Prepared by the Nevada Seismological Laboratory and the Nevada Bureau of Mines and Geology, University of Nevada, Reno
in cooperation with the Nevada Earthquake Safety Council, the Nevada Division of Emergency Management, the U.S. Geological Survey, and the Federal Emergency Management Agency

Earthquakes in Nevada

1840s to 2010

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Introduction

Nevada is earthquake country; earthquakes occur every day in the state and a large damaging quake shakes some part of Nevada almost every decade. In fact, Nevada ranks third in the list of states with the most magnitude ≥5 earthquakes, trailing only Alaska and California (Anderson and Miyata, 2006). Because so many earthquakes occur throughout the state, all communities and citizens should be prepared for them.

Most Nevada residents are unfamiliar with the abundance of earthquake activity that this epicenter map depicts. The map includes over 188,000 earthquakes that have occurred in or adjacent to Nevada over the last 155 years (1855–2010). For the first ~110 years of this time period, seismic monitoring stations were absent or were limited. Because of the lack of seismic stations, hundreds of thousands of small earthquakes were not recorded and are missing. For example, thousands of aftershocks following the major events prior to 1962 were not recorded. More than 99% of the earthquakes on this map were recorded just in the last 40 years when multiple seismic networks operated in and around the state.

Earthquakes in Nevada

Earthquakes occur throughout Nevada but are concentrated in several major seismic belts (Slemmons and others, 1965). The locations of these belts and major Nevada earthquakes are shown in the figure titled *Earthquakes of Magnitude ≥6 and Seismic Belts*. The Walker Lane seismic belt (formerly called the Sierra Nevada–Great Basin seismic belt) includes earthquakes located in a 140-km-wide (87 mi) lane paralleling the eastern side of the Sierra Nevada that appears to be a northern extension of the Eastern California seismic belt. Persistently high levels of earthquake activity, with magnitude 6+ earthquakes occurring approximately every decade, characterize the Walker Lane seismic belt. News reports indicate that several large, damaging earthquakes occurred in the Reno–Carson City urban corridor between 1857 and 1914 (examples are 1869, 1887, and 1914). Since then, damaging earthquakes have continued about every twenty years or so in the urban corridor (1933, 1948, 1966, 1994, 2008). Other parts of the Walker Lane seismic belt have also been active, perhaps most notably, the M 7.6 Owens Valley, California earthquake sequence in 1872. The Walker Lane seismic belt is part of the boundary between the Pacific and North American plates. One fifth of the deformation across this plate boundary (10 mm/yr) occurs within the Walker Lane seismic belt (Kreemer and others, 2012). The plate boundary motion is right-lateral strike-slip, and strike-slip earthquakes and faults are common in the Walker Lane seismic belt. High rates of earthquake activity in the Walker Lane seismic belt are easily understood, given the observed geodetic strain and the large number of faults available to release this strain as earthquakes.

The historical activity of the Central Nevada seismic belt began with the 1903 Wonder earthquake, M ~6.0 (Slemmons and others, 1959), and continued through the1959 M 5.7 Dixie Valley earthquake, the last magnitude ≥5 event to occur. The most notable earthquakes include three magnitude 7+ events (1915, 1932, 1954), each with spectacular surface ruptures extending over distances of 60 km (40 mi) or more. The 1915 Pleasant Valley earthquake, M 7.3, was followed by the 1932 Cedar Mountain earthquake, M 7.1, and the 1954 Rainbow Mountain–Fairview Peak–Dixie Valley sequence that included M 7.1 and M 6.9 events, which occurred within 4 minutes and 20 seconds of each other. The latter two earthquakes ruptured faults over an area of 100 km (62 mi) x 14.5 km (9 mi). Earthquake activity in the Central Nevada seismic belt since then has been concentrated in the aftershock areas of the large events. The majority of these aftershock sequences occurred before the establishment of a permanent seismic network in Nevada, and they were largely unrecorded. Aftershocks from large earthquakes (M 7+) occur for about 100 years in Nevada, so the seismic footprints from the 1932 and 1954 events can still be seen, whereas the 1915 aftershock area no longer has significant seismic activity. Paleoseismic studies of the faults in the Central Nevada seismic belt indicate that such episodes of activity are uncommon and that thousands of years typically separate large events (Bell and others, 2004).

The Southern Nevada seismic belt connects the seismic activity in the Walker Lane seismic belt with the Intermountain seismic belt in Utah (Slemmons and others, 1965; Smith, 1978). This belt covers a broad swath (100 km, 60 mi) across southern Nevada, and coincides with the boundary between numerous late Quaternary faults to the north and fewer of these faults to the south (e.g. dePolo, 2008). Large east-west regional topographic and geophysical anomalies coincide with this belt (Eaton and others, 1978), as well as some east-northeast-striking faults (dePolo, 2008). Geodetic measurements indicate that as much as 1.8 mm/yr of left-lateral slip occurs across the Southern Nevada seismic belt (Kreemer and others, 2010). Many earthquakes that occurred in the western part of this seismic belt in the 1960s and 1970s were triggered by nuclear tests (Boucher and others, 1969).

Even though seismic monitoring stations were not present throughout much of Nevada and Nevada's history, nearly all of Nevada has some recorded earthquakes. The recent 2008 Wells earthquake, M 6.0, which occurred in northeastern Nevada outside of the major seismic belts, is an important example of this kind of activity. Reservoir-induced earthquakes around Lake Mead, such as the M 5 event in 1939, were also outside of the major seismic belts. These and other historical events remind us that earthquakes can occur anywhere in Nevada.

In Nevada, earthquakes generally occur in the brittle upper part of the Earth's crust. Pancha and others (2006) found that 98% of earthquakes recorded in Nevada between 1990 and 1999 had depths of 17 km (10.5 mi) or less, indicating an approximate thickness of this brittle layer.

