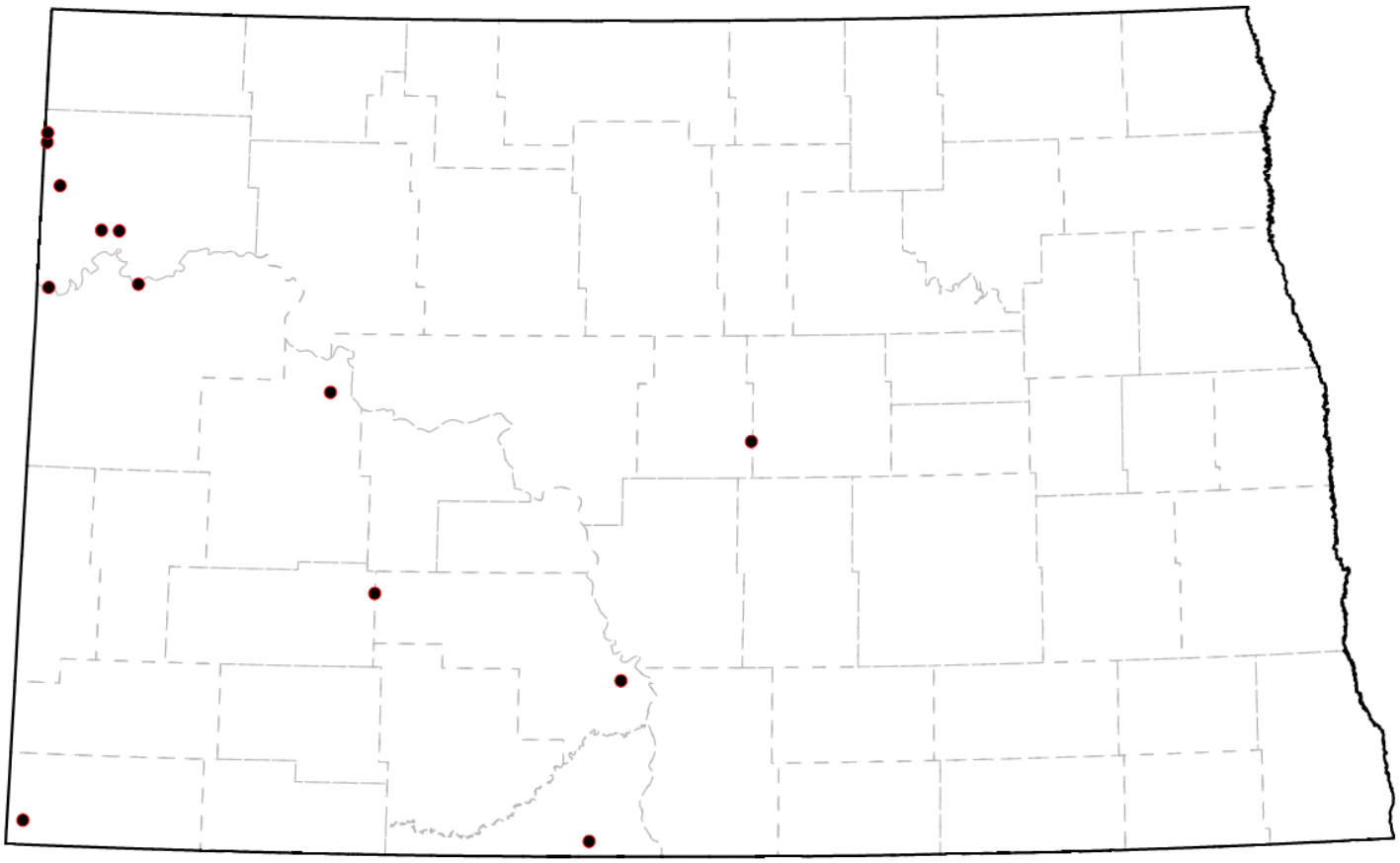
NORTH DAKOTA EARTHQUAKE CATALOG
(1870 - 2015)

Fred J. Anderson



MISCELLANEOUS SERIES NO. 93
NORTH DAKOTA GEOLOGICAL SURVEY
Edward C. Murphy, State Geologist
Lynn D. Helms, Director Dept. of Mineral Resources
2016

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By

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On the cover: Locations of earthquakes reported to have originated in North Dakota and included in this investigation.

Abstract

The North Dakota Earthquake Catalog (1870-2015) provides seismological information on thirteen earthquakes that have been reported to have occurred in the state along with a brief discussion of eight additional historic earthquakes that were reported to have been felt in the state but are known to have originated outside the state. Today and historically, the state continues to be in one of the most geologically stable areas of the North American Continent. Earthquakes that have occurred in the state are generally of magnitude (M) 3.0 or less and may occur about once per decade. The largest earthquake to have occurred in the state remains to be the July 8, 1968 M 4.4 Huff earthquake which is also the first earthquake in the state to have had an instrumentally located epicenter. Prior to this event, the locations of earthquakes in the state were more likely to have been determined by individual reports of observed earthquake intensity effects such as ground shaking. There are currently three seismic monitoring stations in operation in North Dakota with the capabilities to detect earthquakes that originate at local, regional, and global distances: one location south of Bismarck near Huff, one in the Red River Valley just northwest of Fargo, and one southeast of Devils Lake near Maddock.

Acknowledgements

The author would like to acknowledge the continued work of Mr. Elroy Kadrmas, GIS Specialist at the NDGS, for his contributions to cartographic design work in previous earthquake map compilations for North Dakota and Mr. Mike Stickney at the Montana Bureau of Mines and Geology, Earthquake Studies Office in Butte, Montana for past consultation with the author on technical seismological matters.

Author's Note

The intent of this catalog is to provide a compilation of the available seismological information and data sources for earthquakes that have occurred in the state along with the details of the events from the original sources where the earthquakes were first reported in the geoscience and government literature of the time. This catalog also serves as a companion volume to North Dakota Geological Survey Geologic Investigation No. 187, Earthquakes in North Dakota, a 1:1,000,000 scale earthquake location map compilation completed in 2015 by the author.

All magnitudes included in this report are as Richter (local) magnitudes or as originally reported in the source documentation for the particular seismic event. Further collection of individual newspaper accounts for the events included here was beyond the scope of this study, but with the continuing improvement and availability of digital newspaper records, would be a logical and beneficial next step in recovery of these original primary seismological information sources.

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INTRODUCTION

North Dakota continues to be one of the least seismologically active areas in the United States. Minor earthquakes with magnitudes of 3 or less do occur in the state at a frequency of about once per decade. Since the early 1900's there have been 13 earthquakes reported to have originated with the state. There have also been several earthquakes from surrounding states, primarily Montana, that reportedly have been felt by residents of North Dakota. Recent installation of new broadband seismic monitoring instrumentation in southern Benson, eastern Cass, and southeastern Morton counties in addition to seismometers located in surrounding states and provinces now permit the monitoring of seismological activity in the state. This catalog provides an accounting of the earthquakes that have occurred in the state over the last century and up to today and includes original reporting source documentation and seismological related observations where available.

REGIONAL TECTONIC SETTING AND SEISMICITY

Major Faults and Tectonic Boundaries

The state of North Dakota is underlain by Precambrian age basement rocks of the Superior Cratonic Province in the east and rocks of the Trans-Hudson Province in the west (Figure 1). Between these two provinces is a north-south trending transition zone; the Superior Trans-Hudson Boundary Zone, which sutures the two larger provinces together. The rocks in the Superior Cratonic Province form a greenstone-granite-gneiss terrane of Archean age rocks which are 2.7 billion years old. The rocks in the Trans-Hudson Province, underlying the western part of the state, are about a billion years younger and consist of metamorphosed sedimentary and volcanic rocks that were sutured to the Superior Province by the rocks in the Superior Trans-Hudson Boundary Zone; the end product of orogenic events (i.e. mountain building) that occurred in late Archaen-early Proterozoic time. A small sliver of metamorphic rocks of late Archean age, 3.4 – 2.5 billion years old, are underlain in the extreme southwestern part of the state southwest of the Cedar Creek Anticline. These are the oldest rocks found in the state and belong to the Black Hills Domain of the Trans-Hudson Orogen (Anderson, 2007, Nesheim 2012, Sims, et.al 1991). The largest structural feature in North Dakota is the Williston Basin, a structural and depositional basin which covers nearly three-quarters of the state.

There are ten faults that occur within these Precambrian age basement rocks of North Dakota and possibly one that has yet to be fully characterized (Sims, 1991, Nesheim, 2012). Eight of the ten faults occur in western North Dakota and tend to be somewhat concentrated in the northwestern part of the state in the deeper parts of the Williston Basin (Figure 1). These faults are the Brockton-Froid, Nesson, Makoti, Stanton, Heart River, Fort Yates, Cedar Creek, and Hartville-Rawhide fault. The remaining two faults that occur in northeastern and southeastern North Dakota near the state and provincial borders of Minnesota and Manitoba and South Dakota and Minnesota are the Vermillion and Wheaton Fault, respectively. All of the faults that occur in or near the state follow NW-SE or SW to NE orthogonal trends that are consistent with the regional structural geologic framework. One additional northwestward trending fault may be present in northwest North Dakota near Williston but has yet to be fully investigated. The alignment of earthquake epicenters in this area suggests an underlying structural component that has yet to be identified.

