Basic Seismological Characterization
for
Laramie 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 Laramie 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. Only two earthquakes have been recorded in Laramie County. These earthquakes are discussed below.

The first earthquake that was recorded in Laramie County occurred on March 24, 1927. This intensity III event was centered approximately 5 miles north of Cheyenne. The earthquake was felt by at least five residents who described a rapid trembling that lasted five seconds. Two people on the fourth floor of a building also felt the earthquake. Some reports indicated that two shocks were felt, and that the ground "trembled and bumped" (Neumann, 1929).

The U.S. Geological Survey recorded a very small earthquake, located approximately 10 miles west-southwest of Cheyenne, on June 5, 1967. No magnitude or intensity have been associated with the event.

On September 12, 1980, a magnitude 3.2 non-tectonic earthquake occurred approximately 16 miles west of Cheyenne. The event was identified as an explosion of 150 tons of dynamite and it was felt 20 miles west-northwest of Cheyenne (Stover and von Hake, 1982).

Regional Historic Seismicity

Several earthquakes have also occurred near Laramie County. Two of the first earthquakes to be felt and recorded in southeast and south-central Wyoming occurred between Laramie, Wyoming and Estes Park, Colorado on November 7-8, 1882. The first and largest earthquake, which occurred on November 7, 1882, was estimated to have a magnitude of 6.2 and a maximum intensity of VII. It was felt over most of Colorado, the southern half of Wyoming, and northeastern Utah (Kirkham and Rogers, 1985). The second earthquake, which occurred on November 8, 1882, was only felt from Denver to Laramie. In Laramie, the first event caused considerable apprehension, and some people ran out into the streets. Clocks were stopped, plaster was cracked, and some glass in windows was broken (Case, 1993). Kirkham and Rogers (1985) documented that the earthquake was felt as an intensity VI event in Laramie.

The earliest recorded earthquake that originated in Albany County occurred in the Laramie area on January 13, 1898. The intensity IV event shook buildings and rattled dishes, windows, and loose objects in Laramie. Before the shock waves were felt, many Laramie residents reported that they "heard a noise similar to that which a heavy wagon would make moving at a good speed a block or two away" (The Daily Boomerang, January 14, 1898). Because the earthquake occurred at 11:45 pm, a number of people were awakened by the shaking of their beds.

On September 20, 1931, an earthquake with a maximum intensity of IV was felt in Laramie and at the Summit Tavern, located east-southeast of Laramie in the Laramie Mountains. There were reports from Laramie that windows and dishes rattled, and some residents ran from their homes (The Laramie Republican-Boomerang, September 21, 1931).

Another intensity IV earthquake occurred on November 10, 1935. This earthquake, thought to have an epicenter in Laramie, was felt in Laramie, Rawlins, and Rock River. In Laramie, buildings shuddered slightly, dishes rattled, and a low rumbling sound was heard. The earthquake lasted less than ten seconds (The Laramie Republican-Boomerang, November 11, 1935).

The most significant earthquake to occur in the area, a magnitude 5.5, intensity VI event, occurred on October 18, 1984. That earthquake, with an epicenter located approximately 4 miles west-northwest of Toltec, was felt in Wyoming, South Dakota, Nebraska, Colorado, Utah, Montana, and Kansas. Stover (1985) reports that cracks were found in the exterior brick walls of the Douglas City Hall and a public school in Medicine Bow. Chimneys were cracked at Casper, Douglas, Guernsey, Lusk, and Rock River. A wall in a Laramie-area school was slightly cracked by the earthquake. The earthquake was one of the largest felt in eastern Wyoming. There were a number of aftershocks to the main event, with the most significant being a magnitude 4.5, intensity IV event, and a magnitude 3.8 event occurring on October 18, 1984; a magnitude 3.5 event on October 20, 1984; magnitude 3.3 events on October 19, November 6, and December 17, 1984; a magnitude 3.1 event on October 22, 1984; a magnitude 3.2 event on October 24, 1984; and a magnitude 2.9 event on December 5, 1984.

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:

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.

Laramie 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 this zone, and there has been some historic seismicity in the county, it may be reasonable to assume that a maximum 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 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. Laramie County will have adopted the IBC as of January 2003.