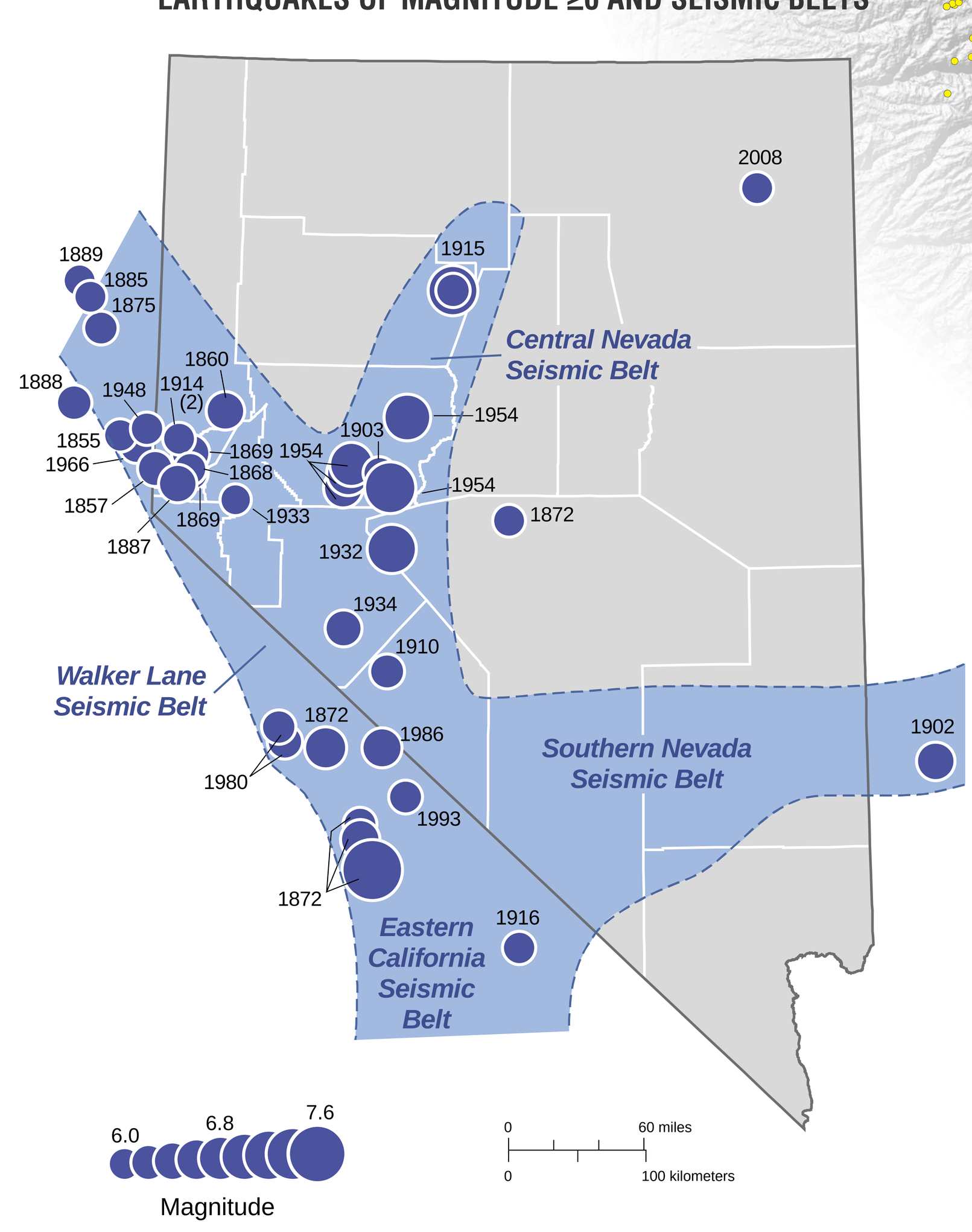
Earthquake Behavior

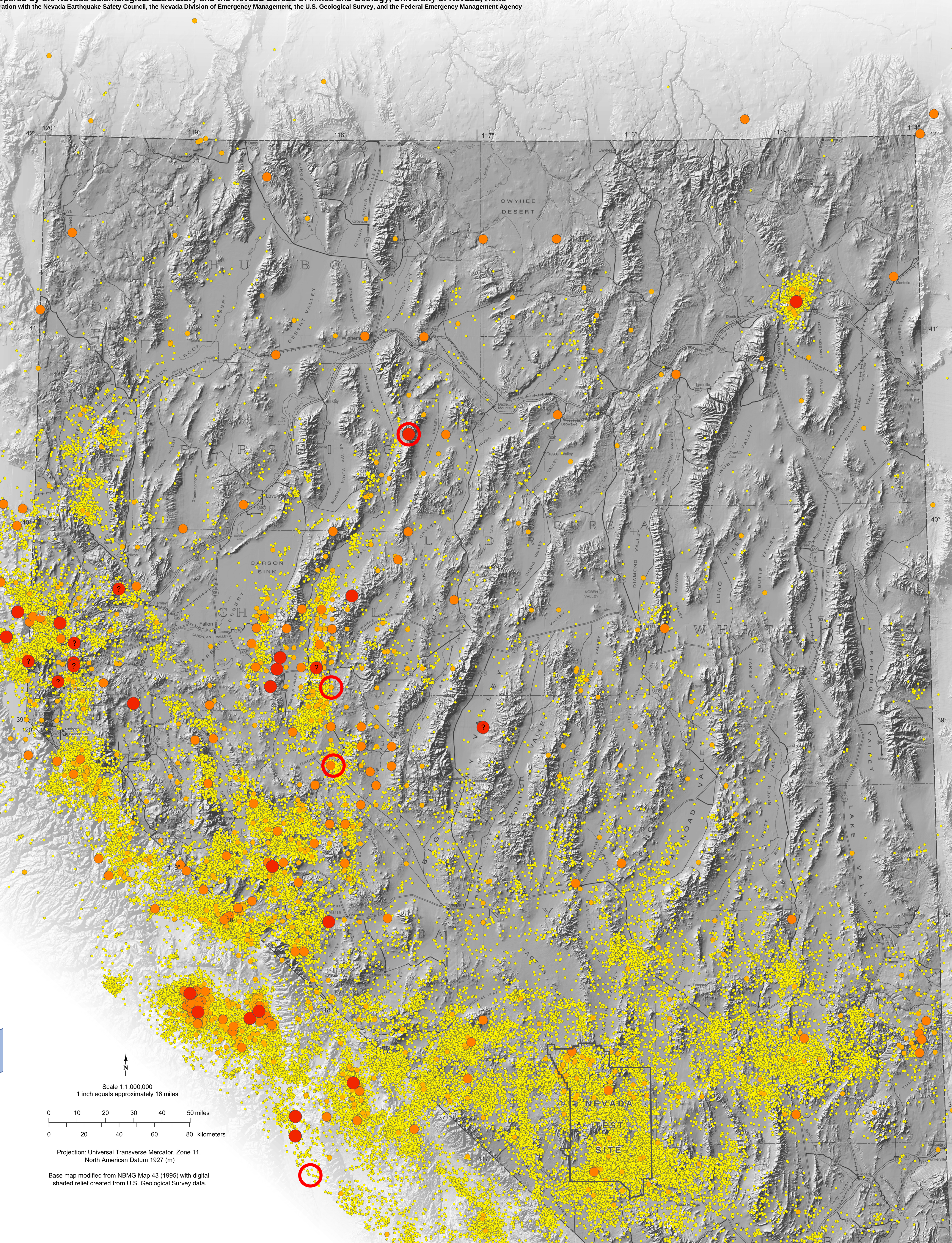
Earthquakes in Nevada have a wide range of behavior from a single isolated event to complicated and energetic earthquake sequences with thousands of events. Earthquakes can be classified as foreshocks, mainshock, aftershocks, and multiple earthquakes. Like snowflakes, each earthquake sequence has its own unique character.

