty with appointments in the Lab. Many of the research staff arriving during Brune's tenure had already departed. Remaining were David von Seggern, Ken Smith, Rasool Anooshepoor, Glenn Biasi, and Feng Su. Time and space is insufficient to recount the research of each in this short history. Suffice it to say, it was robust. More than 10 papers a year authored by faculty and graduate students were leaving the Lab for publication in professional journals.



Yui Miyata

Ileana Tibuleac

Ileana Tibuleac provided a new face and additional directions of research in the Lab upon her arrival in 2005. With a Ph.D. from Southern Methodist University granted in 2000 under the guidance of Eugene Herrin, an expert in bomb discrimination techniques, a subsequent post-doc at Princeton University with Tony Dahlen, and time at the U.S. Air Force Research Laboratory, Tibuleac joined the Lab as an Assistant Research Professor. Her healthy record of publications, supported by the National Science Foundation and the Air Force, record her use of ambient noise to better locate and earthquakes and define crustal structure, and study of the M5.0 Mogul earthquake in Reno[275-277]. After leaving the Lab in 2016, she today continues her research in Florida with the Air Force Technical Applications Center.

Matt Purvance (2006-2010) completed his Ph.D. in the Seismo Lab in 2005 numerically investigating the physics of precariously balanced rocks. He stayed on until 2010 as Assistant Research Professor furthering that line of research until choosing to move on. He is today happily ensconced in the Sierra Nevada and a software engineer with the ITASC Consulting Group, Inc.

Matt Purvance

NEVADA Seismological Laboratory

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Graduate Degrees 1999-2009 in Seismology

(1999) M.S. **Shields, G**. Source parameter investigation of the 1993 Rock Valley earthquake sequence. 59 (Brune).
(2000) Ph.D. **Ichinose, G.A**. Seismicity and stress transfer studies in eastern California and Nevada: Implications for earthquake sources and tectonics. 357 (Anderson).
(2001) Ph.D. **Abbott, R.E**. Geophysical constraints on seismic hazard and tectonics in the western Basin and Range. 135 (Louie).
(2005) Ph.D. **Purvance, M.D.** Overturning of slender blocks: Numerical investigation and application to precariously balanced rocks in southern California. 247 (Brune, J.).
(2007) M.S. **Heimgartner, M.N.** The geophysical structure of the Sierra Nevada crustal root. 51 (Louie).
(2007) Ph.D. **Pancha, A.** Seismic hazards in the Basin and Range province, United States. 382 (Anderson).
(2007) Ph.D. **Pei, D.** Modeling and inversion of dispersion curves of surface waves in shallow site investigations. 182 (Louie?).
(2007) Ph.D. **Scott, J.B.** Seismic noise in the shallow subsurface: Methods for using it in earthquake hazard assessment. 159 (Louie).
(2008) M.S. **Clark, M.** A hydrogeologic and geophysical investigation of a fault as a groundwater flow barrier in Reno, Nevada. 90 (Louie).

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2010– 2023: Fourth Director of the Seismological Laboratory – Graham Kent

Anderson, after 11 years of service, decided in 2009 to step down from overseeing the lab and focus on his research. Jim Brune had then signed papers to retire in 2011. With knowledge of the impending retirement and vacancy of this position, the University granted the Lab permission to seek a new one. The new Director would be the first new appointment to the academic faculty of the Seismo Lab since the hire of John Louie more than 25 years prior. A search was started. Advertisements were placed. Candidates were interviewed. And thereafter the Seismo Lab faculty asked Graham Kent if he would serve as Director. He said yes, and that's how the fellow oft to be seen in summer with deck shoes, polo shirts, shorts and a tie when needed became the Lab's leader. Kent received his Ph.D. from Scripps Institution of Oceanography in San Diego in 1992, followed with 4 years of research at Woods Hole Oceanographic Institute, then returned to UC San Diego as a Research Geophysicist and Director of their Visualization Center until coming to Reno.

The seismic network – permanent components

Politics of the atom again raises its head

President George W. Bush in 2002 had approved the DOE's plan to store nuclear waste in Nevada. Thereafter DOE considered site characterization largely complete, studies on the test site diminished, and by June 2008 tendered a license application to open the facility. Political opposition to the license, always signifcant, reached a crescendo with the election of Barrack Obama to the White House in September of that same year. Obama had campaigned with the promise to stop the Yucca repository. By March of 2009 Obama's Secretary of Energy pulled the license application, announced plans to terminate the program, and activities at the site for the most part ceased in 2010. As a result, DOE's funding for the Lab's network progressively lessened and ultimately ceased in the years leading up to Kent's arrival. A substantial amount of support for operations of the network was now lost. Support that had reached to millions of dollars a year was now effectively zero and network support now largely limited to the ANSS program. A creative atmosphere was needed to regain that support from other sources.

