

**Basic Seismological Characterization
for
Niobrara County, Wyoming**

by

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BACKGROUND

Seismological characterizations of an area can range from an analysis of historic seismicity to a long-term probabilistic seismic hazard assessment. A complete characterization usually includes a summary of historic seismicity, an analysis of the Seismic Zone Map of the Uniform Building Code, deterministic analyses on active faults, “floating earthquake” analyses, and short- or long-term probabilistic seismic hazard analyses.

Presented below, for Niobrara County, Wyoming, are an analysis of historic seismicity, an analysis of the Uniform Building Code, deterministic analyses of nearby active faults, an analysis of the maximum credible “floating earthquake”, and current short- and long-term probabilistic seismic hazard analyses.

Historic Seismicity

The enclosed map of “Earthquake Epicenters and Suspected Active Faults with Surficial Expression in Wyoming” (Case and others, 1997) shows the historic distribution of earthquakes in Wyoming. Six 3.0 and greater earthquakes have been recorded in Niobrara County. Those earthquakes, one from a neighboring county, and one from Western Nebraska are discussed below.

The earliest recorded earthquake in Niobrara County occurred on October 8, 1889. The event was felt in Lusk, Manville, and Muskrat Canyon and traveled in a northeasterly direction (Case, 1993).

Two earthquakes occurred in the Lusk area in the mid-1900s. On February 25, 1942, an intensity V earthquake, with an epicenter approximately 18 miles south of Lusk, caused no damage (Casper Tribune-Herald, February 27, 1942). On October 3, 1954, an intensity IV earthquake was reported near Guernsey, approximately 38 miles south-southwest of Lusk. Although the event

was felt from Douglas to Wheatland, no damage was reported. Train traffic between Douglas and Wheatland was temporarily halted until it was determined that the tracks had not been damaged (Laramie Republican-Boomerang, October 4, 1954).

In the 1960s, there were two earthquakes in the Lusk area. On March 28, 1964, there was an intensity V earthquake with an epicenter approximately 21 miles southeast of Lusk. No significant damage was reported (Casper Star-Tribune, March 29, 1964). On August 22, 1964, there was a magnitude 4.5, intensity V earthquake recorded with an epicenter approximately 17 miles northwest of Lusk. Much of the town was attending a concert in the town's new high school building. When the attendees felt the tremor, they thought that the furnace had blown up (Wyoming State Tribune, August 23, 1964). Fortunately, no significant damage was reported.

In the 1990s, there were a few earthquakes in the Lusk area. On November 1, 1992, a magnitude 3.0, intensity V earthquake occurred just a few miles southeast of Lusk. Although the earthquake was felt throughout Lusk, little damage was reported (Casper Star-Tribune, November 4, 1992). In 1996, there were two earthquakes in the Lusk area. The first occurred on April 8, 1996. It was a magnitude 3.7, intensity III event, and was located approximately 26 miles northeast of Lusk. Although the earthquake was felt in Lusk, no damage was reported. Another earthquake occurred on May 3, 1996. This earthquake, which was located in southwestern corner of South Dakota, had a magnitude of 3.1. No damage was reported.

Uniform Building Code

The Uniform Building Code (UBC) is a document prepared by the International Conference of Building Officials. Its stated intent is to “provide minimum standards to safeguard life or limb, health, property, and public welfare by regulating and controlling the design, construction, quality of materials, use and occupancy, location and maintenance of all buildings and structures within this jurisdiction and certain equipment specifically regulated herein.”

The UBC contains information and guidance on designing buildings and structures to withstand seismic events. With safety in mind, the UBC provides Seismic Zone Maps to help identify which design factors are critical to specific areas of the country. In addition, depending upon the type of building, there is also an “importance factor”. The “importance factor” can, in effect, raise the standards that are applied to a building.