Earthquakes that Have Occurred in the State

As of this writing, there have been thirteen earthquakes that have occurred in the state since the early 1900's (Table 1), most of which were reported through felt reports chronicled in local North Dakota newspapers. Most of the recent earthquakes that have occurred in North Dakota, those that have occurred since the 1968 M 4.4 Huff event, are of the instrumental variety in that they have not been felt by or reported by residents of the state but have been detected only by sensitive seismological monitoring instruments that have been recently installed from ongoing seismological investigations across the continental U.S. (Anderson, 2016). On average, a minor earthquake may occur in the state around once per decade, but is not likely to be felt by residents (Figure 2). Following are summary descriptions of for each of these thirteen earthquakes:

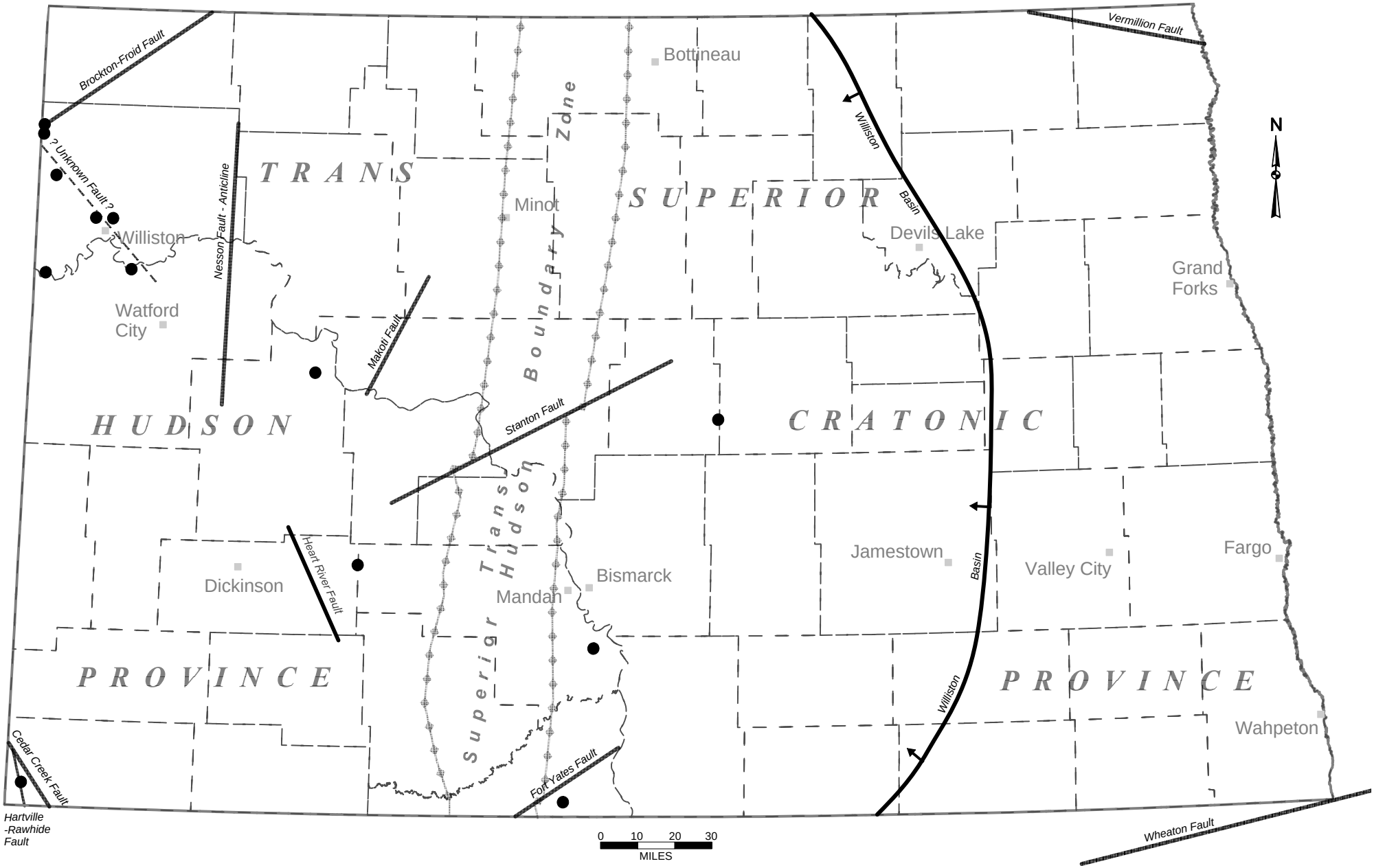

Figure 1. Locations of major faults and tectonic boundaries along with earthquakes that have occurred in North Dakota (as modified from Sims, et.al., 1991, and Nesheim, 2012).

Table 1. Summary of earthquakes that have been reported to have occurred in North Dakota.

Day	Date	Time (local)	Magnitude	Depth (mi.)	Modified Mercalli Intensity	Longitude	Latitude	City or Vicinity of Earthquake
Friday	September 28, 2012	05:53:43	3.3	0.4*	III	-103.48	48.01	SE of Williston
Monday	June 14, 2010	02:58:03	1.4	3.1	I	-103.96	46.03	Boxelder Creek
Sunday	March 21, 2010	11:56:40	2.5	3.1	II	-103.98	47.98	Buford
Sunday	August 30, 2009	20:24:23	1.9	3.1	I	-102.38	47.63	Ft. Berthold SW
Saturday	January 3, 2009	07:53:48	1.5	8.3	I	-103.95	48.36	Grenora
Saturday	November 15, 2008	10:21:27	2.6	11.2	II	-100.04	47.46	Goodrich
Wednesday	November 11, 1998	06:59:37	3.5	3.1	IV	-104.03	48.55	Grenora
Tuesday	March 9, 1982	07:10:50	3.3	11.2	III	-104.03	48.51	Grenora
Monday	July 8, 1968	10:50:12	4.4	20.5	IV	-100.74	46.59	Huff
Tuesday	May 13, 1947	00:02:--	3.7e	U	IV	-100.90	46.00	Selfridge
Sunday	October 26, 1946	15:37:--	3.7e	U	IV	-103.70	48.20	Williston
Friday	April 29, 1927	20:15:--	3.2e	U	III	-102.10	46.90	Hebron
Sunday	August 8, 1915	09:15:--	3.7e	U	IV	-103.60	48.20	Williston

e = magnitude estimated from reported Modified Mercalli Intensity value.

*estimated depth.

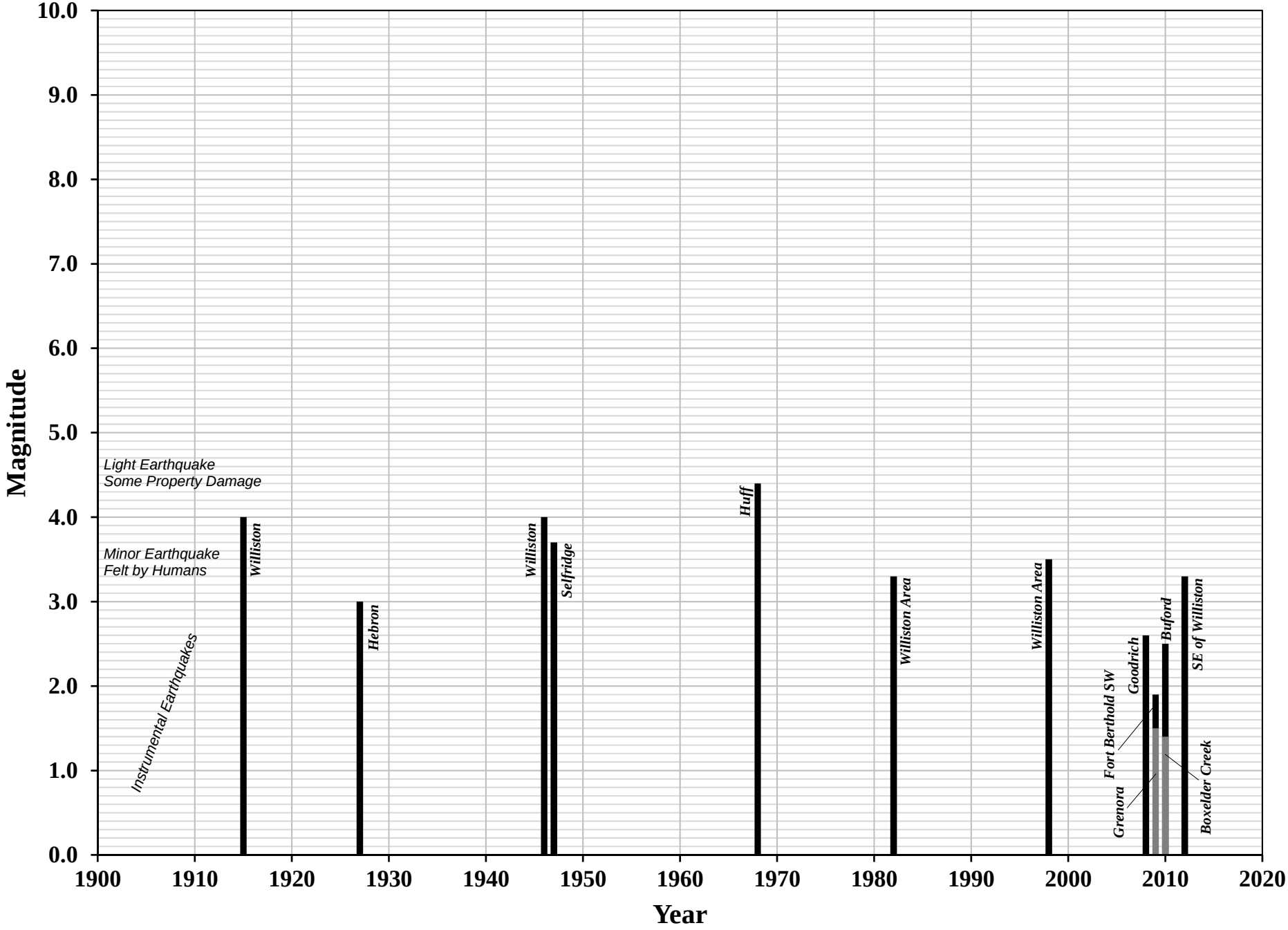

Figure 2. Historical timeline of earthquakes that have originated in North Dakota.

August 8, 1915 M 3.7 Earthquake north of Williston, North Dakota

A magnitude M 3.7 earthquake was recorded four miles north of Williston in southwestern Williams County in northwestern North Dakota during the morning of Sunday, August 8, 1915 at an undetermined depth. This earthquake was originally reported in monthly seismological reports prepared by the U.S. Weather Bureau (1915) and was also compiled in reports of other earthquakes for the midcontinent in a Doctoral Dissertation by Docekal (1970) completed at the University of Nebraska. It was reported that a shock was felt lasting two to five seconds which awakened residents, shook houses, and rattled dishes.