Individual earthquakes can be seen throughout Nevada, and although several are real, many are artifacts of the lack of seismic instruments to record the smaller events. Clusters or swarms of earthquakes are also common in Nevada. These swarms occur over weeks to months and can include a wide range of magnitudes.

Larger earthquakes, M 6 and greater, commonly have foreshocks and numerous aftershocks. In Nevada, foreshocks preceded about 80% of earthquakes with magnitudes ≥6. The behavior of foreshocks ranges from isolated events to earthquake sequences occurring over months with increasing numbers of events and magnitudes. About 20% of the larger earthquakes occurred abruptly with no recorded precursory activity. All larger earthquakes have aftershocks. Aftershocks are adjustments following the mainshock, commonly numerous, and taper away in number and size with time. Aftershocks are expected to follow all larger earthquakes and can continue from decades to as long as a century for the larger earthquakes. Twenty-four percent (24%) of magnitude >6 earthquakes were multiple events (double or triple earthquakes). For 19% of the major events in Nevada, the second earthquake has occurred within 12 hours.

EARTHQUAKES OF MAGNITUDE ≥6 AND SEISMIC BELTS





EARTHQUAKES IN NEVADA WITH MAGNITUDES OF 5.5 OR GREATER

Year	Month	Day	Time GMT	North Latitude*	West Longitude*	Magnitude
1840s	?	?	?	?	?	?
1852?	?	?	?	?	?	?
1857	Sep	03	?	39 18.00?	120 00.00?	6.3
1860	Mar	15	1845	39 41.00?	119 25.00?	6.5
1868	May	30	0511	39 18.00?	119 42.00?	6.0
1869	Dec	27	0130	39 24.00?	119 42.00?	6.4
1869	Dec	27	0550	39 30.00?	120 00.00?	5.5?
1869	Dec	27	0940	39 17.00?	119 42.00?	6.2
1872	Mar	23	2141	40 00.00?	117 30.00?	5.5
1872	Nov	12	?	39.00.00?	117 00.00?	6.0
1873	Nov	05	1700	40 00.00?	118 00.00?	5.5
1875	Apr	02	0200	39 30.00?	115 48.00?	5.5
1887	Jun	03	1048	39 12.00?	119 48.00?	6.5
1894	Nov	18	1049	39 12.00?	119 48.00?	5.5
1903	?	?	?	39 30.00?	118 06.00?	6.0?
1905	Nov	11	2126	42 54.00	114 30.00	5.7
1910	Nov	07	1720	37 30.00	117 00.00	5.5
1910	Nov	19	0225	38 00.00	118 00.00	5.5
1910	Nov	21	2323	38 00.00	118 00.00	6.1
1910	Nov	22	0605	38 00.00	118 00.00	5.5
1914	Feb	18	1817	39 30.00	119 48.00	6.0
1914	Apr	24	0834	39 30.00	119 48.00	6.4
1915	Oct	03	0149	40 30.00	117 30.00	6.1
1915	Oct	03	0653	40 30.00	117 30.00	7.3
1916	Feb	03	0503	41 00.00	117 48.00	5.9
1916	Aug	03	1350	41 30.00	116 30.00	5.6
1916	Aug	03	1421	41 30.00	116 30.00	5.8
1932	Dec	21	0610	38 48.00	117 58.80	7.1
1932	Dec	25	0355	38 48.00	118 00.00	5.5
1933	Jan	05	0651	38 46.20	117 44.40	5.9
1933	Feb	13	2209	38 00.00	118 00.00	5.5
1933	Jun	25	2045	39 06.00	119 18.00	6.0
1933	Oct	27	1059	38 54.00	117 36.00	5.5
1934	Jan	30	1924	38 18.00	118 24.00	5.6
1934	Jan	30	2016	38 16.80	118 22.20	6.1
1934	Jan	30	2030	38 18.00	118 24.00	5.7
1934	Feb	09	0921	38 18.00	118 24.00	5.5
1934	Jun	23	1504	39 06.00	118 48.00	5.5
1939	May	11	1840	38 36.00	117 48.00	5.5
1942	Dec	03	0944	39 42.00	119 18.00	5.9
1942	Dec	17	1507	38 43.80	119 40.80	5.5
1943	Aug	09	0530	38 12.00	118 12.00	5.5
1948	Dec	29	1253	39 33.00	120 04.80***	6.0
1949	Feb	11	2105	36 58.98	117 48.30	5.6
1953	Sep	26	0334	39 31.80	119 58.80	5.5
1954	Jul	06	1113	39 17.40**	118 21.60**	6.2
1954	Jul	06	1118	39 25.20	118 31.80	5.5
1954	Jul	06	1149	39 25.20	118 31.80	5.7
1954	Jul	06	2207	39 12.00**	118 24.00**	6.1
1954	Aug	24	0551	39 21.00**	118 20.40**	6.8
1954	Aug	31	2220	39 36.00	118 12.00	5.8
1954	Sep	01	0518	39 36.00	118 12.00	5.5
1954	Dec	16	1107	39 12.00**	118 00.00**	7.1
1954	Dec	16	1111	39 40.20**	117 52.20**	6.9
1954	Dec	16	1416	39 30.00	118 00.00	5.8
1955	Nov	21	2025	39 25.20	118 04.80	5.5
1959	Mar	23	0710	39 36.00	118 04.20	5.7
1959	Jun	23	1435	38 55.20	118 53.40	5.6
1959	Jun	23	1504	39 06.00	118 48.00	5.5
1964	Mar	22	1630	38 42.00	118 48.00	5.5
1966	Aug	16	1802	37 27.78	114 09.06	5.7
1966	Sep	22	1857	37 22.14	114 10.98	5.0
1992	Jun	29	1014	36 43.26	116 17.64	5.6
1994	Sep	12	1223	38 48.50	119 38.30	5.9
2008	Feb	21	1416	41 09.94	114.52.63	6.0