The current UBC Seismic Zone Map (Figure 1) (1997) has five seismic zones, ranging from Zone 0 to Zone 4, as can be seen on the enclosed map. The seismic zones are in part defined by the probability of having a certain level of ground shaking (horizontal acceleration) in 50 years. The criteria used for defining boundaries on the Seismic Zone Map were established by the Seismology Committee of the Structural Engineers Association of California (Building Standards, September-October, 1986). The criteria they developed are as follows:

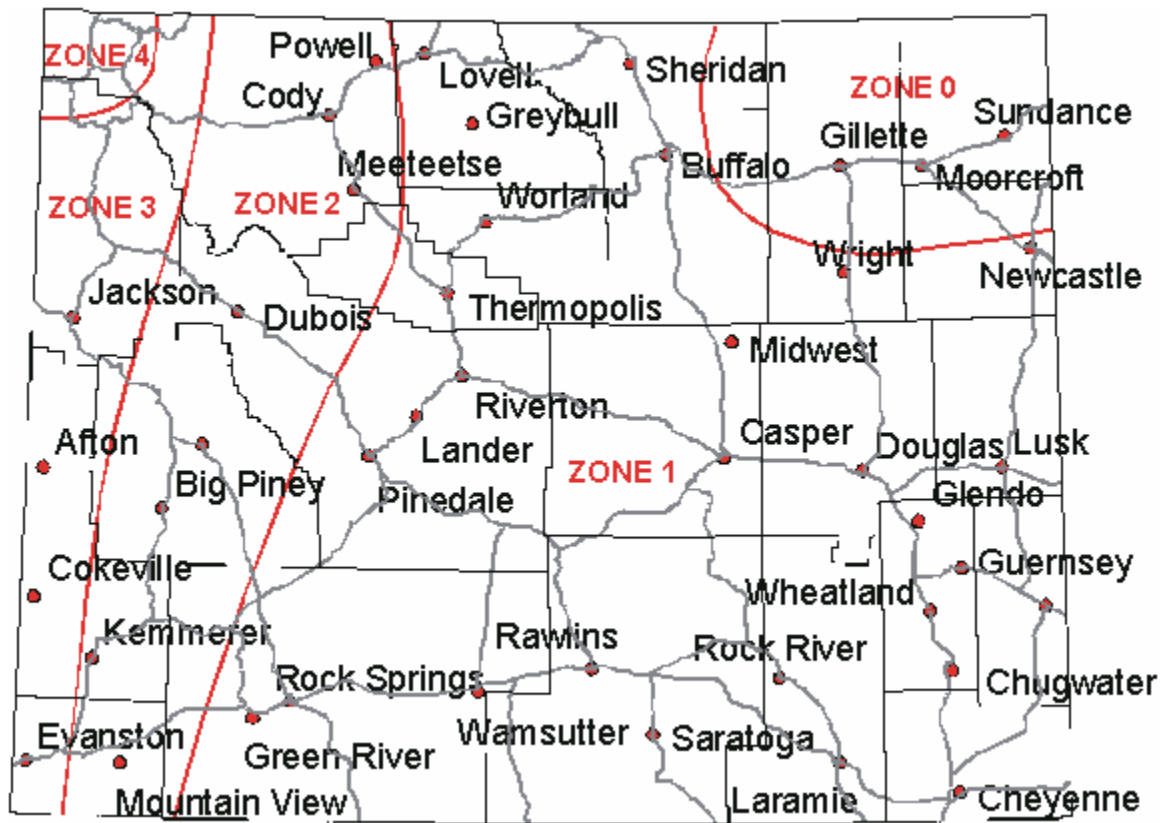


Figure 1. UBC Seismic Zone Map.

Zone Effective Peak Acceleration, % gravity (g)

4	30% and greater
3	20% to less than 30%
2	10% to less than 20%
1	5% to less than 10%
0	less than 5%

The committee assumed that there was a 90% probability that the above values would not be exceeded in 50 years, or a 100% probability that the values would be exceeded in 475 to 500 years.

Niobrara County is in Seismic Zone 1 of the UBC. Since effective peak accelerations (90% chance of non-exceedance in 50 years) can range from 5%-10%g in Zone 1, and there has been significant historic seismicity in the county, it may be reasonable to assume that an average peak acceleration of 10.0%g could be applied to the design of a non-critical facility located in the county if only the UBC were used. Such an acceleration, however, is significantly less than would be suggested through newer building codes.

Recently, the UBC has been replaced by the International Building Code (IBC). The IBC is based upon probabilistic analyses, which are described in a following section. Niobrara County still uses the UBC, however, as do most Wyoming counties as of September 2002.