Day	Date	Time (local)	Time (UTC)	Magnitude	Depth (miles)	MMI	T & R	Longitude	Latitude
Sunday	08/08/1915	9:15:--	15:15:--	3.7e	U	IV	155-99	-103.60	48.20

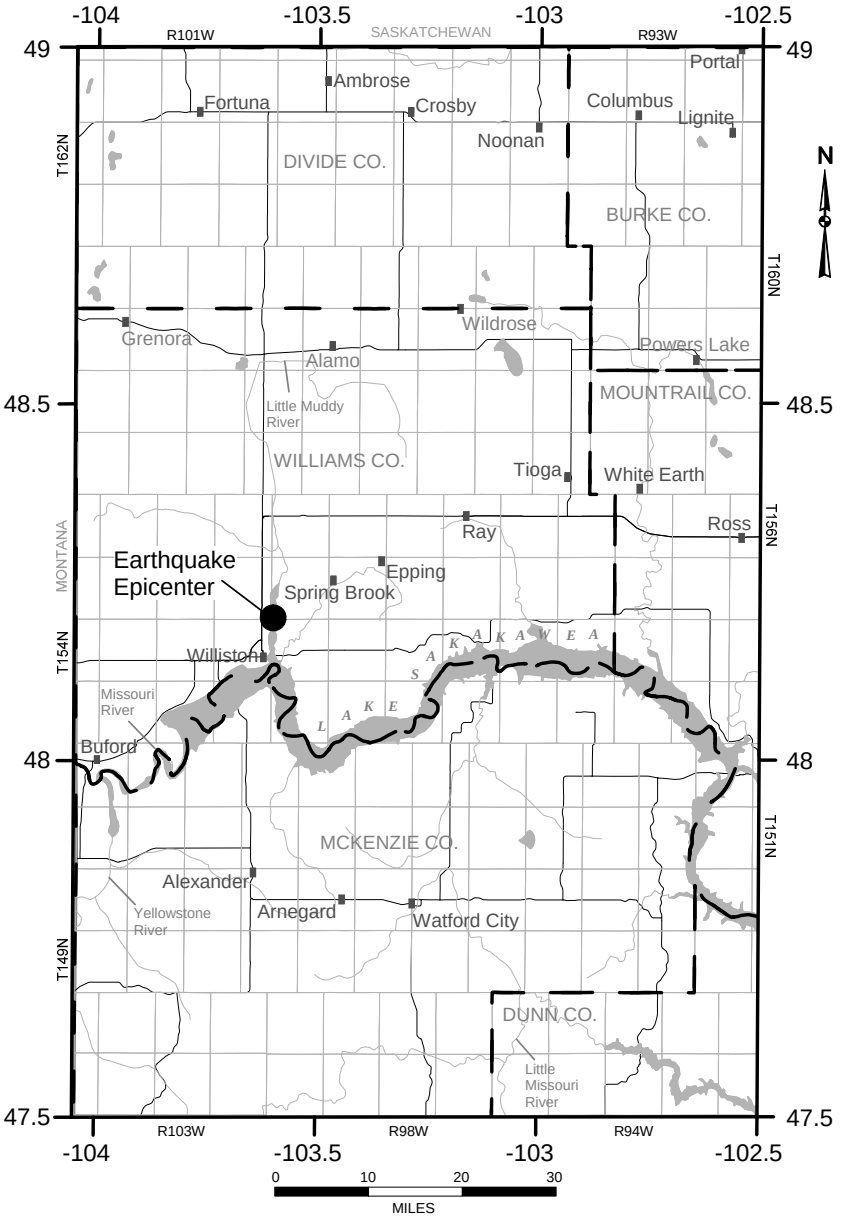

Figure 3. Location of the August 8, 1915 M 3.7e earthquake north of Williston in southwestern Williams County-northwestern North Dakota.

April 29, 1927 M 3.2e Earthquake west of Hebron, North Dakota

An earthquake with an estimated magnitude M 3.2e was reported three miles west of Hebron in northeastern Stark County in western North Dakota on Friday evening, April 29, 1927 at an undetermined depth. This earthquake was originally reported by the U.S. Coast and Geodetic Survey in their seismological report for the months of April, May, and June of 1927 (Neuman, 1930). It was reported that "trembling and rocking in an *east-west* direction" was felt at Hebron. It was also reported that; "Pictures moved, and hanging objects swung." This earthquake was originally reported with a Mercalli Intesity of II which was later upgraded to a III by the USGS's 1981 Map of the Seismicity of North Dakota (Reagor, et. al., 1981). This earthquake was also compiled in reports of other earthquakes for the midcontinent in a Doctoral Dissertation by Docekal (1970) completed at the University of Nebraska.

Day	Date	Time (local)	Time (UTC)	Magnitude	Depth (miles)	MMI	T & R	Longitude	Latitude
Friday	04/29/1927	20:15:--	02:15:--	3.2e	U	III	140-91	-102.10	46.90

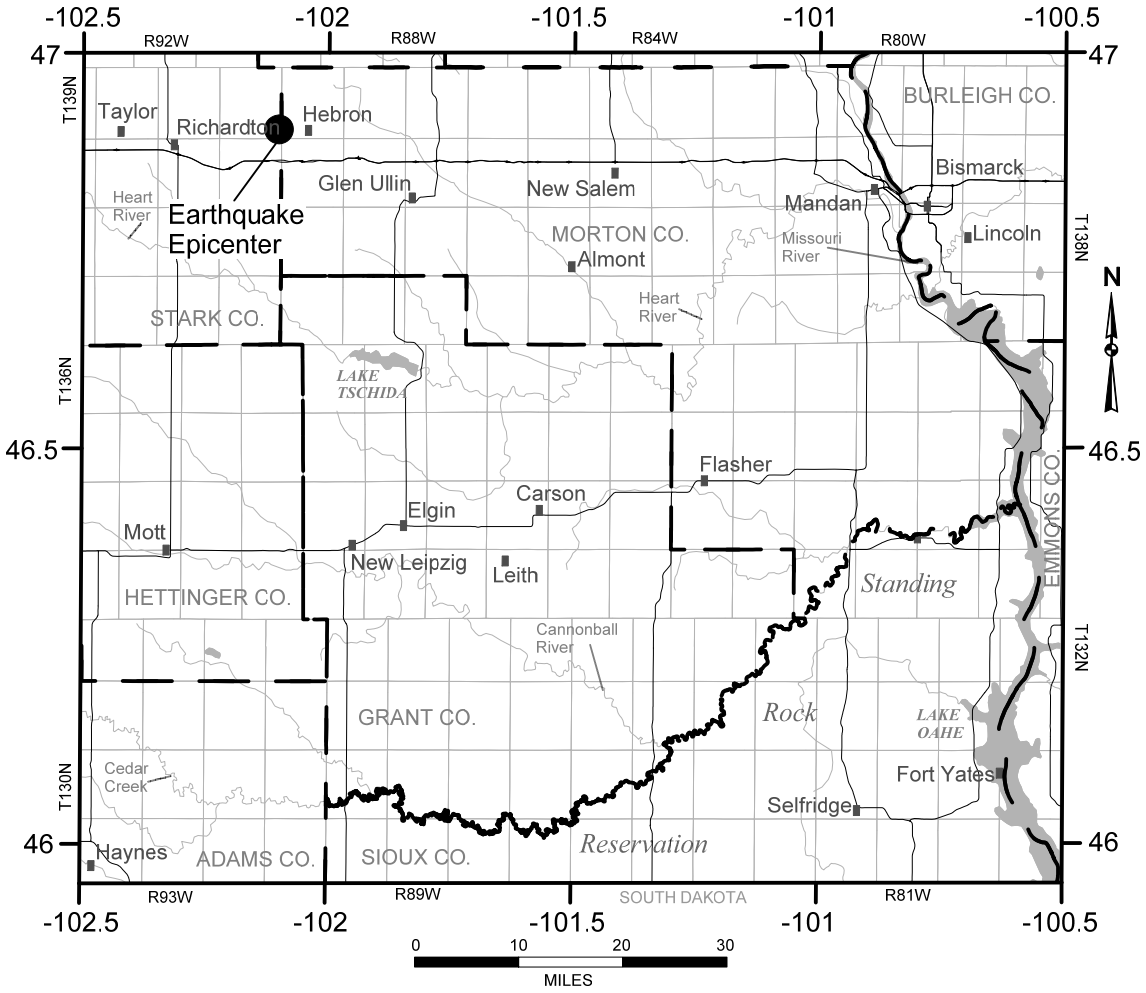

Figure 4. Location of the April 29, 1927 M 3.2e earthquake just west of Hebron in northeastern Stark County in southwestern North Dakota

October 26, 1946 M 3.7 Earthquake northwest of Williston, North Dakota

A magnitude M 3.7 earthquake was recorded six miles northwest of Williston in southwestern Williams County in northwestern North Dakota during the afternoon of Sunday, October 26, 1946 at an undetermined depth. This earthquake was originally reported by the U.S. Coast and Geodetic Survey in their 1946 report on earthquakes occurring in the United States (Bodle and Murphy, 1948) and was also included in a compilation of earthquakes to have occurred in the mid-continent of the United States and published in a Doctoral Dissertation by Docekal (1970) at the University of Nebraska. It was reported that a slight shock lasting five seconds rattled dishes and was felt by many persons at Williston, North Dakota. A very light shock was also reported at the same time in Plentywood, Montana.

Day	Date	Time (local)	Time (UTC)	Magnitude	Depth (miles)	MMI	T & R	Longitude	Latitude
Sunday	10/26/1946	15:37:--	20:37:--	3.7e	U	IV	155-100	-103.70	48.20

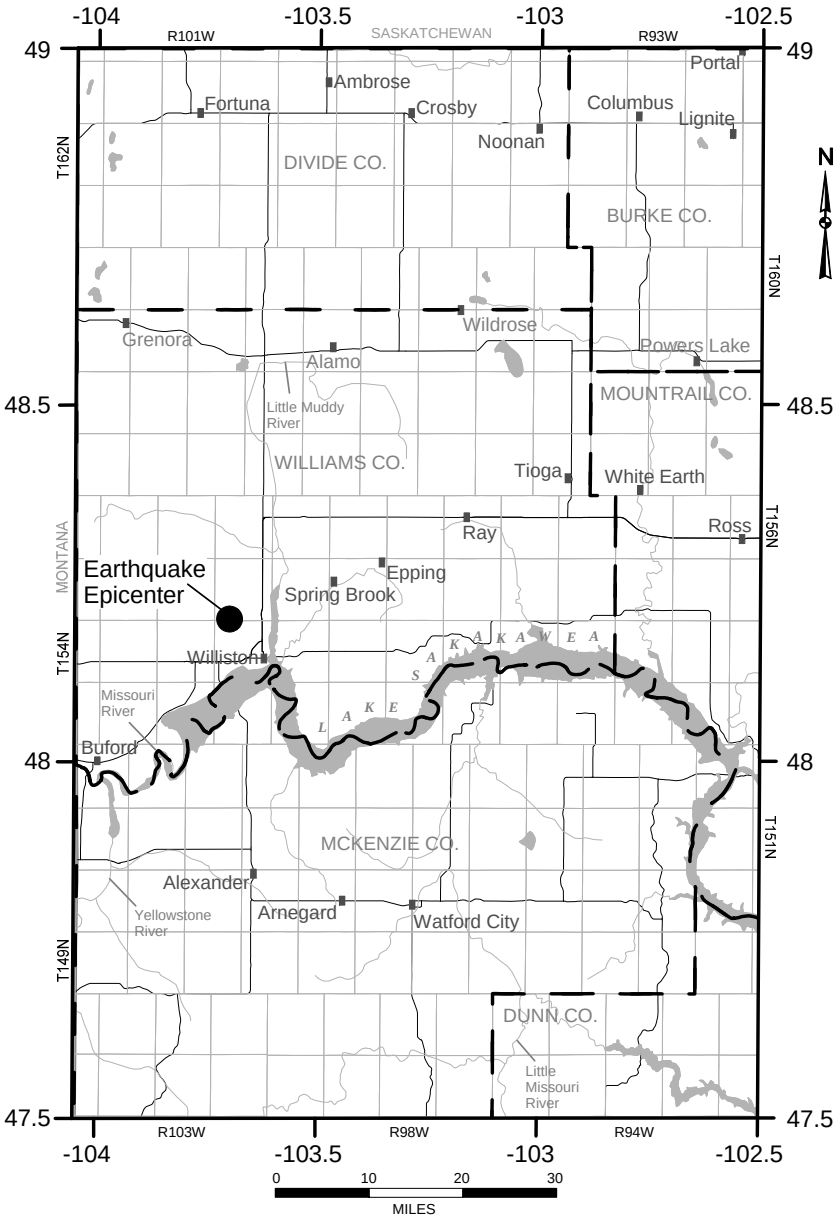

Figure 5. Location of the October 26, 1946 M 3.7e earthquake northwest of Williston in southwestern Williams County-northwestern North Dakota.