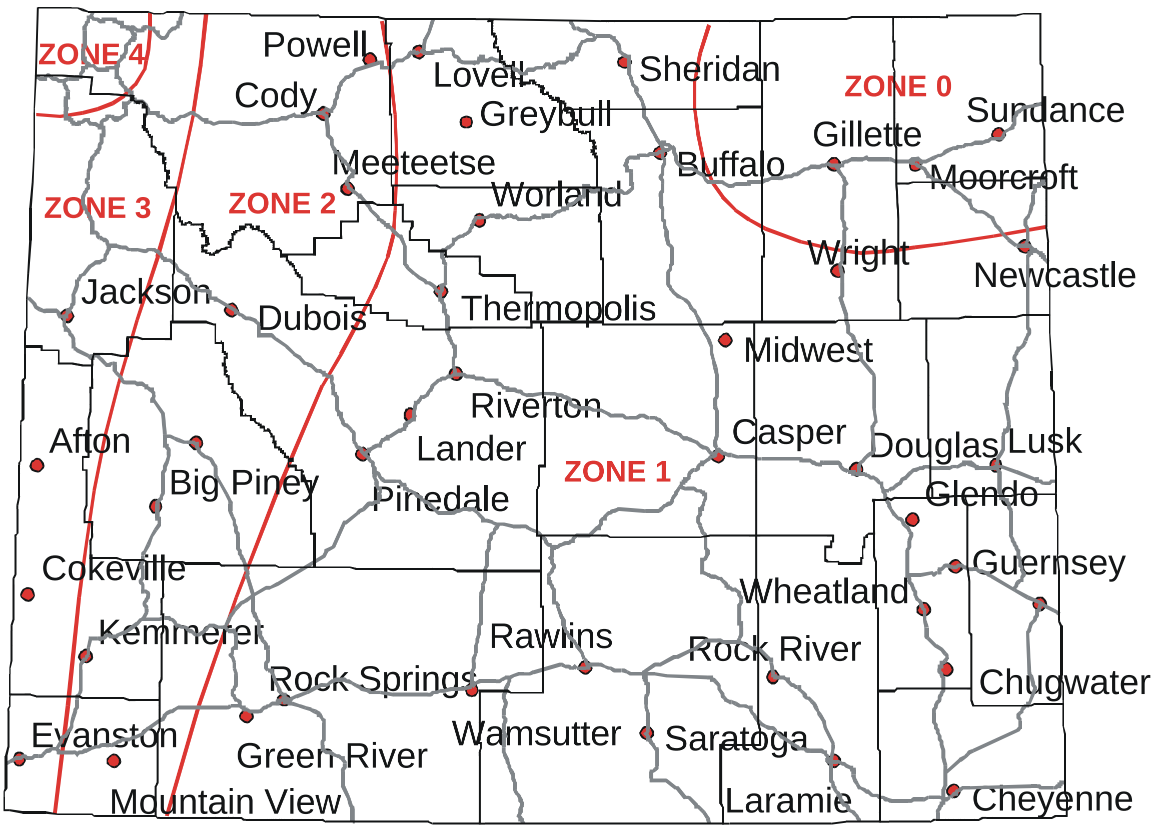

Figure 1. UBC Seismic Zone Map.

Deterministic Analysis Of Regional Active Faults With A Surficial Expression

There are no known exposed active faults with a surficial expression in Laramie County. As a result, no fault-specific analysis can be generated for Laramie 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, Laramie 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 Laramie 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 Laramie County ranges from approximately 2%g in the eastern half of the county to greater than 4%g in the northwestern corner of the county. These accelerations are roughly comparable to intensity IV earthquakes (1.4%g – 3.9%g) and intensity V earthquakes (3.9%g – 9.2%g). Intensity IV earthquakes cause little damage. Intensity V earthquakes can result in cracked plaster and broken dishes. Cheyenne would be subjected to an acceleration of approximately 3-4%g or intensity IV-V.

Based upon the 1000-year map (5% probability of exceedance in 50 years) (Figure 3), the estimated peak horizontal acceleration in Laramie County ranges from 3%g in the southeastern corner of the county to over 7%g in the northwestern corner of the county. These accelerations are roughly comparable to intensity IV earthquakes (1.4%g – 3.9%g) and intensity V earthquakes (3.9%g – 9.2%g). Intensity IV earthquakes cause little damage. Intensity V earthquakes can result in cracked plaster and broken dishes. Cheyenne would be subjected to an acceleration of approximately 5%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 Laramie County ranges from approximately 5%g in the southeastern corner of the county to nearly 14%g in the northwestern corner of the county.