Deterministic Analysis Of Regional Active Faults With A Surficial Expression

There are no known exposed active faults with a surficial expression in Niobrara County. As a result, no fault-specific analysis can be generated for Niobrara County. There are faults that have been recurrently active over the last 20 million years, but none have yet shown to be active in the last 2 million years in Niobrara County.

Floating or Random Earthquake Sources

Many federal regulations require an analysis of the earthquake potential in areas where active faults are not exposed, and where earthquakes are tied to buried faults with no surface expression. Regions with a uniform potential for the occurrence of such earthquakes are called tectonic provinces. Within a tectonic province, earthquakes associated with buried faults are assumed to occur randomly, and as a result can theoretically occur anywhere within that area of uniform earthquake potential. In reality, that random distribution may not be the case, as all earthquakes are associated with specific faults. If all buried faults have not been identified, however, the distribution has to be considered random. "Floating earthquakes" are earthquakes that are considered to occur randomly in a tectonic province.

It is difficult to accurately define tectonic provinces when there is a limited historic earthquake record. When there are no nearby seismic stations that can detect small-magnitude earthquakes, which occur more frequently than larger events, the problem is compounded. Under these conditions, it is common to delineate larger, rather than smaller, tectonic provinces.

The U.S. Geological Survey identified tectonic provinces in a report titled “Probabilistic Estimates of Maximum Acceleration and Velocity in Rock in the Contiguous United States” (Algermissen and others, 1982). In that report, Niobrara County was classified as being in a tectonic province with a “floating earthquake” maximum magnitude of 6.1. Geomatrix (1988b) suggested using a more extensive regional tectonic province, called the “Wyoming Foreland Structural Province”, which is approximately defined by the Idaho-Wyoming Thrust Belt on the west, 104° West longitude on the east, 40° North latitude on the south, and 45° North latitude on the north. Geomatrix (1988b) estimated that the largest “floating” earthquake in the “Wyoming Foreland Structural Province” would have a magnitude in the 6.0 – 6.5 range, with an average value of magnitude 6.25.

Federal or state regulations usually specify if a “floating earthquake” or tectonic province analysis is required for a facility. Usually, those regulations also specify at what distance a floating earthquake is to be placed from a facility. For example, for uranium mill tailings sites, the Nuclear Regulatory Commission requires that a floating earthquake be placed 15 kilometers from the site. That earthquake is then used to determine what horizontal accelerations may occur at the site. A magnitude 6.25 “floating” earthquake, placed 15 kilometers from any structure in Niobrara County, would generate horizontal accelerations of approximately 15%g at the site. That acceleration would be adequate for designing a uranium mill tailings site, but may be too large for less critical sites, such as a landfill. Critical facilities, such as dams, usually require a more detailed probabilistic analysis of random earthquakes. Based upon probabilistic analyses of random earthquakes in an area distant from exposed active faults (Geomatrix, 1988b), however, placing a magnitude 6.25 earthquake at 15 kilometers from a site will provide a fairly conservative estimate of design ground accelerations.

Probabilistic Seismic Hazard Analyses

The U.S. Geological Survey (USGS) publishes probabilistic acceleration maps for 500-, 1000-, and 2,500-year time frames. The maps show what accelerations may be met or exceeded in those time frames by expressing the probability that the accelerations will be met or exceeded in a shorter time frame. For example, a 10% probability that acceleration may be met or exceeded in 50 years is roughly equivalent to a 100% probability of exceedance in 500 years.

The USGS has recently generated new probabilistic acceleration maps for Wyoming (Case, 2000). Copies of the 500-year (10% probability of exceedance in 50 years), 1000-year (5% probability of exceedance in 50 years), and 2,500-year (2% probability of exceedance in 50 years) maps are attached. Until recently, the 500-year map was often used for planning purposes for average structures, and was the basis of the most current Uniform Building Code. The new International Building Code, however, uses a 2,500-year map as the basis for building design. The maps reflect current perceptions on seismicity in Wyoming. In many areas of Wyoming, ground accelerations

shown on the USGS maps can be increased due to local soil conditions. For example, if fairly soft, saturated sediments are present at the surface, and seismic waves are passed through them, surface ground accelerations will usually be greater than would be experienced if only bedrock was present. In this case, the ground accelerations shown on the USGS maps would underestimate the local hazard, as they are based upon accelerations that would be expected if firm soil or rock were present at the surface. Intensity values can be found in Table 1.