Graham Kent, 4rth Director

Obama to zero out Yucca Mountain funding, pull license

By Lisa Mascaro

Published Sunday, Jan. 31, 2010 | 11:50 a.m.
Updated Monday, Feb. 1, 2010 | 9:22 a.m.

WASHINGTON - President Barack Obama plans to zero out funding for Yucca Mountain and "take steps" to withdraw the project's pending license application, according to a preview of the 2011 budget that will be announced Monday.

The president's intention to pull the license application -- a promise he made while campaigning in Nevada -- would be one of the most critical moves yet in stopping the proposed nuclear waste dump in Nevada.

Senate Majority Leader Harry Reid, who has been in ongoing talks with Obama over the dump, called the development "great news."

YUCCA MOUNTAIN

Wally's Licenses

The Lab's expansion of wireless telemetry to the Nevada Test Site, upon assuming the USGS's Yucca Mountain-SNSN network, required acquisition of Federal Communication Commission licenses for mountain top sites needed to convey seismic signals northward to Reno. Wally Nicks had for this purpose secured licenses for the Seismology Lab from the FCC

THE NEW YORK TIMES, WEDNESDAY, MARCH 19, 2008

Auction of Wireless Spectrum Brings U.S. $19 Billion

By STEPHEN LABATON

WASHINGTON — The government announced on Tuesday that it had closed the most lucrative government auction in history as wireless companies bid more than $19 billion for the rights to radio spectrum licenses.

In the coming days, the Federal Communications Commission is expected to publish a list of the winning companies. The major participants included AT&T, Verizon and Google, although many experts said they did not expect Google would bid much more than the minimum reserve price of $4 billion for one of the more attractive groups of licenses.

The spectrum licenses are being surrendered to the government by broadcasters as they complete their conversion to digital television by early next year. The licenses are coveted because they will provide the winners with access to some of the best remaining spectrum — enabling them to send signals farther from a cell tower with far less power, through dense walls in cities and over wider territories in rural areas that are now underserved.

At the same time, the major industry players are preparing for the continuation of an explosive surge in consumer interest in wireless devices offering high-speed Internet. That consumer demand fueled the auction.

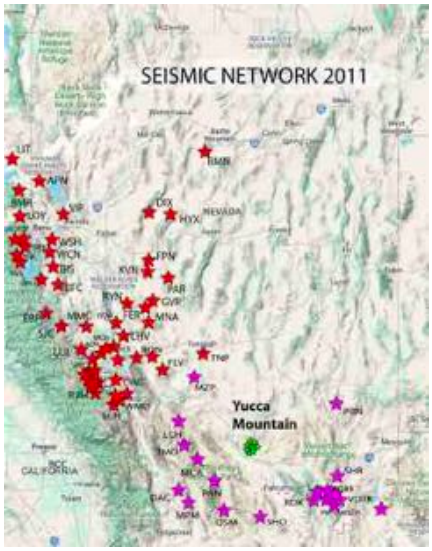
While Google was not expected to post a winning bid, it has already achieved an important victory by influencing the auction rules. The commission forced the major telephone companies to open their wireless networks to a broader array of telephone equipment and Internet applications. It remains to be seen whether a variety of technical and regulatory issues can be resolved to make the promise of more open networks a reality.

In a telephone conference call with reporters, Kevin J. Martin, the chairman of the commission, appeared delighted that the auction was the largest in government history and would yield

for two designated frequencies, 2.1 GHz in northern Nevada and 1.7 Ghz around the test site. The modern generation will recognize that these frequencies fall within the spectral bands first used by cell phones (e.g. 2G). The FCC since 1994 had conducted auctions of licenses for electromagnetic spectrum used for wireless and broadcast services. The frequencies dedicated to the Lab were to come up for auction in 2008. The FCC thus rescinded Wally's licenses, with the proviso that they would reimburse the lab a sum commensurate to the value of the Lab's operations that depended on the licenses. Nicks requested a large reimbursement, though in hindsight, not as large as he might have, but the onetime payment approaching a $1 million temporarily filled a large gap in the hole left by the demise of the Yucca Mountain project.