These accelerations are roughly comparable to intensity V earthquakes (3.9%g – 9.2%g) and intensity VI earthquakes (9.2%g – 18%g). Intensity V earthquakes can result in cracked plaster and broken dishes. Intensity VI earthquakes can result in fallen plaster and damaged chimneys. Cheyenne would be subjected to an acceleration of approximately 9%g or intensity V-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 Laramie County analyses. This conservative approach is in the interest of public safety.

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).

<u>**Abridged Modified Mercalli Intensity Scale**</u>

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.

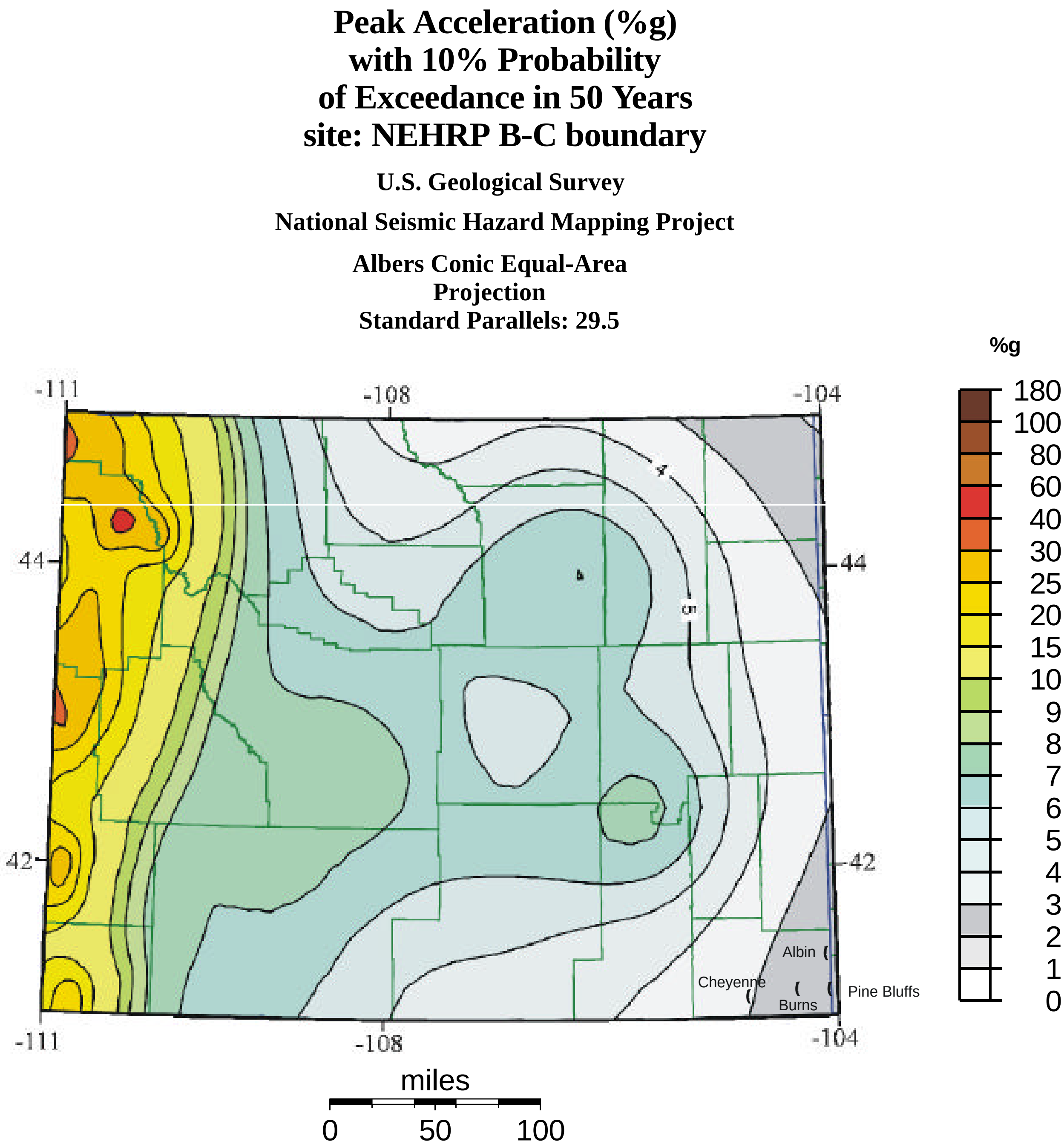

Figure 2. 500-year probabilistic acceleration map (10% probability of exceedance in 50 years).