Based upon the 500-year map (10% probability of exceedance in 50 years) (Figure 2), the estimated peak horizontal acceleration in Niobrara County ranges from 3%g in the eastern portion of the county to approximately 4%g in the western portion of the county. These accelerations are roughly comparable to intensity IV earthquakes (1.4%g - 3.9%g) to intensity V earthquakes (3.9%g - 9.2%g). These accelerations are comparable to the low end of accelerations to be expected in Seismic Zone 1 of the Uniform Building Code. Intensity IV earthquakes cause little damage. Intensity V earthquakes may result in cracked plaster and broken dishes. Lusk would be subjected to an acceleration of approximately 3%g or intensity IV.

Based upon the 1000-year map (5% probability of exceedance in 50 years) (Figure 3), the estimated peak horizontal acceleration in Niobrara County ranges from 5%g in the eastern part of the county to 8%g in the southwestern corner of the county. Those accelerations are roughly comparable to intensity V earthquakes (3.9%g - 9.2%g). Intensity V earthquakes can result in cracked plaster and broken dishes. Lusk would be subjected to an acceleration of approximately 6%g or intensity V.

Based upon the 2500-year map (2% probability of exceedance in 50 years) (Figure 4), the estimated peak horizontal acceleration in Niobrara County ranges from 9%g in the eastern half of the county to approximately 16%g in the southwestern corner of the county. Those accelerations are roughly comparable to intensity VI earthquakes (9.2%g – 18.0%g). Intensity VI earthquakes can result in fallen plaster and damaged chimneys. Lusk would be subjected to an acceleration of approximately 11%g or intensity VI.

As the historic record is limited, it is nearly impossible to determine when a 2,500-year event last occurred in the county. Because of the uncertainty involved, and based upon the fact that the new International Building Code utilizes 2,500-year events for building design, it is suggested that the 2,500-year probabilistic maps be used for Niobrara County analyses. This conservative approach is in the interest of public safety.