Smith Saves a Piece

With the 2010 cessation of funding it was the expectation of DOE that the SNSN would cease recording and be removed[278]. Argument was made, in part based on earthquakes that had occurred on the Nuclear Test Site in 1992 and 1993, that it was perhaps not a good idea to now cease monitoring entirely. Complete removal would preclude any ability to confirm that the

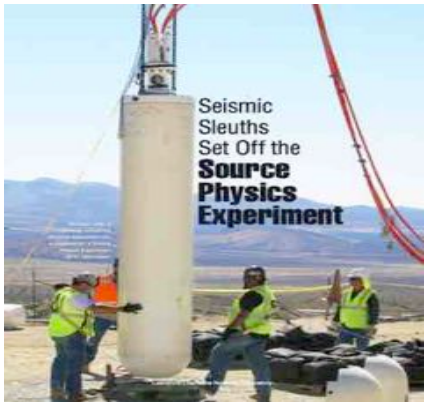


Seismic stations go offline in southern Nevada with cessation of DOE Yucca Mountain project. Only 8 remain recording adjacent and on Yucca Mountain (green stars)

United States was not conducting very low yield nuclear tests on the site. The national labs, primarily Lawrence Livermore, provided Smith and the Lab the interest and funds to continue operating 8 of the then more than 20 stations that had been telemetering seismic signals to UNR. The relationship of the Lab's network to the national lab's interests was to grow and provide additional support for network activities.

Source Physics Experiments

Although Nuclear Tests at the Test Site had stopped in 1992 and characterizations of the potential repository for nuclear waste at Yucca had ceased, there still remained a major interest within our National Labs to improve on existing capabilities to detect and distinguish underground explosions



Lawrence Livermore 2021 Science & Technology Report.

from earthquakes, particularly those of low yield[279]. It thus began the National Lab's efforts in 2010 to begin preparing a near annual occurrence of chemical explosions on the Test Site for that purpose, each referred to as a source physics experiment. With the Seismo Lab's expertise, telemetry, and recording capabilities already in place, it was natural that the Seismo Lab was enlisted in the deployment of seismometers and recording of the explosions. The experiments now provide a major portion of the Lab's operating funds that disappeared with the demise of the Yucca Mountain project. Each experiment raises tensions in the Lab as time ticks toward the planned explosions. It is a technical dance. The Lab techs must ensure seismometers are in order, the communications network to convey seismic signals to the Lab must be perfect, and computers and attendant software poised to correctly record them. The Lab is a happy place and cheers are heard when recovery of blast seismic signals are 100 percent.

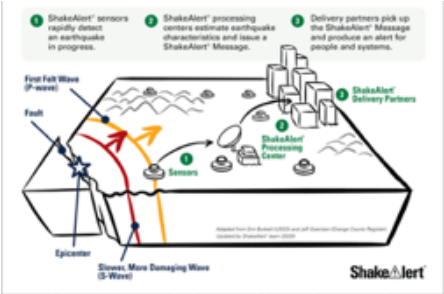
University of Nevada, Reno

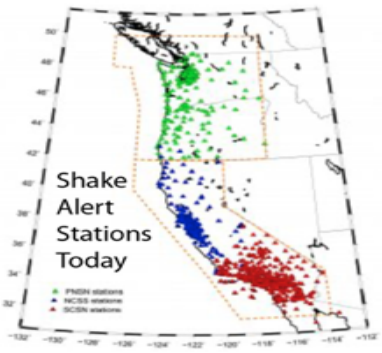
Nevada Seismological Laboratory

The Source Physics Experiments (SPEs) *at Yucca Mountain began in 2010, continue today, and have occurred in 3 phases. They are a joint effort between the Lawrence Livermore, Los Alamos, and Sandia National Labs, the Nevada National Security Site (formerly the Nuclear Test Site), and the Seismological Laboratory. SPE Phase I included chemical explosions over the span of 2010 to 2016, the largest being equivalent to ~5 tons of TNT. Each was placed in shallow (<~400m) boreholes drilled in a granite pluton on the test site. The Phase II experiment extended the annual occurrence of blasts to 2019. In these cases the detonations occurred in weaker sedimentary rock or, in the parlance of the investigators, Dry Alluvium Geology (DAG). Detonations for these were likewise in a shallow borehole but the blasts an order of magnitude larger, reaching the equivalent of ~50 tons of TNT. The 3rd and ongoing phase is the Rock Valley Direct Comparison Experiment. Here investigators will do the unprecedented and drill down and detonate an explosion at the hypocenter of the 1993 Rock Valley earthquake. Reinstalling all of the seismometers that recorded the Rock Valley earthquake will provide a direct comparison of the earthquake and blast signals when the blast takes place. Concurrent and into the future additional low yield chemical explosions are expected to continue with the Low Yield Nuclear Monitoring (LYNM) program*

ShakeAlert Earthquake Early Warning (EEW) System

The quest to predict earthquakes yet remains unfulfilled. Technology however has advanced to the point that alerts of potentially damaging ground motions produced by large earthquakes can be communicated ahead of the seismic waves that emanate from the earthquake and cause the damage, saving lives in the process. Such alerts are possible because earthquakes produce several types of seismic waves (a P-wave that travels nearly twice as fast as the damaging S-waves and surface waves) and electronic telecommunications are virtually instantaneous in comparison to the slow velocity that seismic waves travel. The speed difference between the P-wave and following damaging waves allows people or facilities at distances from the source of a large earthquake to potentially receive an alert before the damaging waves arrive. The principles are the keystone to the USGS-operated Shake Alert Early Warning System. The network of seismometers incorporated into the network now extend across California, Washington, and Oregon. The USGS is now providing funds to the Lab to extend the Shake Alert System into Nevada. Exciting times for the Lab.