* In degrees and decimal minutes
** From Doser (1986)
*** In California next to the Nevada border.

The data depicted on this map would have been lost without the efforts of these dedicated professors, scientists, technicians, analysts, and students, including Charles Friend, J.C. Jones, Vincent P. Gianella, David (Burt) Slemmons, James I. Gimlett, Austin E. Jones, Alan R. Ryall, Floriana Ryall, Wally Nicks, Roger Greensfelder, J. Koeing, Steve Malone, Woody Savage, Doug Van Wormer, Keith Priestley, Austin Wilson, Bill Peppin, Gloria Smith, Ute Vetter, James Brune, Arturo Aburto, John G. Anderson, and David von Seggern. The current staff of the Nevada Seismological Laboratory is modernizing the network, expanding the network throughout Nevada, and continuing to process and locate thousands of earthquakes per year in the state. The current staff is Director Graham Kent, Ken Smith, Glenn Biasi, John Torrisi, David Slatter, Gabe Plank, Ryan Presser, Tom Rennie, and many dedicated and hard-working students.

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One magnitude less than 4.0 epicenter on this map is a happy face.

Nevada Bureau of Mines and Geology
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PEER-REVIEWED MAP
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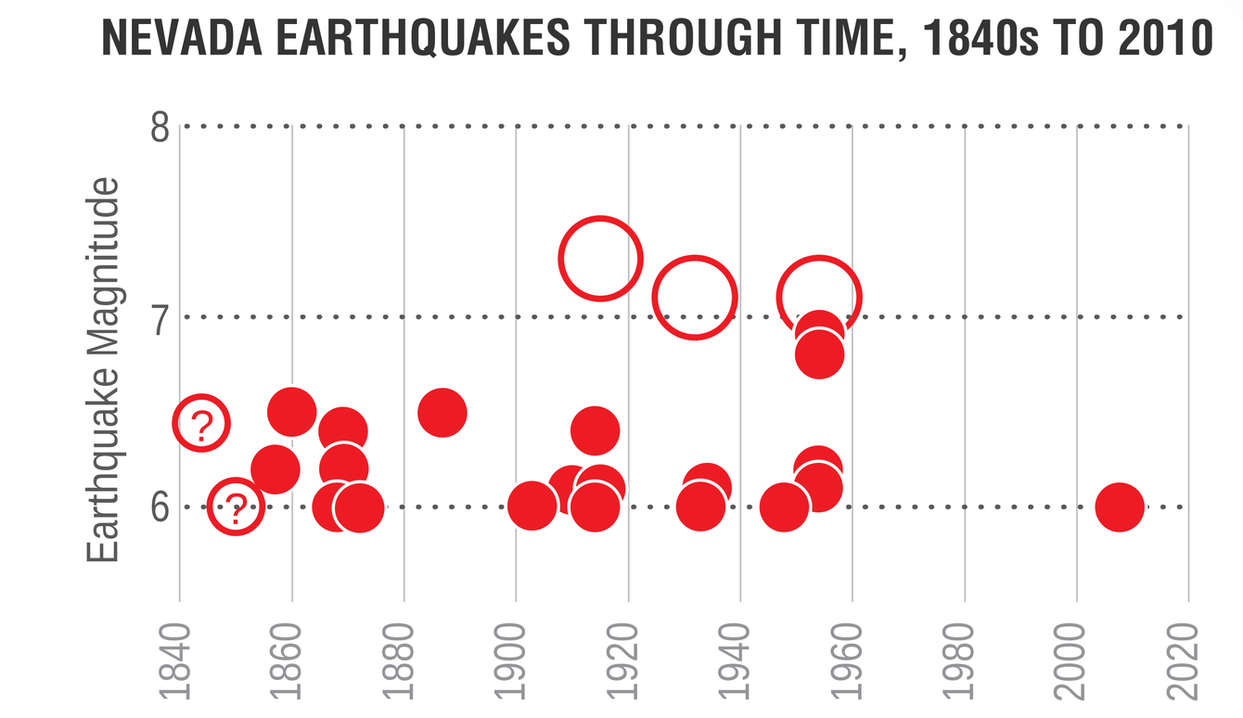
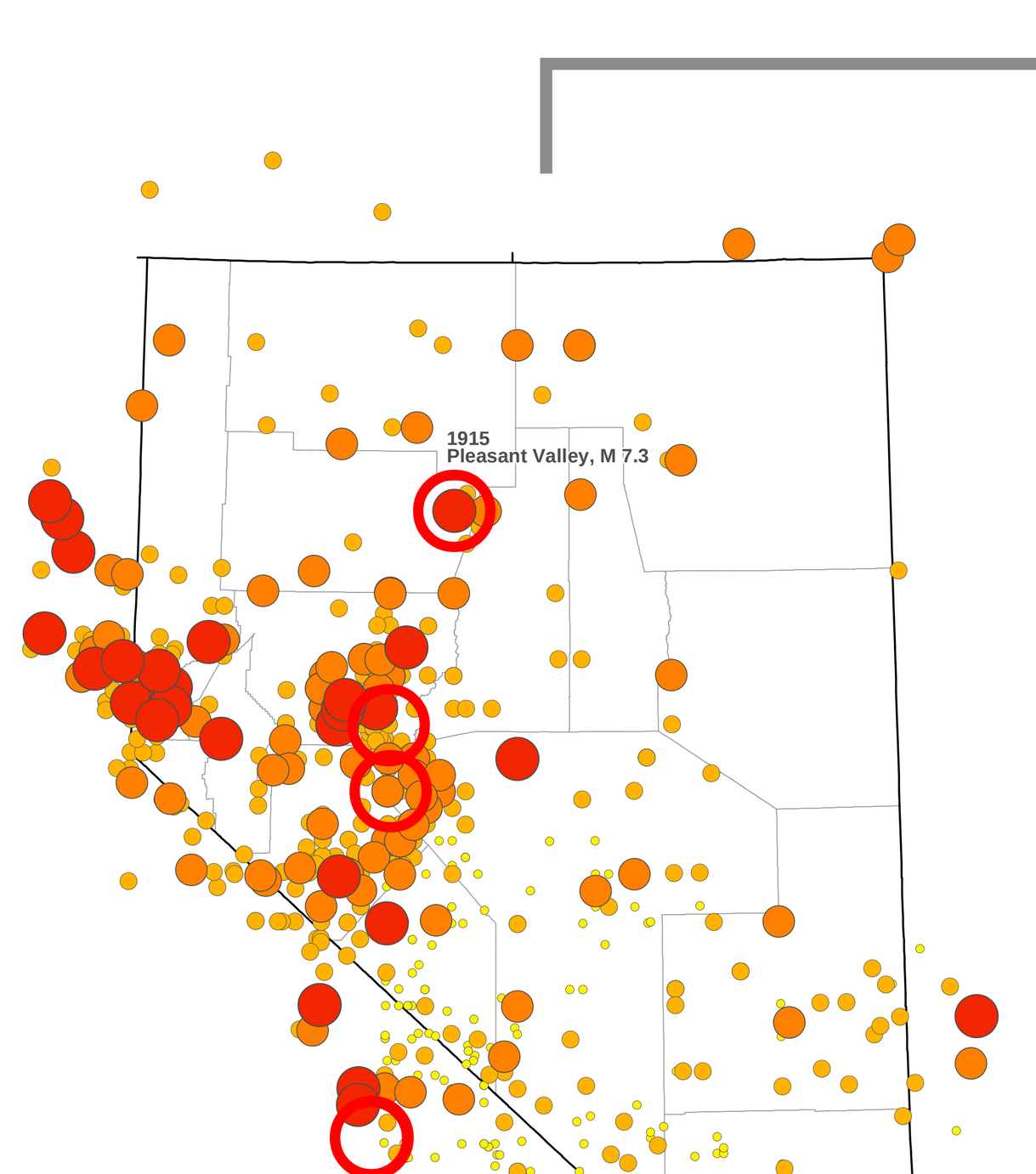
NEVADA EARTHQUAKES THROUGH TIME, 1840s TO 2010



Earthquakes Through Time

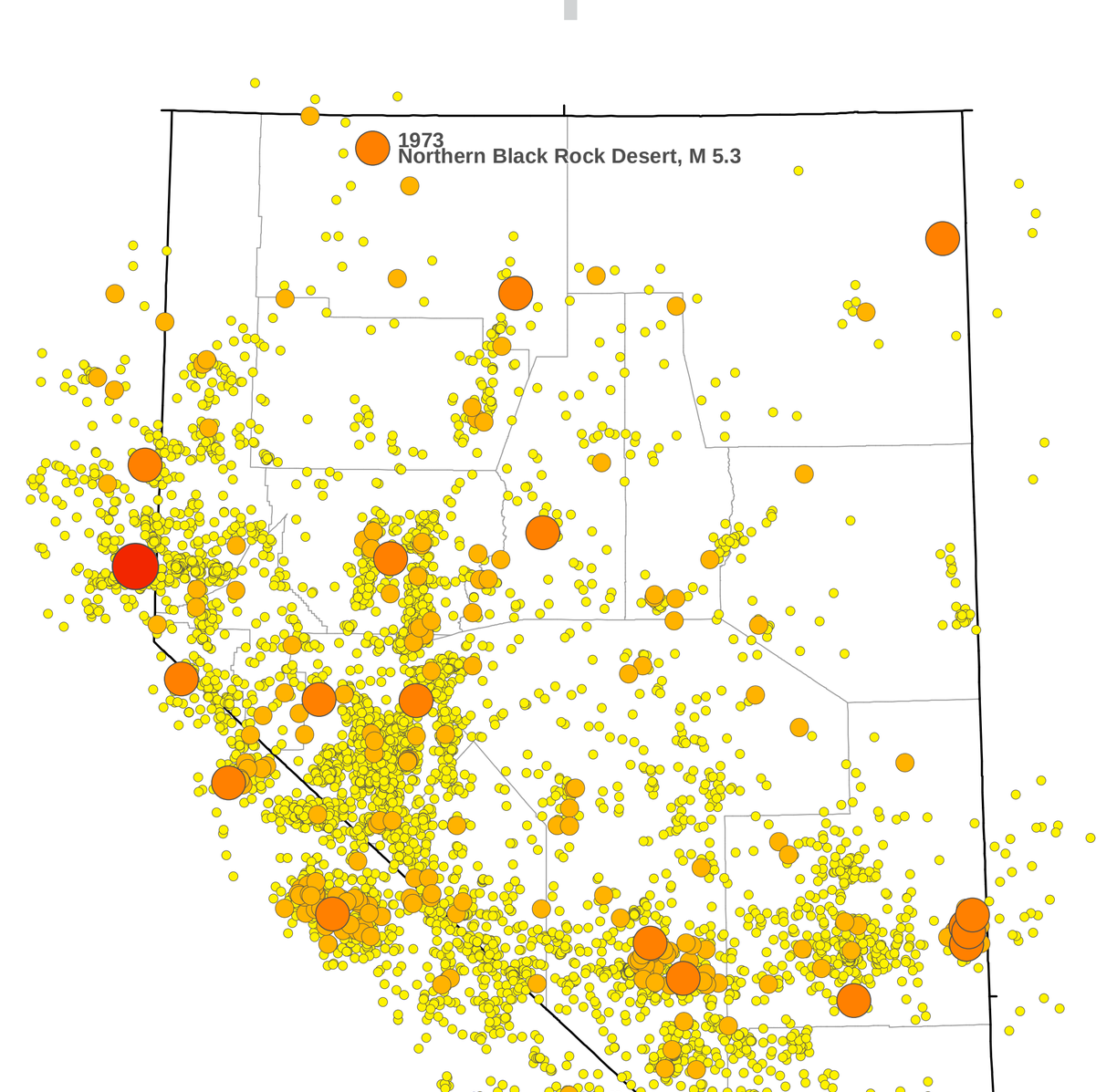
170 Years of Earthquake History in Nevada