**Peak Acceleration (% g)
with 10% Probability
of Exceedance in 50 Years
site: NEHRP B-C boundary**

U.S. Geological Survey
National Seismic Hazard Mapping Project

Albers Conic Equal-Area
Projection
Standard Parallels: 29.5

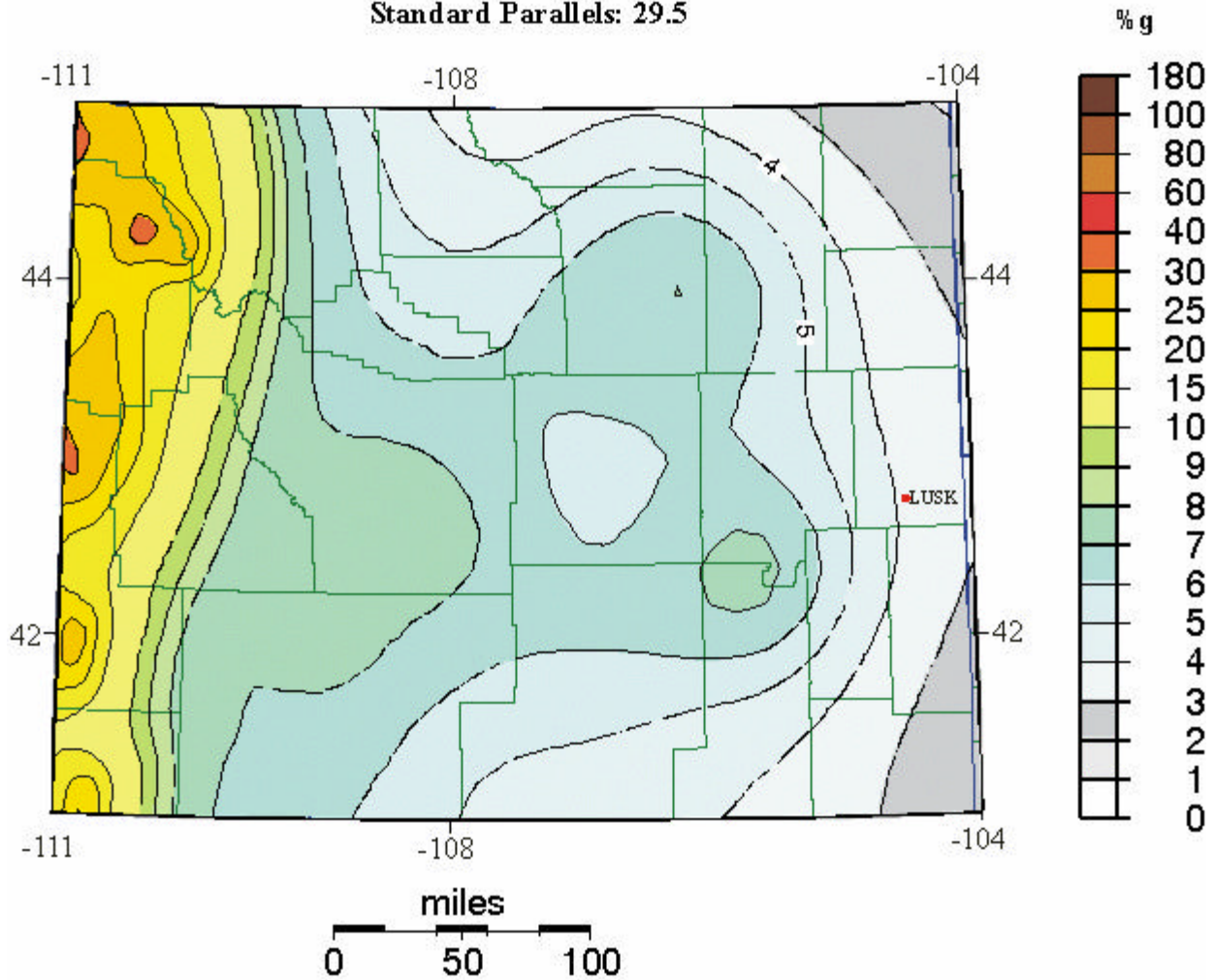


Figure 2. 500-year probabilistic acceleration map (10% probability of exceedance in 50 years).