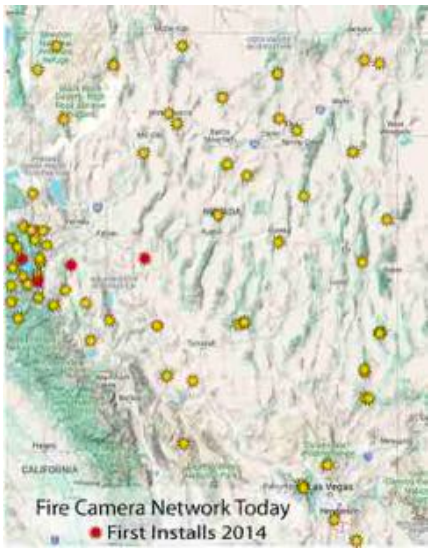
Fire Cameras and Potential for a Multi-Hazard Network

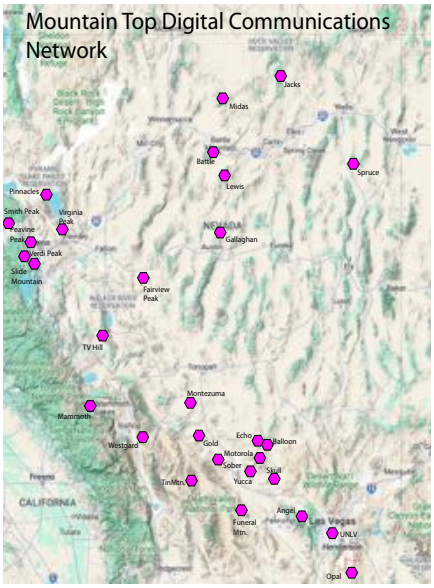
Seismology Lab field crew installing fire camera on remote Nevada mountain top.

The spectre of fire in and around the Lake Tahoe basin was large upon Kent's arrival at UNR. Fire suppression over the preceding 100 years had allowed unnatural buildups of dead wood beneath the forest canopy. Literally hundreds of large fires had burned large patches of the Sierra Nevada in the preceding decades. With an idea sourced from a school children's competition, the Sony company reached out to Kent in 2010 to measure interest in deploying their cameras on mountain tops around Lake Tahoe to monitor and provide warning of developing forest fires. Thus became the first academic deployment of pan-tilt-zoom (PTZ) cameras focused on fire detection. The technology of those cameras was insufficient for the extreme weather conditions of Sierran peaks. Technology improved by 2013, a new TCP/IP security camera built by Axis was installed above Carson City, just in time to watch a 43 square mile fire produce 7 million dollars of damage across the Valley in the Pine Nut Range. With that, Kent worked with the Tahoe Prosperity Center to seek funds to build more sites around the Tahoe Basin, ultimately succeeding to create the AlertTahoe network of fire cameras. Interest and financial support from the Bureau of Land Managment (BLM), the United States Forest Service (USFS), California and Nevada State Fire Chiefs, supports the Lab's operation of cameras in the Tahoe area and across all of Nevada as part of a yet larger AlertWildfire sys-

tem that also extends across California, Oregon and other western States.

The array of mountaintop digital telemetry stations now extends across Nevada. It today functions to gather and transmit signals from seismometers and fire cameras to the Seismology Lab. An initial desire to place seismometers with the expansive network of fire cameras in remote parts of Nevada has not yet been realized. Nonetheless, the potential now exists to do so, and likewise broaden the impact and service of the network to a much broader community of scientists with interests in the study of climate and other natural disasters, in so doing evolving to a multi-hazards monitoring network.





The seismic network – portable components

The 2016 M5.5 Nine Mile Ranch and M6.5 Monte Cristo earthquakes were the largest Nevada earthquakes to occur between 2010 and 2023. Portable seismometers were delivered to each to record aftershocks. With them graduate student Rachel Hatch-Ibarra revealed a unique system of multiple faults that slipped during the sequence[280], though public attention was perhaps more focused on the damage produced to a house where Mark Twain is known to have stayed. The Monte Cristo quake was the largest since the 1954 ruptures that brought Burt Slemmons to studying earthquakes. The event occurred in the midst of the COVID pandemic, but the Seismo Lab nonetheless successfully deployed portable instruments to the epicentral area. The effort was key to studying the faulting process to a level of detail not possible with the sparsely distributed permanent network[281,282].