Although the number of earthquakes recorded has increased through time due to an increase in the number of seismic monitoring stations, the occurrence of the larger, well-recorded events has been variable through the last 170 years with recent years exhibiting relative quiescence. Larger earthquakes in Nevada have occurred as individual events or in groups. There have also been decades without them. To illustrate this temporal variability, we show earthquake epicenters over four time periods and a graph of magnitude ≥6 earthquakes over time. The time periods for the maps are selected based on the number of seismic stations and their density and, thus, the earthquake-locating capability. The precision of earthquake locations and the number of recorded events improves with time.



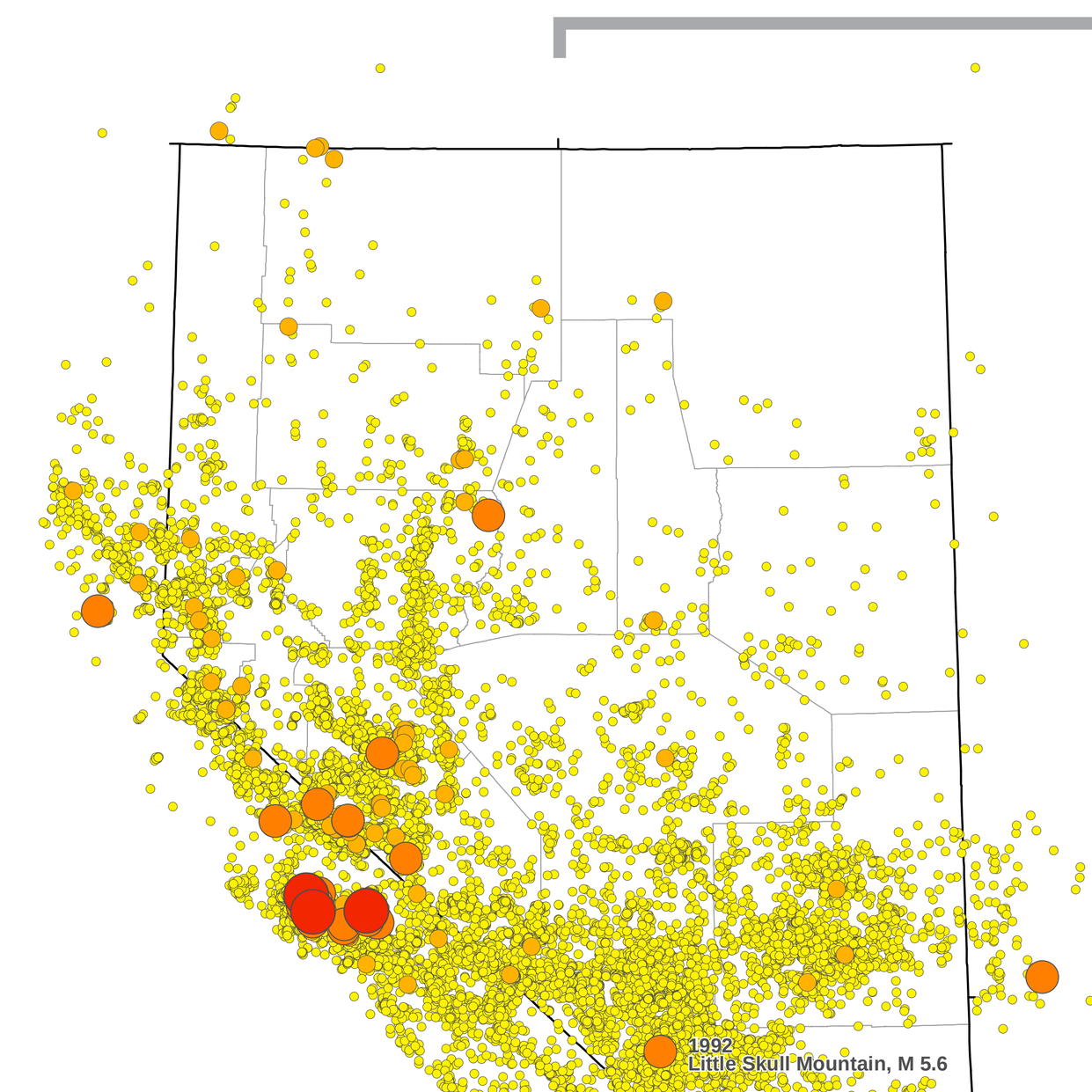
1840s to 1961

This early period includes the largest earthquakes in Nevada's history, with three events of magnitude 7 or greater. During this time period, earthquakes were recorded by seismic stations generally located outside the state and, for the earliest events, from newspaper and diary accounts. Consequently, hundreds of thousands of smaller earthquakes occurred but were not recorded. Over this nearly 120-year-period, 1217 earthquakes were documented in and adjacent to Nevada. The latitude/longitude locations of many of the earliest events were approximated, which creates some artificial vertical and horizontal alignments of epicenters. Nevertheless, the seismically active areas of Nevada (the Walker Lane, the central Nevada, and the southern Nevada seismic belts) can all be seen. The lack of seismic monitoring stations in the state limited the size of earthquakes that are in the regional catalogs from this time period. For example, before 