May 13, 1947 M3.7 Earthquake near Selfridge, North Dakota

A magnitude M 3.7e earthquake was recorded five miles south of Selfridge in central Sioux County in south-central North Dakota during the late evening – early morning of Tuesday, May 13, 1947 at an undetermined depth. This earthquake was found reported in a Doctoral Dissertation of a compilation of earthquakes that occurred in the mid-continent of the United States, completed by Docekal (1970) at the University of Nebraska. It was reported that "a shock centered near Selfridge, North Dakota, was felt in the Missouri River Valley, possibly for 200 miles from Beulah, North Dakota to Pierre, South Dakota."

Day	Date	Time (local)	Time (UTC)	Magnitude	Depth (miles)	MMI	T & R	Longitude	Latitude
Tuesday	05/13/1947	00:02:--	05:02:--	3.7e	U	IV	129-82	-100.90	46.00

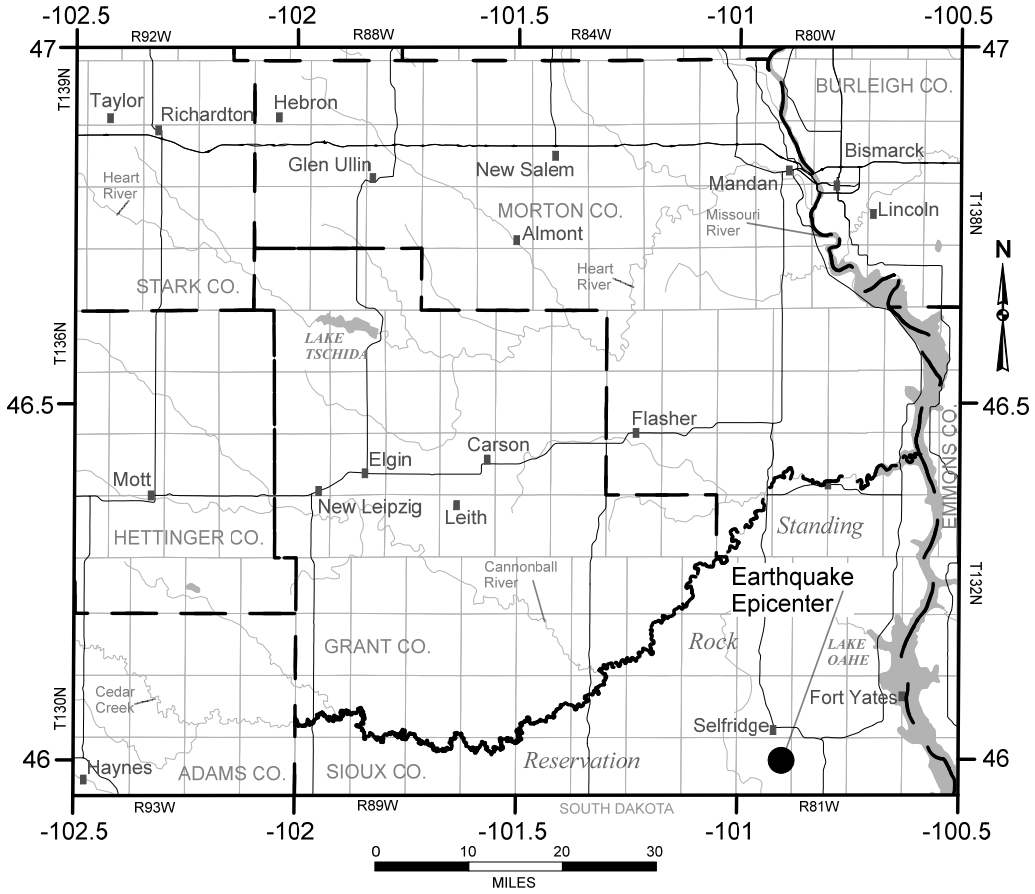

Figure 6. Location of the May 13 M 3.7e earthquake south of Selfridge in south-central Sioux County-south-central North Dakota.

July 8, 1968 M 4.4 Earthquake near Huff, North Dakota

A magnitude M 4.4 earthquake was recorded five miles southwest of Huff in eastern Morton County in south-central North Dakota during the morning of Monday, July 8, 1968 at an estimated depth of 20.5 miles. This earthquake was the first instrumentally verified earthquake recorded in North Dakota and was reported to have been felt over approximately 3,000 square miles of south-central North Dakota. It was reported that "a television set shifted and sounds like thunder were heard." Additionally, Mercalli earthquake intensity IV effects were noted at Bismarck, Fort Rice, Huff, Linton, Mandan, Menoken, and Moffit; and Mercalli intensity I-III effects at Almont, Flasher, Halliday, and St. Anthony (Coffman and Cloud, 1970).

Day	Date	Time (local)	Time (UTC)	Magnitude	Depth (miles)	MMI	T & R	Longitude	Latitude
Monday	07/08/1968	10:50:12	16:50:12	4.4	20.5	IV	136-80	-100.74	46.59

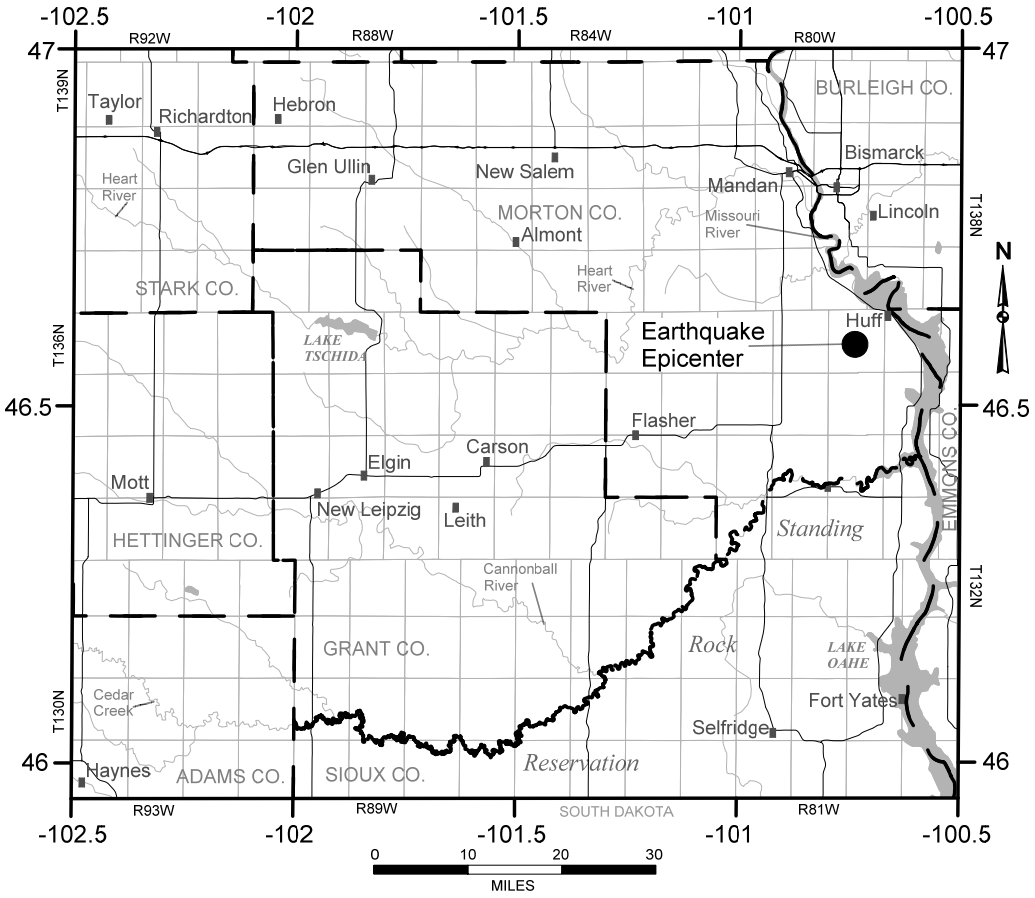

Figure 7. Location of the July 8, 1968 M 4.4 earthquake near Huff in eastern Morton County, south-central North Dakota.

March 9, 1982 M 3.3 Earthquake southwest of Grenora, North Dakota

A magnitude M 3.3 earthquake was recorded six miles southwest of Grenora in northwestern Williams County in northwestern North Dakota during the morning of Tuesday, March 9, 1982 at an estimated depth of 11.2 miles. Intensity III effects were reported by telephone by observers in Antelope, Montana, and Grenora, North Dakota (Stover, 1985).

Day	Date	Time (local)	Time (UTC)	Magnitude	Depth (miles)	MMI	T & R	Longitude	Latitude
Tuesday	03/09/1982	07:10:50	13:10:50	3.3	11.2	III	158-103	-104.03	48.51