Network Operations

Field Crews

John Torrisi (1993-2019), Ryan Presser (2008-2018), and Nathan Edwards (2006-2011) provided the needed expertise and continuity in network field operations as the Lab transitioned to the new director. That too was aided by Austin Wilson's post official-retirement presence, ultimately marking his 40 years of experience in the Lab's field operations! When Kent became Director, they were using funds acquired by the sales of the FCC cell frequencies to upgrade the main communications ('backhaul') link between Reno and Las Vegas. Installation of the backhaul link was slow, physical, and arduous. New radios, antennas, batteries, and electronics were transported up and installed on Nevada mountain tops, and tons of old bulky analog gear and microwave dishes carried back down. Edwards soon moved on. Young and bearded Kent Straley (2013-2022), fresh out of the military, was hired as his replacement. John Richards (2015-2019) and Corey Pang (2016-2022) joined not long after. Mentored by Torrisi and Presser, they ultimately finished the project. Straley would later become the Lab's chief field technician. Like academics, expertise is passed down from old to young.

Kent Straley

John Richards and Corey Pang

Fire camera development and installation was soon to become prominent in lab activities. Early efforts included developing prototype systems for the Bureau of Land Management. Hat's off again to Presser and Torrisi. Presser designed the electronics for the camera, communication, and seismic sites while Torrisi acquired access to the needed communication frequencies and designed the solar arrays and tower installations.

Will Honjas assumed Manager responsibilities for field operations in 2018 upon Presser and Torrisi deciding to move on. By this time fire camera operations were dominating the lives of field crews. Alexander Babb (2019-2022) joined Honjas and Straley to streamline the process of fire camera deployments. They reduced the time needed to build and install a camera to 4 days and 8 hours, respectively, from what had originally been 3 weeks and 3 days. The success prompted the hiring of additional technicians in 2020 to move the camera program forward, among them Mitch Menns (2019-2022), Andrew Rosenberg-Main (2020->), Charles Smart (2020 – 2022), Katerina Berg (2021-2022) and Corey Pang (2020-2022). The rapid expansion was quickly challenged by the onset of the COVID pandemic in 2020. Masks came on, work became remote, and separate field teams were formed to limit personal interactions. Overcoming logistical complications the program barely skipped a beat. All but Honjas and Andrew Rosenberg-Main left soon thereafter.

Will Honjas, Jr.

Andrew Rosenberg-Main

In the Lab

Tom Rennie was left the primary responsibility of reading seismic records and locating earthquakes for the network catalog after Arturo Aburto's 2007 and network seismologist Diane dePolo's 2015 departures. The record reading room remains in his capable hands to this day, giving continuity in operations as he comes up on his 30th anniversary at the Lab. Mickey Cassar (2015-2019) and Danielle Molisse (2012-2016) asssisted with the effort. Dr. Emily Morton (2019-2023), a recent graduate of New Mexico State with a calming presence, assumed DePolo's network seismologist position in 2019, only to depart a short time later to the University of Utah in 2023.

Emily Morton

The success of network operations provided the Lab an opportunity to add an Education & Outreach Seismologist to the staff in 2014. Annie Kell had recently finished her Ph.D. with Kent applying active-source imaging techniques to tectonic problems and immediately segued into the position. Her communication skills, vibrant personality, and technical expertise were perfect for the task. The Lab's funds to support the position terminated in 2021, a disappointing loss for the Lab and University.

Annie Kell

The amount of computer programming required to deal with the vast sums of data being recorded by the combined seismic and fire camera network was increasing, leading to the hire of computer programmers to contribute to the networks' operations. Gabe Plank had been a student in the Department of Geological Sciences and Engineering (DGSE) in 1999. He shifted gears from geology to computer programming and was in 2008 working for a San Francisco

tech startup, when at the suggestion of John Louie, Ken Smith offered to hire Plank to help with Lab's increasing computer needs as a systems analyst. By 2012 he had been promoted to Manager of the Lab's Data Center, initially overseeing the programming of some 20 data servers, which has since grown to more than a hundred. In the parlance, between gigs as a musician, Plank continues to manage the networks routers, switches, servers, and software development needed to keep the fire camera platforms up and running.