**Peak Acceleration (%g)
with 5% Probability
of Exceedance in 50 Years
site: NEHRP B-C boundary**

U.S. Geological Survey
National Seismic Hazard Mapping Project

Albers Conic Equal-Area
Projection
Standard Parallels: 29.5

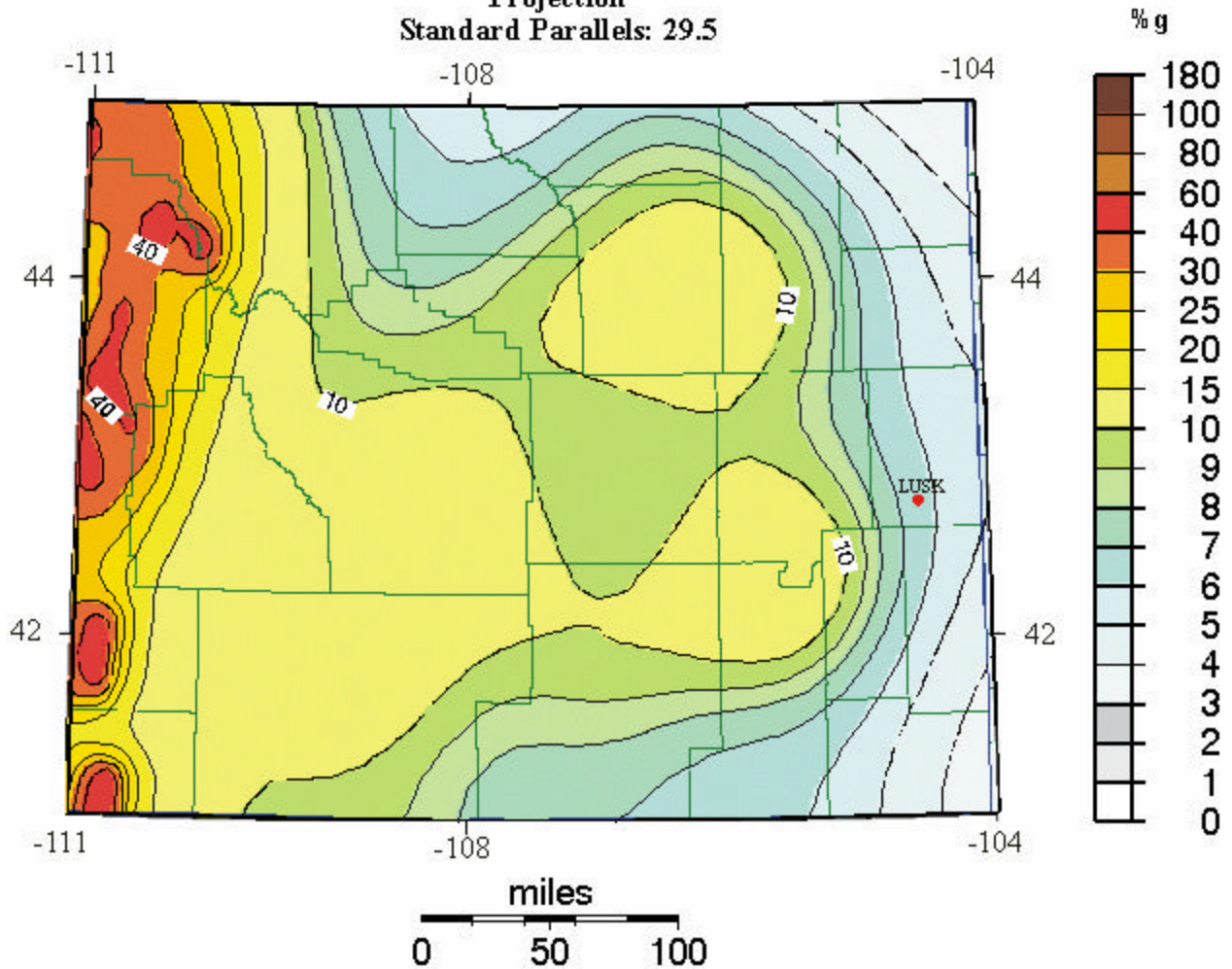


Figure 3. 1000-year probabilistic acceleration map (5% probability of exceedance in 50 years).