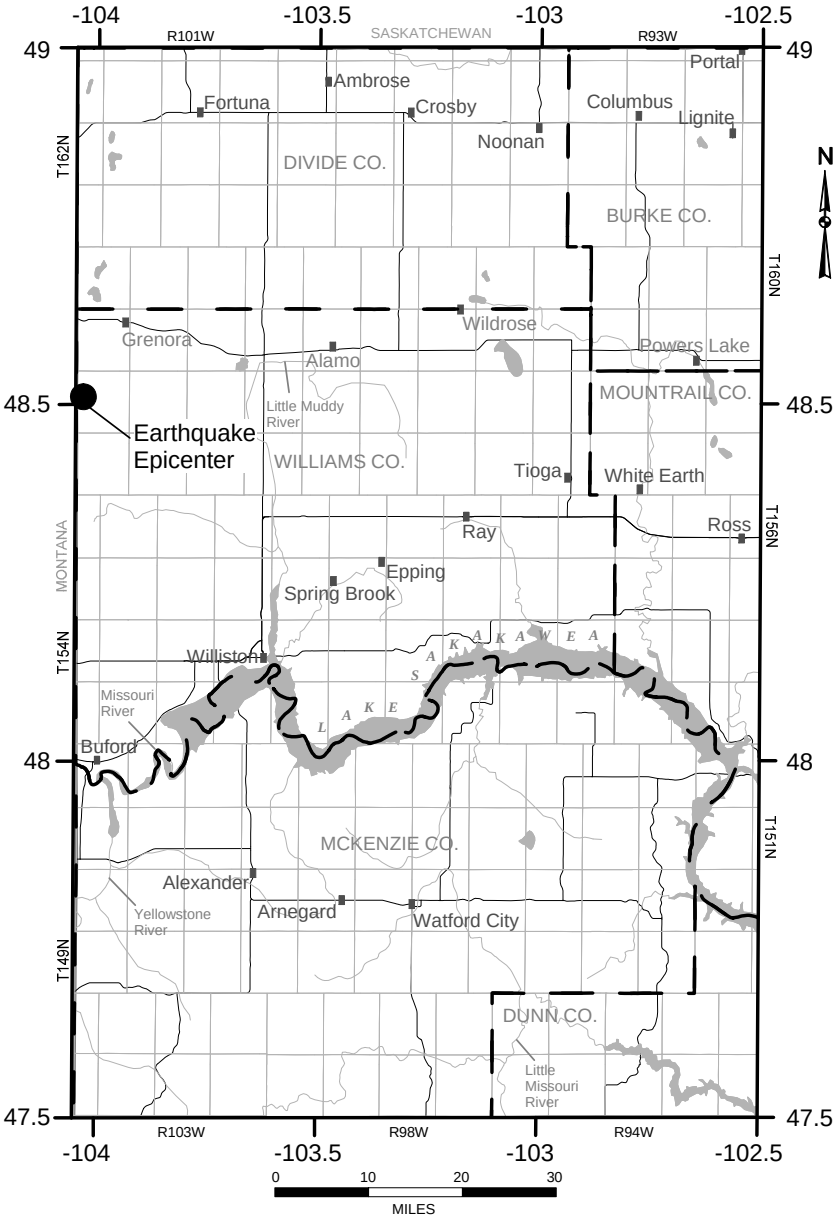

Figure 8. Location of the March 9, 1982 M 3.3 earthquake southwest of Grenora in western Williams County-northwestern North Dakota.

November 11, 1998 M 3.5 Earthquake southwest of Grenora, North Dakota

A magnitude M 3.5 earthquake was recorded six miles southwest of Grenora in northwestern Williams County in northwestern North Dakota during the morning of Wednesday, November 11, 1998 at an estimated depth of 3.1 miles. This earthquake was originally reported by the United States Geological Survey-National Earthquake Information Center as an event for eastern Montana (USGS, 2010).

Day	Date	Time (local)	Time (UTC)	Magnitude	Depth (miles)	MMI	T & R	Longitude	Latitude
Wednesday	11/11/1998	06:59:37	11:59:37	3.5	3.1	IV	159-103	-104.03	48.55

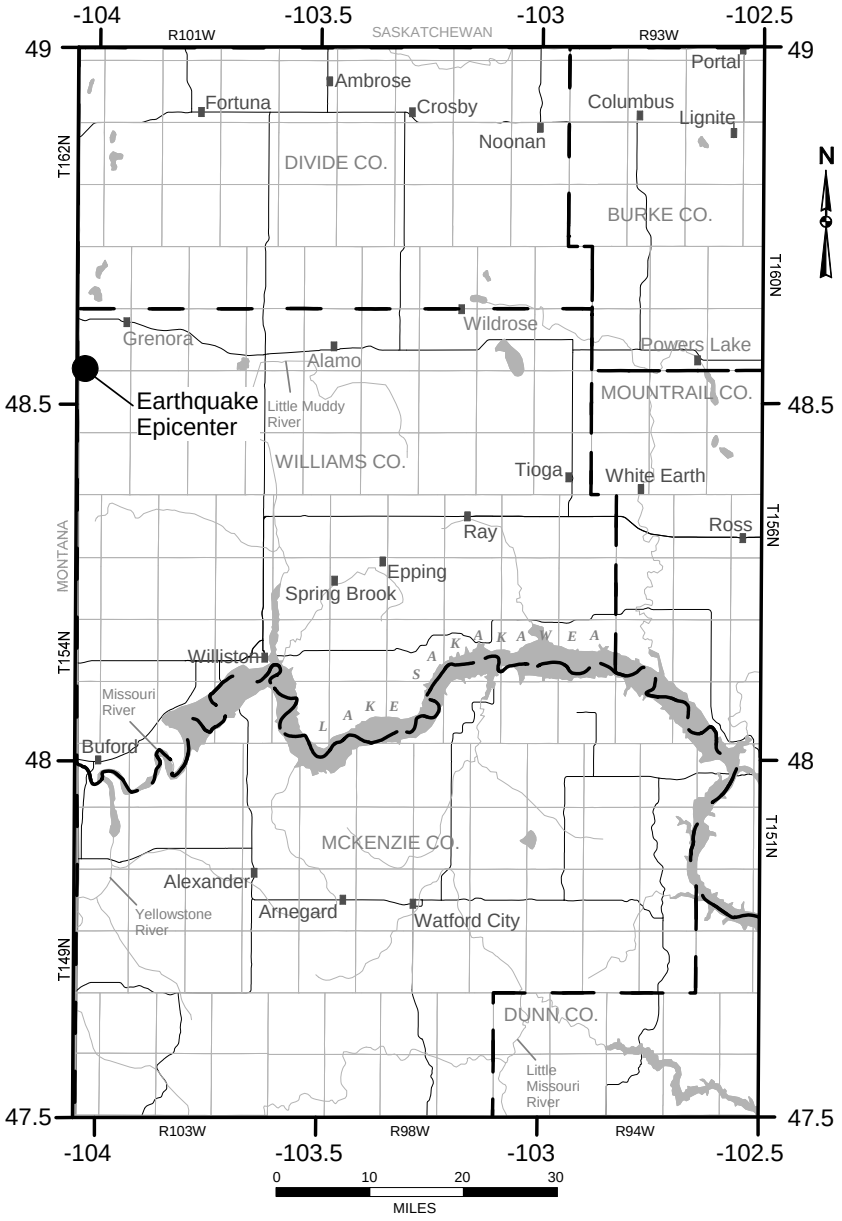

Figure 9. Location of the November 11, 1998 M 3.5 earthquake southwest of Grenora in western Williams County-northwestern North Dakota.

November 15, 2008 M 2.6 Earthquake near Goodrich, North Dakota

A magnitude M 2.6 earthquake was recorded four miles east of Goodrich in southeastern Sheridan County in central North Dakota during the morning of Saturday, November 15, 2008, with an estimated depth of 11.2 miles. This earthquake was reported by the U.S. Geological Survey National Earthquake Information Center in Golden, Colorado. No felt reports were reported.

Day	Date	Time (local)	Time (UTC)	Magnitude	Depth (miles)	MMI	T & R	Longitude	Latitude
Saturday	11/15/2008	10:21:27	16:21:27	2.6	11.2	II	146-74	-100.04	47.46

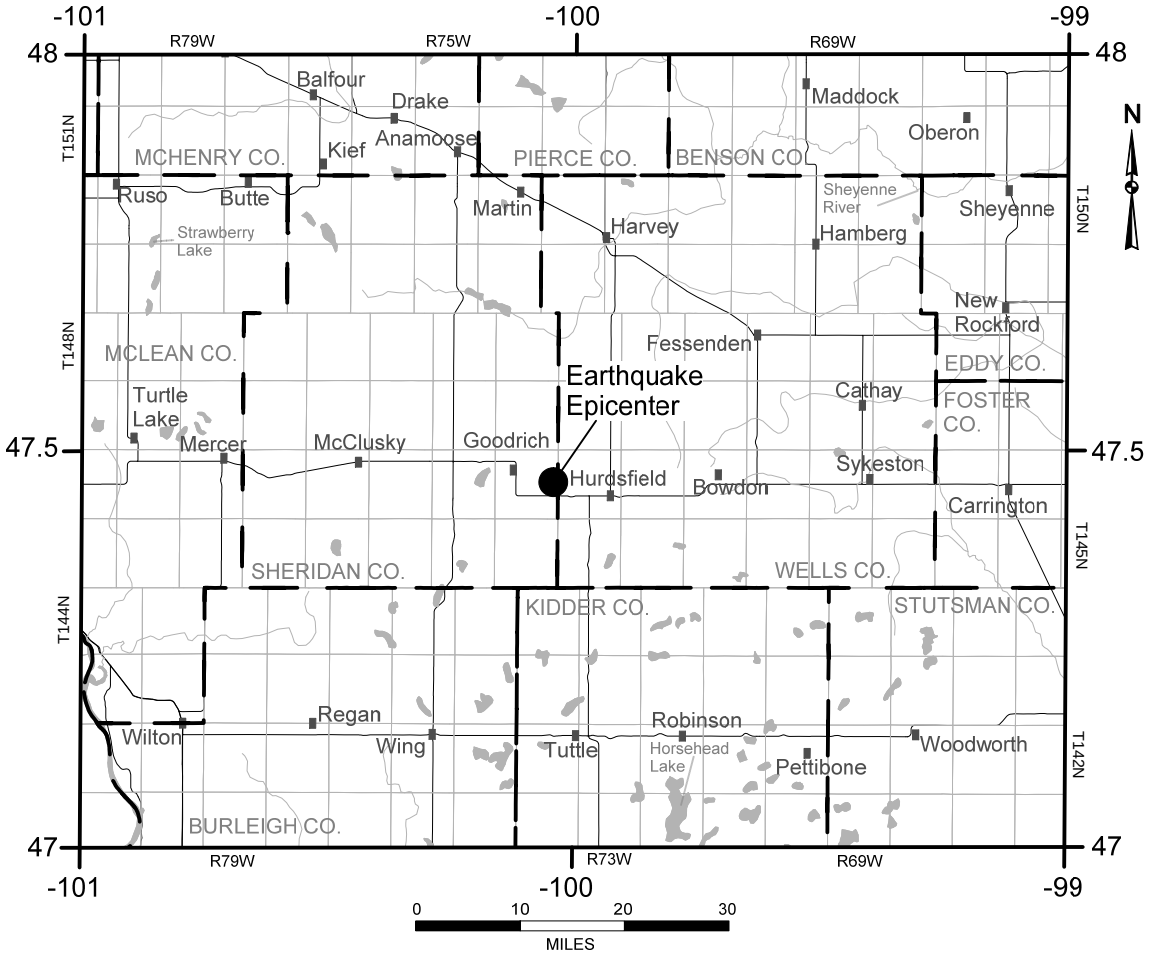

Figure 10. Location of the November 15, 2008 M 2.6 earthquake near Goodrich in southeastern Sheridan County in central North Dakota.

January 3, 2009 M 1.5 Earthquake south of Grenora, North Dakota

A magnitude M 1.5 earthquake was recorded 20 miles south of Grenora in western Williams County in northwestern North Dakota during the morning of Saturday, January 3, 2009 at an estimated depth of 8.3 miles. This earthquake was reported by the Earthquake Studies Office at the Montana Bureau of Mines and Geology during review of seismic data collected by the Dagmar, Montana seismic station (Stickney, 2009). No felt reports were reported.