Gabe Plank

Mark Williams came to the Lab to address expanding needs of the network after his 2012 M.S. degree at the University of Oregon. He commenced by developing programs for seismic event reporting, focal-mechanism generation, and other requirements for ANSS, as well as internal state-of-health monitoring for the entire network. In 2015 he turned his attention to writing second- and third-generations of the computer codes operating the fire camera platform, including upgraded architecture for image acquisition, on-demand timelapse, and the public-facing AlertWildfire website. He creatively leveraged Amazon's cloud services (AWS) to store large amounts of image data to be distributed to the public in near real-time. My memories have him appearing most content standing at his desk in a darkened room lacking windows with the warm glow of a computer screen adjacent. Regrettably for the Lab, he seems to have used his mastery in computer sciences to remove any traces of his existence on the internet. Sean Reeves has since taken his place and receiving kudos for yet further re-architecting the fire camera computing environment.

Sean Reeves

Much as the vast sums of data led to the hire of new programmers, the increasing complexity of overall operations led Kent to hire Dr. Jayne Bormann in 2019 as the Earthquake Early Warning and Fire Camera Project Manager and appointed the associate director in 2021. Bormann had previously received her Ph.D. in geodesy from UNR in 2013 and was an Assistant Professor of Geophysics at Cal State University in Long Beach, before returning to Reno. She has since departed the Lab in 2022 a position in San Diego with ALERTCalifornia.

Jayne Bormann

Kent's stewardships of the Lab was also impacted by the retirements of Lori McClellan and Erik Williams. The business grants management and travel they so adroitly navigated was now to be taken over by Erika Wicks and Administrative Assistant Sydney Hernandez. These two keep the faculty and staff out of budgetary troubles, make possible the arrival of paychecks and travel authorizations, and quite simply are a critical and integral part of the Lab's operations.

Erika Wicks

Sydney Hernandez

Field Crews and Network Management Today

Only Rennie, Slater, and Plank were to continue their contributions from before and through Kent's administration of the Lab. Their longevity underscores the value of their contributions. The exodus of so much staff was not a welcome event and did not favorably impact the operations or morale. The partings did nevertheless provide Kent the opportunity to bring in a new group of scientists and

technicians, make some changes in the management structure, and better pose the network for future successes.

Early 2023 was greeted with Bill Savran accepting the position of Network Manager. Savran was a 2012 UNR undergraduate with family in Nevada and returning home. During his absence he earned a Ph.D. in geophysics jointly with faculty at the U.C. and State University campuses in San Diego. That was followed by 5 years as a computer scientist at the Southern California Earthquake Center. He is today the one juggling contracts, writing proposals, meeting deadlines, and scheming how to expand the impact of the network beyond just seismology. The energy and intensity he places toward the tasks augers well for the Lab's future.

Bill Savran

A national search months later led to hiring Kyren Bogolub as the Lab's Network Seismologist. Bogulub, originally from Montana, gained her Ph.D. from University of Colorado and followed that with a brief stint overseeing seismological operations at the Colorado Geological Survey. A fun fact, her thesis entitled Geophysical Characteristics of the High Plains of Colorado and the Sierra Nevada, California was conducted under the adviserships of the Center for Neotectonic Studies alum Craig Jones. The Lab is now benefitting from her oversight of record reading room operations and public outreach for the Lab. Her technical skills and passion for teaching and sharing science make her a perfect fit for the task.

Kyren Bogulub

Today, Honjas and Rosenberg-Main oversee field operations and are the old guys on the block. They've been joined by Bryce Unger, Brandon Bell, Jeremy Wesley, Ryan Brandani, and Jackson Mendelsohn. The preceding departures of technicians, at least in part, was driven by the inability to pay salaries commensurate to those being offered outside the university for these talented individuals. Honjas' clever administrative relabeling of technicians' positions appears to have alleviated the issue. The smooth running and growth of the Lab's field operations is now in their good hands.

Lab Research and Investigators

Academic faculty in the Lab during this period were Anderson, Louie, and Kent, joined in 2016 by Wesnousky. Other faculty with research responsibilities included Glenn Biasi, Ileana Tibuleac, and Ken Smith, all present since or before John Anderson's Directorship. Network operations had recovered from the demise of the Yucca Mountain project with new funds from the fire cameras, earthquake early warning, and source physics experiments at the test site. These funds though, quite in contrast to the older Yucca Project, were dedicated solely to network operations in the absence of any specific support for research. It was thus relatively smaller contracts and grants awarded to the faculty from the National Science Foundation and USGS that now supported research and graduate students. The increased pressure to sequester funds outside of the Yucca mountain project certainly contributed to Biasi and Tibuleac's decisions to leave the Lab around 2017.