**Peak Acceleration (% g)
with 2% Probability
of Exceedance in 50 Years
site: NEHRP B-C boundary**

U.S. Geological Survey
National Seismic Hazard Mapping Project

Albers Conic Equal-Area
Projection
Standard Parallels: 29.5

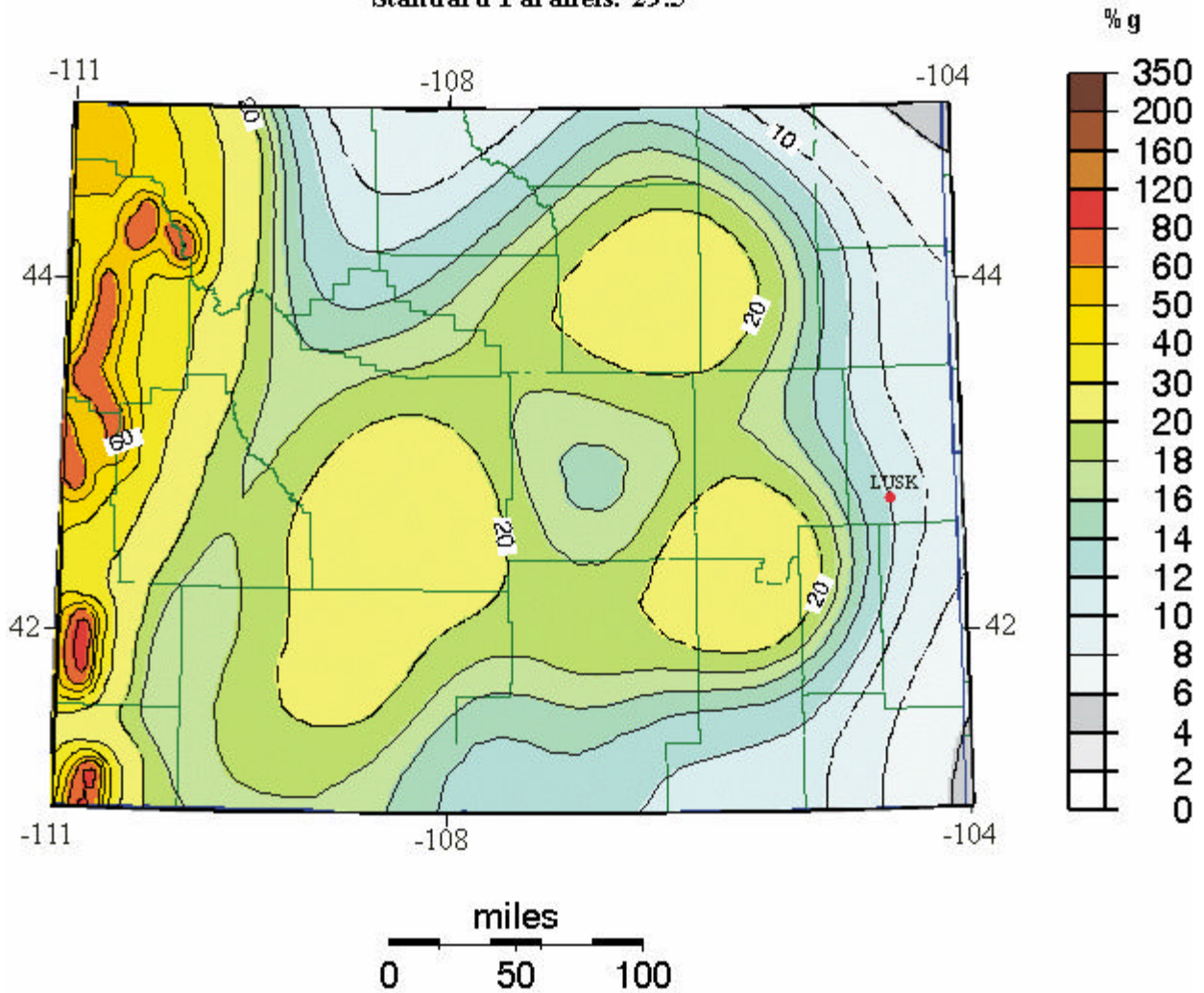


Figure 4. 2500-year probabilistic acceleration map (2% probability of exceedance in 50 years).

Table 1:

Modified Mercalli Intensity	Acceleration (%g) (PGA)	Perceived Shaking	Potential Damage
I	<0.17	Not felt	None
II	0.17 – 1.4	Weak	None
III	0.17 – 1.4	Weak	None
IV	1.4 – 3.9	Light	None
V	3.9 – 9.2	Moderate	Very Light
VI	9.2 – 18	Strong	Light
VII	18 – 34	Very Strong	Moderate
VIII	34 – 65	Severe	Moderate to Heavy
IX	65 – 124	Violent	Heavy
X	>124	Extreme	Very Heavy
XI	>124	Extreme	Very Heavy
XII	>124	Extreme	Very Heavy

Modified Mercalli Intensity and peak ground acceleration (PGA) (Wald, et al 1999).

Abridged Modified Mercalli Intensity Scale

Intensity value and description:

- I** Not felt except by a very few under especially favorable circumstances.
- II** Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
- III** Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing automobiles may rock slightly. Vibration like passing of truck. Duration estimated.
- IV** During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing automobiles rocked noticeably.
- V** Felt by nearly everyone, many awakened. Some dishes, windows, and so on broken; cracked plaster in a few places; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
- VI** Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight.
- VII** Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars.
- VIII** Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed.
- IX** Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
- X** Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks.
- XI** Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
- XII** Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into the air.

Summary

There have been eight historic earthquakes with magnitudes greater than 3.0 recorded in or near Niobrara County. Because of the limited historic record, it is possible to underestimate the seismic hazard in Niobrara County if historic earthquakes are used as the sole basis for analysis. Earthquake and ground motion probability maps give a more reasonable estimate of damage potential in areas without exposed active faults at the surface, such as Niobrara County.

Current earthquake probability maps that are used in the newest building codes suggest a scenario that would result in moderate damage to buildings and their contents, with damage increasing from the northeast to the southwest. More specifically, the probability-based worst-case scenario could result in the following damage at points throughout the county:

Intensity VI Earthquake Areas

Lance Creek
Lusk
Node
Van Tassell
Mule Creek
Redbird
Manville
Keeline

In intensity VI earthquakes, some heavy furniture can be moved. There may be some instances of fallen plaster and damaged chimneys.

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