Day	Date	Time (local)	Time (UTC)	Magnitude	Depth (miles)	MMI	T & R	Longitude	Latitude
Saturday	01/03/2009	07:53:48	13:53:48	1.5	8.3	I	156-103	-103.95	48.36

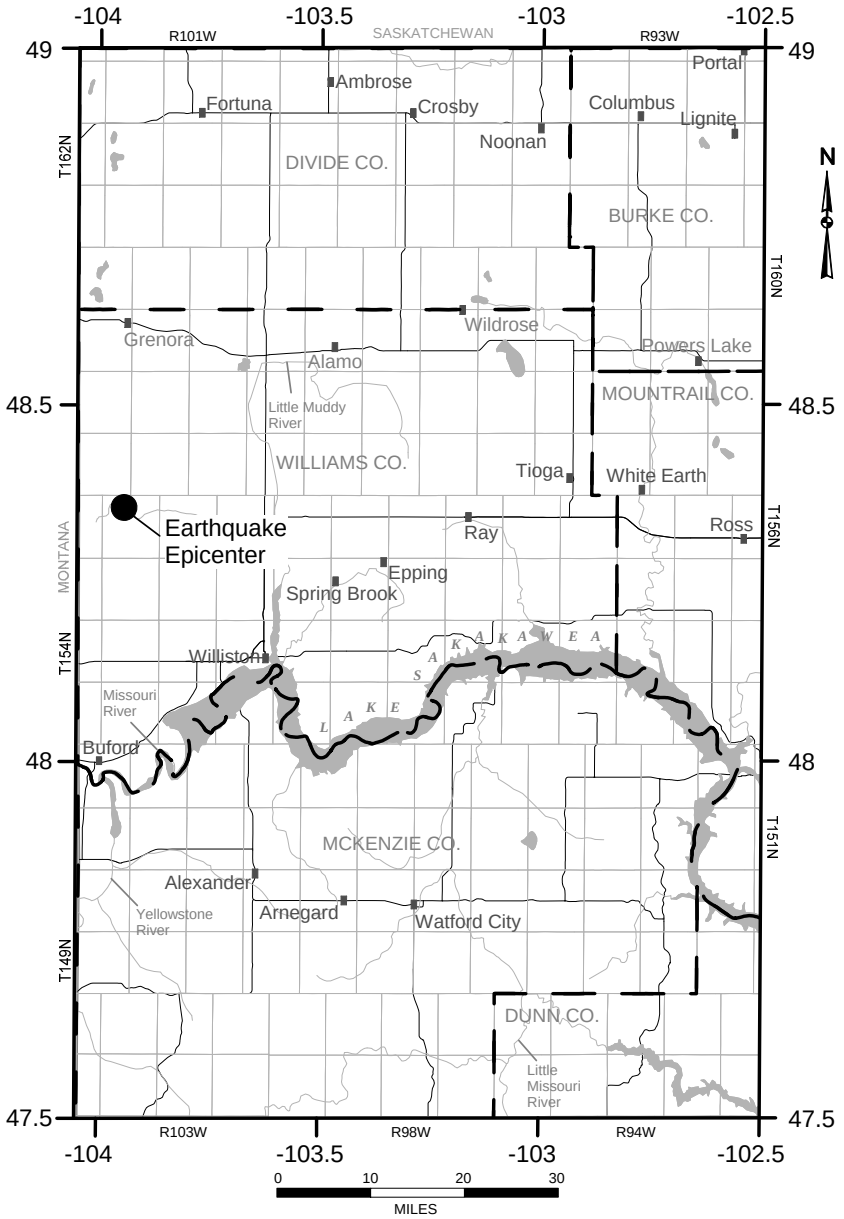

Figure 11. Location of the January 3, 2009 M 1.5 earthquake south of Grenora in western Williams County-northwestern North Dakota.

August 30, 2009 M 1.9 Earthquake in Southwest Fort Berthold, North Dakota

A magnitude M 1.9 earthquake was recorded 25 miles south- southeast of New Town in northeastern Dunn County during the evening of Sunday, August 30, 2009 at an estimated depth of 3.1 miles. This earthquake was reported by Frolich, et.al. (2015) from an earthquake relocation study of seismological data collected during the 2008 to 2012 pass of the EarthScope Transportable Seismic Array through the state. No felt reports were reported.

Day	Date	Time (local)	Time (UTC)	Magnitude	Depth (miles)	MMI	T & R	Longitude	Latitude
Sunday	08/30/2009	20:24:23	01:24:23	1.9	3.1*	I	148-92	-102.38	47.63

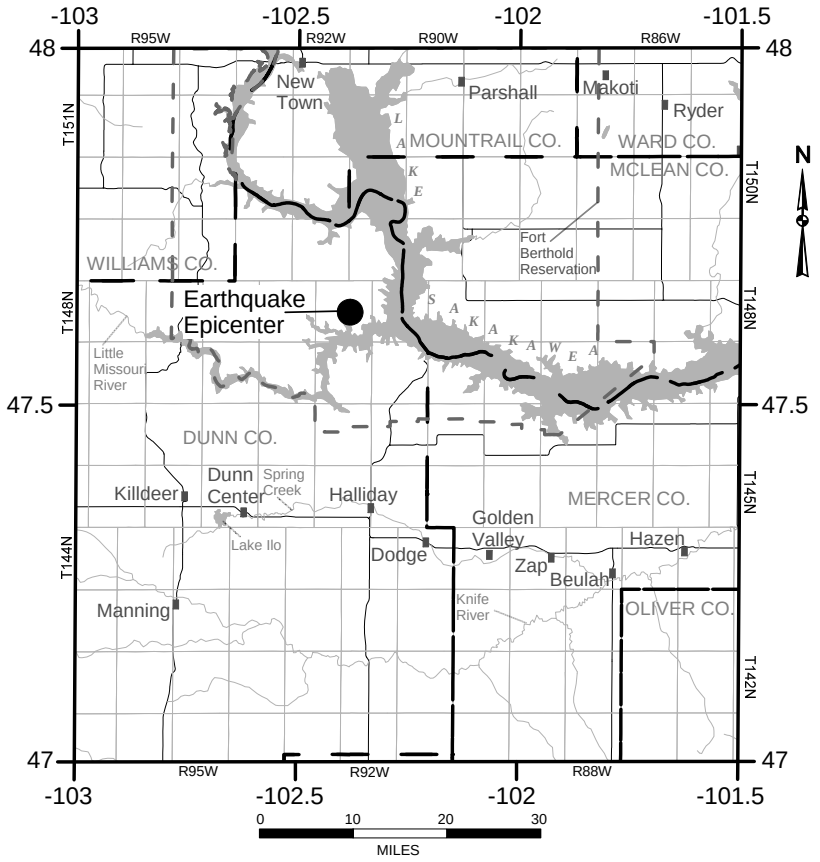

Figure 12. Location of the August 30, 2009 M 1.9 earthquake in the southwestern Fort Berthold Reservation in northeastern Dunn County - west-central North Dakota.

March 21, 2010 M 2.5 Earthquake near Buford, North Dakota

A magnitude M 2.5 earthquake was recorded one mile south of Buford and 20 miles southwest of Williston in western Williams County during the early morning of Sunday, March 21, 2010 at an estimated depth of 3.1 miles. This earthquake was reported by Frolich, et.al., (2015) from an earthquake relocation study of seismological data collected during the 2008 to 2012 pass of the EarthScope Transportable Seismic Array through the state. The earthquake epicenter was located just south of Buford at the confluence of the Yellowstone and Missouri Rivers. No felt reports were reported.

Day	Date	Time (local)	Time (UTC)	Magnitude	Depth (miles)	MMI	T & R	Longitude	Latitude
Sunday	03/21/2010	11:56:40	16:56:40	2.5	3.1*	II	152-104	-103.98	47.98

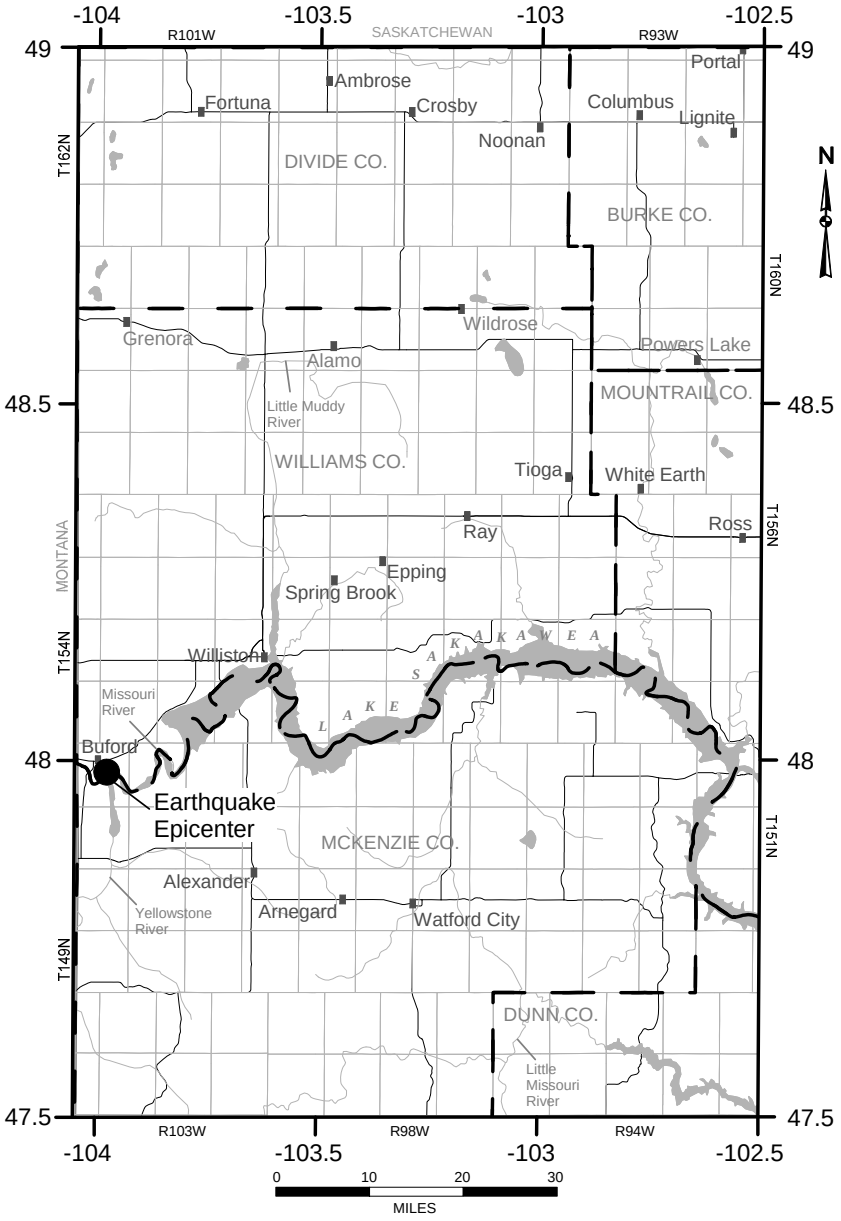

Figure 13. Location of the March 21, 2010 M2.5 earthquake just south of Buford in western Williams County, North Dakota at the confluence of the Yellowstone and Missouri Rivers.