1938, the smallest magnitude assigned to an event was 2.5. Between 1939 and 1969, lower magnitudes were assigned to events but the vast majority of the earthquakes had magnitudes greater than M 2.5, even during the famous 1954 earthquake sequence (Slemmons and others, 1965). Several of the largest earthquakes that occurred between the 1840s and 1961 broke the ground surface and created ruptures as long as 75 km (47 mi) (1932) and with ground offsets of as much as 5.8 m (19 ft) vertically (1915). The largest event, the M 7.3, Pleasant Valley earthquake was preceded by a M 6.1 foreshock 5 hours earlier. This was an energetic earthquake sequence with a mainshock that shook the entire state.



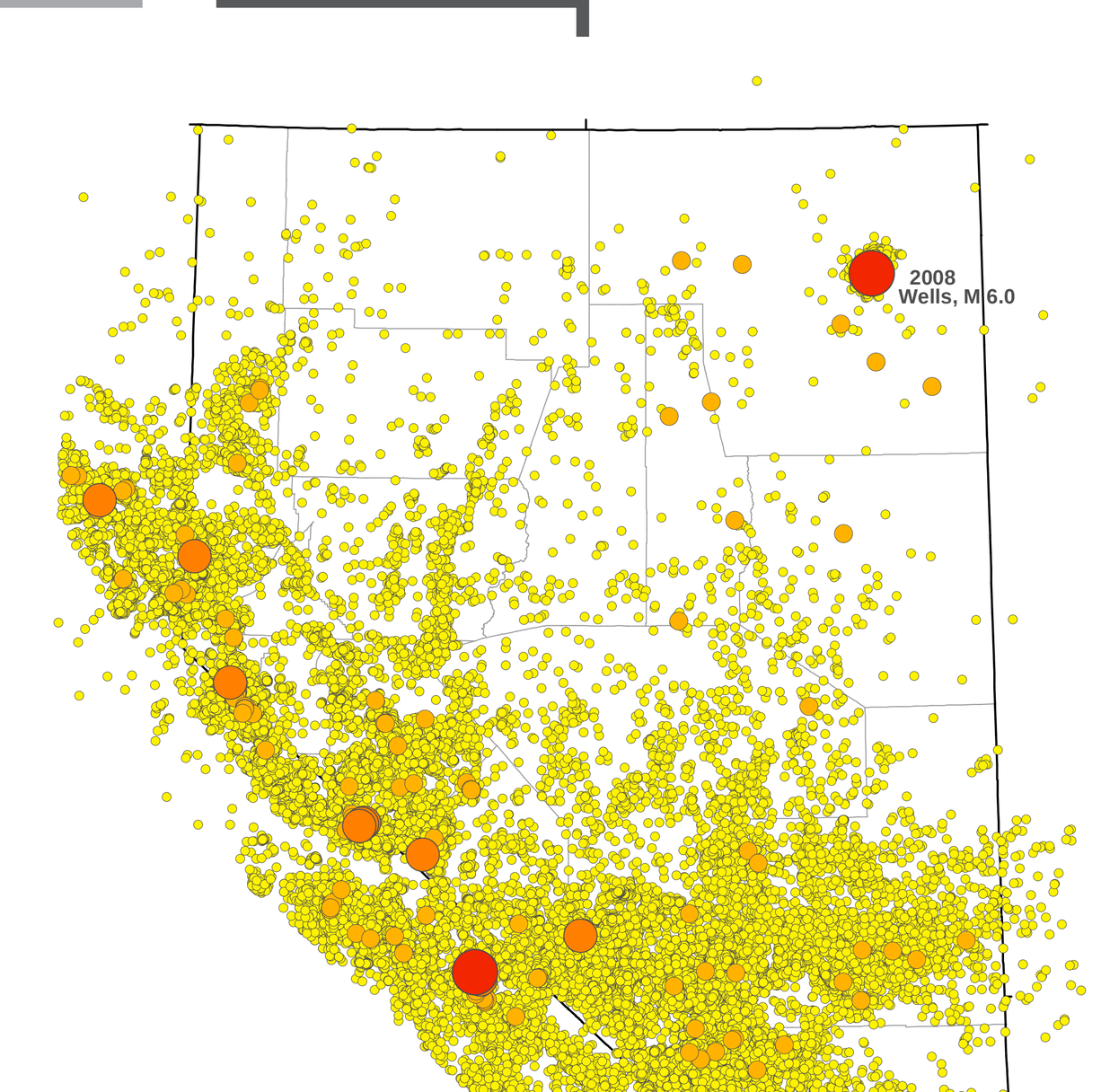
1962 to 1979

In 1962, the University of Nevada established a permanent seismic network in western Nevada and the Seismological Laboratory recorded and processed the data. During this 18-year time period, 7691 earthquakes were recorded in the map area and notable epicenter alignments emerged paralleling fault trends and outlining aftershock zones. This map shows much more realistic patterns in seismicity compared to the earlier map, underscoring the tremendous importance of seismic stations in accurately determining earthquake locations. The largest event in this time period, a M 5.3, occurred on March 3, 1973 and was located in the northernmost Black Rock Desert, west of the Bilk Creek Mountains in northwestern Nevada. The mainshock was followed 8 hours later by a M 5.1 aftershock. Several M 4.7 events were also included in this swarm. Another M 5.1 occurred in northeastern Nevada, east of Wells, near the Nevada–Utah border on March 29, 1970. Many of the largest events during this time period were in northern Nevada.