Withstanding the pressures of funding and, as in prior years, Anderson, Biasi, Louie, Smith, Tibuleac and Wesnousky put forth with graduate

(left to right) Bryce Unger, Ryan Brandani, Jackson Mendelsohn , Zack Davis, Brandon Bell, (upper) Will Honjas, Jeremy Wesley, Andrew Rosenberg-Main

students a continual stream of studies addressing topics ranging from fundamental physics of faulting, seismic hazard, and neotectonics in Nevada and around the globe. Kent cleverly enlisted his background in marine geophysics to guide graduate student in seismic reflection techniques to study the history of earthquake faults in Lake Tahoe, the Salton Sea, and other bodies of water in the West. For the interested, the results of these studies are documented in more than a hundred peer-reviewed professional publications and more than two dozen graduate theses.

Retirements, Hires, and New Students

After 12 years as Director, Graham Kent announced his decision in 2022 to step down and commence a sabbatical leave to begin in July of 2023. John Anderson, recently accorded the prestigious Bruce Bolt Award for a career of achievements at the intersection of seismology and earthquake engineering[283], decided at the end of 2022 to retire after 34 years on the Seismo Lab faculty. John Louie followed the same path 6 months later, after a mere 31 years on the faculty. The retirements created the first new openings for faculty in as many years.

Kent gladly led a search committee to seek a replacement to fill the new vacancy left by Anderson. The international search led to offering Dr. Daniel Trugman the position, and all were pleased he accepted. Trugman more than filled the desire that any candidate be poised to leverage the Lab's seismic network for his research. The Assistant Professor's Ph.D. was obtained at the University of California in San Diego in 2017 for a thesis entitled Deviant earthquakes: Data-driven Constraints on the Variability in Earthquake Source Properties and Seismic Hazard. Since that time he has been a primary contributor in developing high-precision earthquake catalogs, provided fundamental constraints on earthquake nucleation, and triggering processes at both lab and field scales, with a practical aim of better quantifying the relationship between earthquake source properties and strong ground motion. That's a mouthful. Suffice it to say his efforts were just recognized with the Seismological Society of America's Richter Early Career Award[284]. This last year he appears to have published more papers than the entire lab's entire annual output in recent years. His slight frame and easy demeanor belie the remarkable productivity. The presence of Trugman and the students he guides bodes well for the future of the Seismo Lab.

Daniel Trugman

Graduate students studying with Trugman today: (left to right) Danielle Kinkel, Vivian Rojas, Maia Zhang, Annie Patton, (lower) AvigyanChatterjee

The Lab finds a New Director: Dr. Christie Rowe

It is customary that senior faculty be replaced with younger faculty upon their retirement. The logic is reasonable. Younger scientists with recent Ph.D.'s are involved with research most topical to the time, have a longer future ahead of them, and cost less. University administration did not want to see the Lab go without a Director, so here made an exception and permitted a search to go forward for a scientist with a longer track record of accomplishments. Wesnousky headed up the search committee. The Lab was soon in unanimous agreement that Dr. Christie Rowe of McGill University be offered the position. Rowe has a Ph.D. from University of California Santa Cruz, commenced her career at McGill University in 2011, and has been Canada's Research Chair in Earthquake Geology since 2017.

Christie Rowe, 5th Director

Excited at the prospect of her leadership, the Lab is pleased she accepted the challenge. Her arrival is scheduled for July 1, 2024. She will be the Lab's 5th Director commencing her tenure in the Lab's 50th year. The next Chapter in Lab history will be hers to make. Wesnousky is certainly done writing about it.

s.g.wesnousky 05-13-2024

amended 11-13-2024

Graduate Degrees 2010-2023 in Seismology.

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(2010) Ph.D. **Kell-Hills, A.** Interpretations of a 3D Seismic Volume, Hawthorne Geothermal Field, Nevada. 45 (Louie).

(2010) M.S. **Sarmiento, A.C.** Earthquake recurrence and modes of deformation in the central and northern Walker Lane: Observations from paleoseismic trenches across the Carson and Sierra Nevada Range fronts. 142 (Wesnousky & Watters).

(2010) M.S. **Thompson, M.** Analysis of shear wave velocity measurements for prediction uncertainties in Southern California. 71 (Louie).

(2012) M.S. **Eisses, A.** New constraints on slip-rates, recurrence intervals, and strain partitioning beneath Pyramid Lake, Nevada. 71 (Kent & Louie).

(2012) M.S. **Frary, R.** Fault Imaging with High-Resolution Seismic Reflection for Earthquake Hazard and Geothermal Resource Assessment in Reno, Nevada. 57 (Louie).

(2012) Ph.D. **Smith, S.B.** Submarine Paleoseismology in Lake Tahoe, CA/NV and Puget Sound, WA. 150 (Karlin, K.).