June 14, 2010 M 1.4 Earthquake near Boxelder Creek, North Dakota

A magnitude M 1.4 earthquake was recorded 29 miles southwest of Bowman in southwestern Bowman County during the early morning of Monday, June 14, 2010 at an estimated depth of 3.1 miles. This earthquake was reported by Frolich, et. al. (2015) from an earthquake relocation study of seismological data collected during the 2008 to 2012 pass of the EarthScope Transportable Seismic Array through the state. The earthquake epicenter was located near Boxelder Creek along the Cedar Creek Anticline. No felt reports were reported.

Day	Date	Time (local)	Time (UTC)	Magnitude	Depth (miles)	MMI	T & R	Longitude	Latitude
Monday	06/14/2010	02:58:03	07:58:03	1.4	3.1*	I	129-106	-103.96	46.03

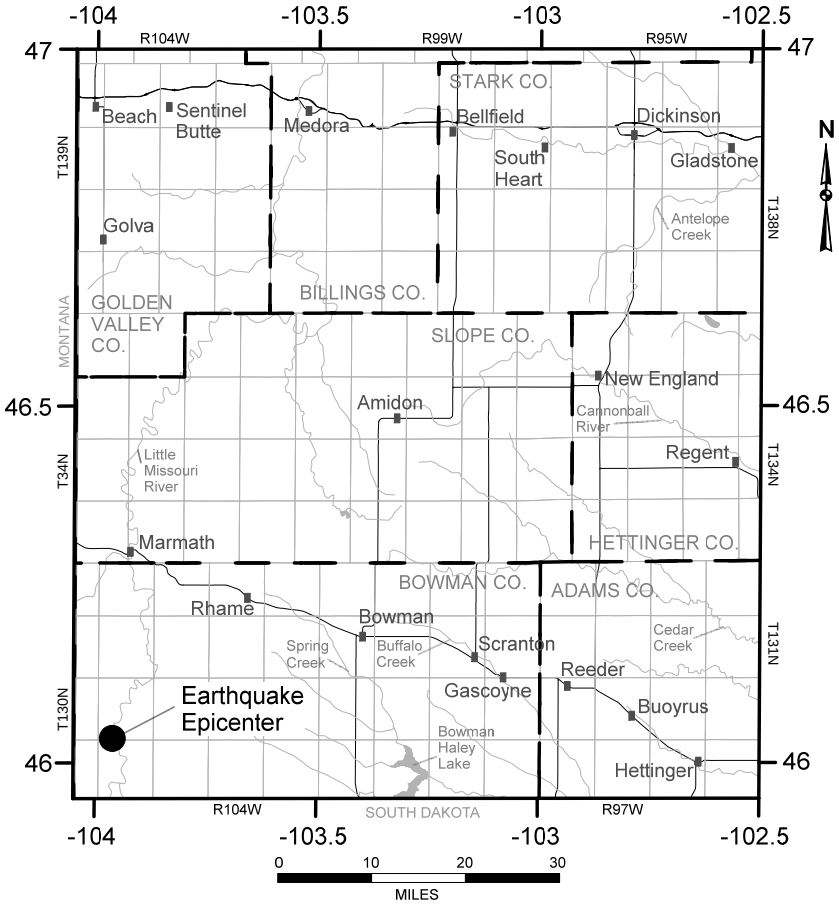

Figure 14. Location of the June 14, 2010 M 1.4 earthquake just west of Boxelder Creek in southwestern Bowman County, North Dakota along the Cedar Creek Anticline.

September 28, 2012 M 3.3 Earthquake Southeast of Williston, North Dakota

A magnitude M 3.3 earthquake was recorded 12 miles southeast of Williston in northern McKenzie County during the early morning of Friday, September 28, 2012 at an estimated depth of 0.4 miles. This earthquake was reported by the Earthquake Studies Office at the Montana Bureau of Mines and Geology during review of seismic data collected by the Dagmar, Montana seismic station (Stickney, 2012). The earthquake epicenter was located beneath Lake Sakakawea. No felt reports were reported.

Day	Date	Time (local)	Time (UTC)	Magnitude	Depth (miles)	MMI	T & R	Longitude	Latitude
Friday	09/28/2012	05:53:43	10:53:43	3.3 Md	0.4	III	152-99	-103.48	48.01

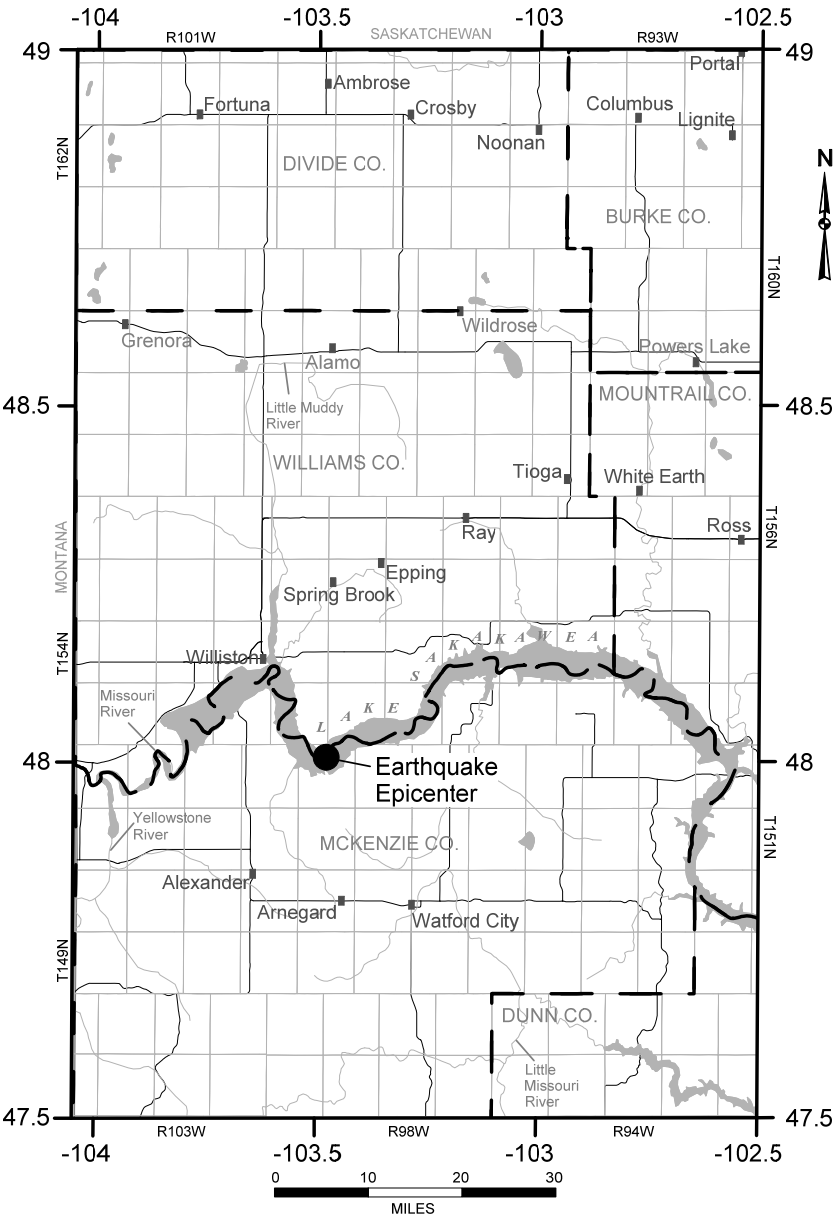

Figure 15. Location of the September 28, 2012 M 3.3 earthquake southeast of Williston, North Dakota, centered in the middle of Lake Sakakawea.

Additional Notable Earthquakes that Have Been Felt in the State

There have been several additional notable regional earthquakes that have been reported to have been felt in North Dakota as well. These events include earthquakes near Wahpeton in the late 1800's, the Pembina area in 1900, the Northern Great Plains Earthquake of May 16, 1909 in northeastern Montana; which was felt across the entire state, an earthquake in the Havana area in the early 1930's, an earthquake near Medicine Lake, Montana in the early 1940s, the Hebgen Lake Montana earthquake of 1959, a M 7.3 event which is also reported to be Montana's largest earthquake and was reported to have been felt in Williston and westernmost North Dakota, and earthquakes that originated in the area of Morris, Minnesota in the mid 1970's and mid 1990's (Bluemle, 2000, Stover and Coffman, 1993).

Active Seismic Monitoring Stations in the Region

Prior to 2008, the state of North Dakota did not have any seismic monitoring instrumentation in place capable of recording earthquakes. Now North Dakota has three operating broadband seismic monitoring stations (Table 2) in the south-central and eastern parts of the state (Figure 3) one near Maddock in the east-central part of the state in southern Benson County, one near Gardner, just northwest of Fargo in the southwestern Red River Valley in southeastern North Dakota in Cass County and one near Huff in south-central North Dakota in southeastern Morton County. Our closest seismic monitoring station to the west is near Dagmar, Montana and is operated by the Montana Bureau of Mines and Geology's Earthquake Studies Office. A second Montana station that is close to North Dakota is located near Angela in eastern Montana. The regional station network can provide complete seismic monitoring coverage across North Dakota and includes the following additional six stations: Rapid City and Miller, South Dakota; two stations in eastern Minnesota (5 Mile Ranch and at the Agassiz National Wildlife Refuge); one station in southeastern Saskatchewan at Aquistore, and one in southwestern Manitoba at Lac Du Bonnet.