1980 to 1992

During the period from 1980 to 1992, the number and spatial distribution of seismic stations in the state increased; the crustal velocity models used in locating earthquakes were improved; and earthquake location programs became more sophisticated. The measurement of earthquake waves was improved from hand measurements off paper records to data that were recorded and analyzed using interactive computer programs. All these technological advancements combined to greatly improve the accuracy and number of earthquake locations. Epicenters formed tight clusters and seismic alignments were much more pronounced, especially within the Walker Lane seismic belt. Over the 13-year period, 53,909 earthquakes were recorded and processed in the map area at the University of Nevada, Reno Seismological Laboratory. Earthquakes occurred across the state, but there was an apparent lack of earthquakes in the northern and northeastern parts of the state, where there was a corresponding lack of instrumentation. The largest earthquake in Nevada during this time period was the 1992 Little Skull Mountain earthquake (M 5.6), on the Nevada Test Site.



1993 to 2010

Continued improvements in earthquake recording and location and the consolidation of the Nevada seismic networks resulted in the recording of 125,574 earthquakes over this 18-year period in the map area. During this post-nuclear testing time, a remarkable number of earthquakes were recorded in southern Nevada because of the high-quality seismic network used to monitor the Nevada Test Site and the proposed Yucca Mountain high-level nuclear waste repository. For an 18-month period during 2007 and 2008, seismometers were installed throughout the state as part of the US Array, also called the Bigfoot array, part of the National Science Foundation's Earthscope Experiment. The 2008 Wells earthquake (M 6.0) was the largest event to occur during this time period in Nevada, and it was well recorded and located with this array. Since this time, the number of seismometers in Nevada has been substantially reduced due to budget cuts, the removal of the US Array stations, and the closing of the Yucca Mountain project.

Sources of the Data

This map shows earthquakes that are known to have occurred in Nevada from the 1840s through 2010. The primary source of data is the earthquake catalog produced by the Nevada Seismological Laboratory at the University of Nevada, Reno. Additional earthquakes in southern and eastern Nevada, recorded by the Southern Great Basin Seismic Network, which was responsible for monitoring the Nevada Test Site (1978–1992) and by the University of Utah Seismographic Stations (1850–2010), respectively, were incorporated. When the same earthquake was located by more than one network, the preferred location shown on the map was determined through consideration of which network had the best station coverage. Artificial events, such as mine blasts, nuclear explosions, and hole collapses following nuclear explosions, have been removed when recognized. Earthquakes induced by reservoir-filling and those triggered by nuclear explosions are included.

It is important to recognize that earthquake catalogs are not complete at all magnitude ranges. When seismic monitoring stations are absent or are sparsely distributed, smaller earthquakes may not be detected and located consistently. The completeness threshold of the earthquake catalogs is directly related to station coverage. This threshold has generally—but not always—improved with time. Seismic networks are sometimes installed temporarily for specific purposes and are removed or redeployed when a study is complete.

Prior to 1887, there were no seismographic stations operating in Nevada, and there were only a few by the late 1960s. Earthquakes from the 1850s through 1900 were located and magnitudes estimated from historical reports (Toppozada and others, 1981; dePolo and others, 2003). The locations of these early events are not precisely known. From 1900 until 1962, locations rely heavily on data from stations outside Nevada, with minimal contributions from local information. Slemmons and others (1964 and 1965) compiled the early part of the earthquake catalog.

The Nevada Seismological Laboratory established its network in 1962 and incorporated the Southern Great Basin Seismic Network in 1992. During this period the locations are generally well constrained in western Nevada and adjacent parts of eastern California between the latitudes of Reno and Goldfield and on the Nevada Test Site. Few seismic stations have been located in northern, eastern, and parts of southern Nevada, and only the larger earthquakes have generally been recorded. The number of earthquakes recorded in Nevada is proportional to the number of seismometers operating in the state, which has fluctuated over time. This can be seen in northeastern and eastern Nevada where, other than the Wells earthquake sequence, the number of earthquakes with magnitude greater than 4 is similar to the number of earthquakes with magnitude under 4. Nevada was fortunate that the US Array was deployed in Nevada when the 2008, M 6.0 Wells earthquake occurred and over 1000 aftershocks were recorded.

Wherever seismic stations are dense enough, smaller earthquakes outnumber larger ones by a ratio of more than 10 to 1. This map can be considered complete above magnitude 7 since 1860, above about magnitude 5.5 for all of Nevada since 1900, above about magnitude 4.0 for all of Nevada since 1940, above magnitude 3.0 for the instrumented parts of Nevada since 1962, and above magnitude 2.0 for instrumented areas since 1980 (Savage and dePolo, 1993). Locations and magnitudes of the major earthquakes outside of Nevada are from Real and others (1978), Arabasz and Smith (1979), Toppozada and others (1981), Toppozada and others (2000), and Pancha and others (2006) and the U.S. Geological Survey Northern California Seismic Network.

Uses of the Earthquake Map

The distribution of epicenters of past earthquakes is sometimes used to anticipate the locations of future large earthquakes. However, the following points should be considered before making such judgments. The absence of earthquake activity at any particular location does not necessarily mean that earthquakes will not occur there in the future. Moderate to large earthquakes have often been preceded by periods of quiescence. The time represented here (~150 years) is far too brief to include all areas of previous earthquake activity. There are many faults where geologists can see evidence of major prehistoric earthquakes, but where historic earthquakes are absent on the map. Nearly every mountain range in Nevada is bounded on one or both sides by faults that produced earthquakes in the geologic past and may be capable of producing earthquakes in the future. This map presents all identified earthquakes recorded in Nevada, regardless of the quality of the location or magnitude. The quality of locations diminishes with increasing time before present and increasing distance from seismic monitoring stations, most of which are in western Nevada.

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