(2013) Ph.D. **Bormann, J.M.** New Insights into Strain Accumulation and Release in the Central and Northern Walker Lane, Pacific-North American Plate Boundary, California and Nevada, USA. 150 (Hammond, W.C.).

(2013) M.S. **Gray, K.** Hardrock seismic reflection through cover: Defining controls on mineralization via reflection attribute analysis. 85 (Louie).

(2013) M.S. **Kent, T.** Comparing Deformation at Soda Lake Geothermal Field from GPS and 3D Seismic. 40 (Kent, L.).

(2013) Ph.D. **Schmauder, G.C.** Evaluating Late Pleistocene and Holocene Rupture, Seismic Hazards and Ground Motion in the Lake Tahoe Basin. 169 (Kent & Louie).

(2014) Ph.D. **Kell, A.M.** The application of active-source seismic imaging techniques to transtensional problems the Walker Lane and Salton Trough. 138 (Kent & Louie).

(2014) M.S. **Seaman, T.** Investigating the Seismicity and Stress Field of the Truckee-Lake Tahoe Region, California-Nevada. 65 (Smith).

(2015) M.S. **Basler-Reeder, K.J.** Joint Optimization of Vertical Component Gravity and Seismic P-wave First Arrivals by Simulated Annealing. 62 (Louie).

(2015) M.S. **McBean, K.M.** Statistics of Ground Motions in a Foam Rubber Model of a Strike-Slip Fault. 39 (Anderson).

(2016) M.S. **Brailo, C.M.** A Light Detecting and Ranging (LiDAR) and Global Positioning System (GPS) Study of the Truckee Meadows, NV. Quaternary Fault Mapping with ArcGIS, 3D Visualization and Computational Block Modeling of the Greater Reno Area. 91 (Kent).

(2016) M.S. **Mlawsky, E.T.** Basin Geometry Estimates using Terrestrial Gravimetry Study of Bridgeport Valley, CA. 33 (Louie).

(2016) Ph.D. **Ruhl, C.J.** Characterizing the Physical and Statistical Properties of Earthquake Swarms and Microseismicity in Western Nevada and Eastern California. 166 (Smith).

(2017) M.S. **Pierce, I.K.D**. Slip Rate of the West Tahoe Fault and the Age of Glacial Deposits Near Lake Tahoe, California. 63 (Wesnousky).

(2017) M.S. **West, L.T.** Sensitivity Tests Between Vs30 and Detailed Shear Wave Profiles Using 1D and 3D Site Response Analysis, Las Vegas Valley. 423 (Louie).

(2018) Ph.D. **Angster, S.J.** Contributions to the Neotectonics of the Central and Northern Walker Lane. 186 (Wesnousky).

(2018) M.S. **Reedy, T.**J. Extension and Quaternary Faulting in the Northern Central Nevada Seismic Belt. 63 (Wesnousky).

(2018) M.S. **Shaw, K.A.** Geohazards Related to the California High Speed Rail: A Case Study of the Garlock Fault Crossing. 63 (Kent).

(2019) M.S. **Naphan, D.O.** Effects of Energy Directionality on ReMi™ Analysis. 46 (Louie).

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(2021) M.S. **Eckert, E.** The Reno ShakeOut Hazard Scenario. 51 (Smith, L.).

(2021) Ph.D. **Scalise, M.E.** Earthquake Wave Propagation in Nevada Sedimentary Basins. 157 (Louie).

(2022) M.S. **Graham, J.R.** Model Surface Wave Dispersion Analysis Across a Basin Boundary. 42 (Louie).

(2022) Ph.D. Yazdi, M. Reducing the Uncertainties in Ground Motion Prediction Equations by Incorporating the Frequency and Amplitude of the Fundamental Peak of the Earthquake Horizontal-to-Vertical Spectral Ratios. 151 (Anderson & Motamed).

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283 *The Bruce Bolt Medal honors the legacy of Professor Bolt. It is awarded jointly by COSMOS, Earthquake Engineering Research Institute (EERI), and the Seismological Society of America (SSA) to recognize individuals worldwide who work at the intersection of Seismology and Earthquake Engineering, whose accomplishments involve the promotion and use of earthquake measurements, and whose leadership in the transfer of scientific and engineering knowledge into practice or policy has led to improved seismic safety. The annual award is presented at the annual meeting of the recipient's choice among the three sponsoring organizations.*

284 *Established in 2005, the Charles F. Richter Early-Career Award is part of SSA's longstanding commitment to supporting the next generation of seismologists. The award honors outstanding contributions to the goals of the Society by a member early in her or his career and given no more than once a year. An awardee's contributions should advance seismology and/or the understanding of earthquakes for the benefit of society and reflect the core values of SSA.*