Table 2. Seismic monitoring stations in North Dakota

Station		Operational Date	Seismic Monitoring Instrumentation	Network	County	Longitude	Latitude
Name	ID						
Maddock	MDND	10/4/2008	Streckeisen STS-2	USArray Reference	Benson	-99.60	47.85
Huff	E28B	8/18/2009	Streckeisen STS-2	Central and Eastern US	Morton	-100.69	46.57
Gardner	D32B	11/20/2013	Streckeisen STS-2.5	Central and Eastern US	Cass	-97.02	47.14

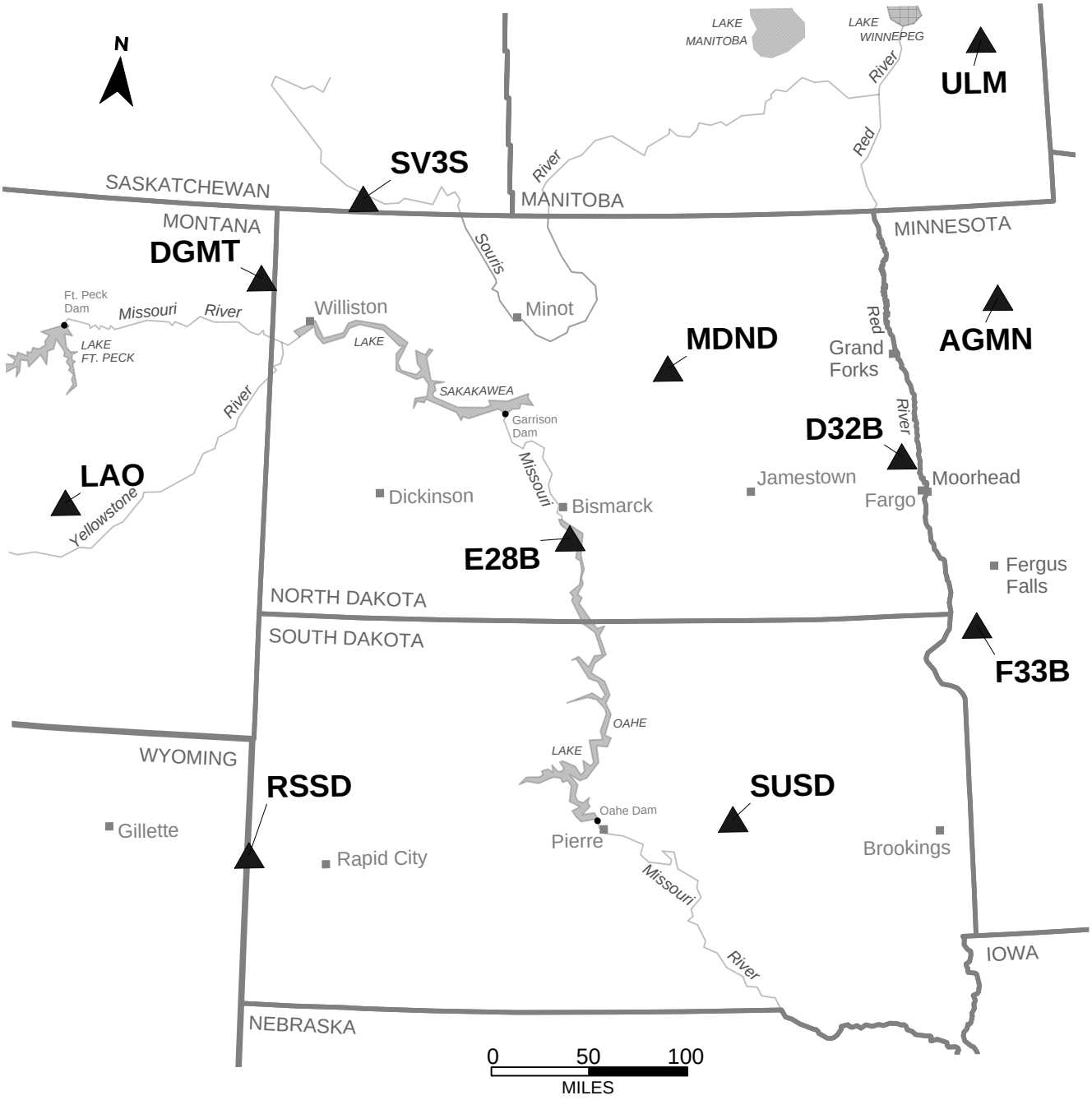

Figure 16. Seismic monitoring stations located in around North Dakota. Stations (shown as black triangles) include the LASA Array Station near Angela, Montana (LAO), Dagmar, Montana (DGMT), Rapid City, South Dakota (RSSD), Aquistore, Saskatchewan, Canada (SV3S), Huff Hills, North Dakota (E28B), Maddock, North Dakota (MDND), Miller, South Dakota (SUSD), Gardner, North Dakota (D32B), 5 Mile Ranch, Herman, Minnesota (F33B), Agassiz National Wildlife Refuge, Minnesota (AGMN), and Lac du Bonnet, Manitoba, Canada (ULM).

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APPENDIX I

Modified Mercalli Earthquake Intensity Scale of 1931

Intensity	Description of Observable Phenomena
I	Not felt – or, except rarely under especially favorable circumstances. Under certain conditions, at and outside the boundary of the area in which a great shock is felt: sometimes birds, animals, reported uneasy or disturbed; sometimes dizziness or nausea experienced; sometimes trees, structures, liquids, bodies of water, may sway-doors may swing, very slowly.
II	Felt indoors by few, especially on upper floors, or by sensitive, or nervous persons. Also, as in grade I, but often more noticeably; sometimes hanging objects may swing, especially when delicately suspended; sometimes trees, structures, liquids, bodies of water, may sway, doors may swing, very slowly; sometimes birds, animals, reported uneasy or disturbed; sometimes dizziness of nausea experienced.
III	Felt indoors by several, motion usually rapid vibration. Sometimes not recognized to be an earthquake at first. Duration estimated in some cases. Vibration like that due to passing of light, or lightly loaded trucks, or heavy trucks some distance away. Hanging objects may swing slightly. Movements may be appreciable on upper levels of tall structures. Rocked standing motor cars slightly.
IV	Felt indoors by many, outdoors by few. Awakened few, especially light sleepers. Frightened no one, unless apprehensive from previous experience. Vibration like that due to a passing of heavy or heavily loaded trucks. Sensation like heavy body striking building or falling of heavy objects inside. Rattling of dishes, windows, doors; glassware and crockery clink and clash. Creaking of walls, frame, especially in the upper range of this grade. Hanging objects swung, in numerous instances. Disturbed liquids in open vessels slightly. Rocked standing motor cars noticeably.
V	Felt indoors by practically all, outdoors by many or most: outdoors direction estimated. Awakened many, or most. Frightened few –slight excitement, a few ran out doors. Buildings trembled throughout. Broke dishes, glassware, to some extent. Cracked windows – in some cases, but not generally. Overturn vases, small or unstable objects, in many instances, with occasional fall. Hanging objects, doors, swing generally or considerably. Knocked pictures against walls, or swung them out of place. Opened, or closed, doors, shutters, abruptly. Pendulum clocks stopped, started or ran fast, or slow. Moved small objects, furnishings, the latter to slight extent. Spilled liquids in small amounts from well-filled open containers. Trees, bushes, shaken slightly.
VI	Felt by all, indoors and outdoors. Frightened many, excitement general, some alarm, many and ran outdoors. Awakened all. Persons made to move unsteadily. Trees, bushes, shaken slightly to moderately. Liquid set in strong motion. Small bells rang –church, chapel, school, etc. Damage slight in poorly built buildings. Fall of plaster in small amount. Cracked plaster somewhat, especially find cracks in chimneys in some instances. Broke dishes, glassware, in considerable quantity, also some windows. Fall of knick-knacks, books, pictures. Overturned furniture in many instances. Moved furnishings of moderately heavy kind.
VII	Frightened all-general alarm, all ran outdoors. Some, or many, found it difficult to stand. Noticed by persons driving motor cars. Trees and bushes shaken moderately to strongly. Waves on ponds, lakes, and running water. Water turbid from mud stirred up. Incaving to some extent of sand or gravel stream banks. Rang large church bells, etc. Suspended objects made to quiver. Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary buildings, considerable in poorly built or badly designed buildings, adobe houses, old walls (especially where laid-up without mortar), spires, etc. Cracked chimneys to considerable extent, walls to some extent. Fall of plaster in considerable to large amount, also some stucco. Broke numerous windows, furniture to some extent. Shook down loosened brickwork and tiles. Broke weak chimneys at the roofline (sometimes damaging roofs). Fall of cornices from towers and high buildings. Dislodged bricks and stones. Overturned heavy furniture, with damage from breaking. Damage considerable to concrete irrigation ditches.
VIII	Fright general- alarm approaches panic. Disturbed persons driving motor cars. Trees shaken strongly-branches, trunks, broken off, especially palm trees. Ejected sand and mud in small amounts. Changes: temporary, permanent; in flow of springs and wells; dry wells renewed flow; in temperature of spring and well waters. Damage slight in structures (brick) built especially to withstand earthquakes. Considerable in ordinary substantial buildings, partial collapse: racked, tumbled down , wooden houses in some cases; threw out panel walls in frame structures, broke off decayed piling. Fall of walls. Cracked, broke, solid stone walls seriously. Wet ground to some extent, also ground on steep slopes. Twisting, fall of chimneys, columns, monuments, also factor stacks, towers. Moved conspicuously, overturned, very heavy furniture.
IX	Panic in general. Cracked ground conspicuously. Damage considerable in (masonry) structures built especially to withstand earthquakes: threw out of plum some wood-frame houses built especially to withstand earthquakes; great in substantial (masonry) buildings, that some class in large part; or wholly shifted frame buildings off foundations, racked frames; serious to reservoirs; underground pipes sometimes broken.
X	Cracked ground, especially when loose and wet, up to widths of several inches; fissures up to a yard in width ran parallel to canal and stream banks. Landslides considerable from river banks and steep coasts. Shifted sand and mud horizontally on beaches and flat land. Changed level of water in wells. Threw water on banks of canals, lakes, rivers, etc. Damage serious to dams, dikes, embankments. Sever to well-built wooden structures and bridges, some destroyed. Developed dangerous cracks in excellent brick walls. Destroyed most masonry and frame structures, also their foundations. Bent railroad rails slightly. Tore apart, or crushed endwise, pipe lines buried in earth. Open cracks and broad wavy folds in cement pavements and asphalt road surfaces.
XI	Disturbances in ground many and widespread, varying with ground material. Broad fissures, earth slumps, and land slips in soft, wet ground. Ejected water in large amounts charged with sand and mud. Caused tsunami waves of significant magnitude. Damage severe to wood-frame structures, especially near shock centers. Great to dams, dikes, embankments often for long distances. Few, if any (masonry) structures remained standing. Destroyed large well-built bridges by the wrecking of supporting piers, or pillars. Affected yielding wooden bridges less. Bent railroad rails greatly, and thrust them endwise. Put pipe lines buried in earth completely out of service.
XII	Damage total-practically all works of construction damaged greatly or destroyed. Disturbances in ground great and varied, numerous shearing cracks. Landslides, falls of rock of significant character, slumping or river banks, etc., numerous and extensive. Wrenched loose, tore off, large rock masses. Fault slips in firm rock, with notable horizontal and vertical offset displacements. Water channels, surface and underground, disturbed and modified greatly Dammed lakes, produced water falls, deflected rivers, etc. Waves seen on ground surfaces (actually seen, probably, in some cases). Distorted lines of sight and level. Threw objects upward into the air.