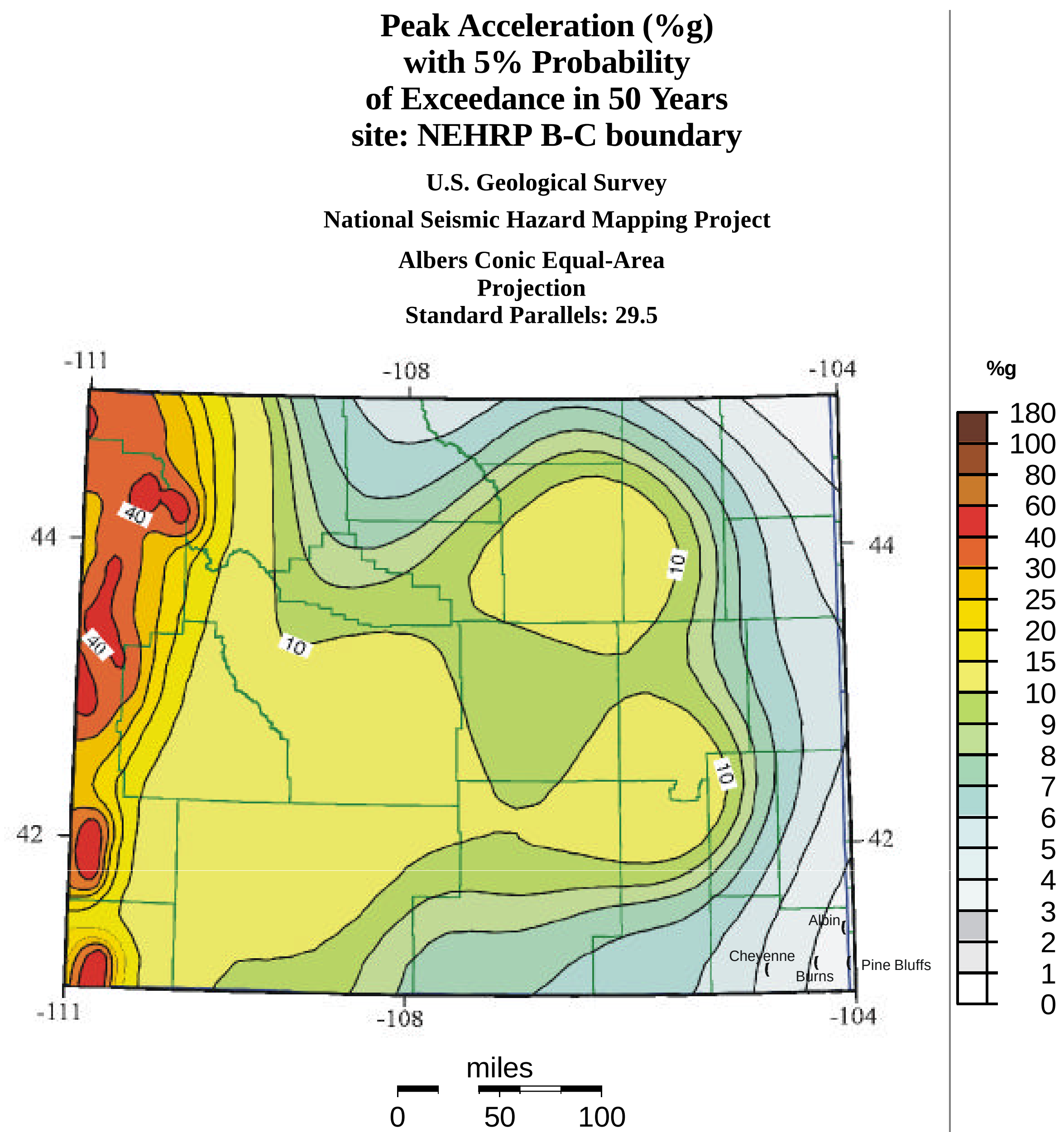

Figure 3. 1000-year probabilistic acceleration map (5% probability of exceedance in 50 years).

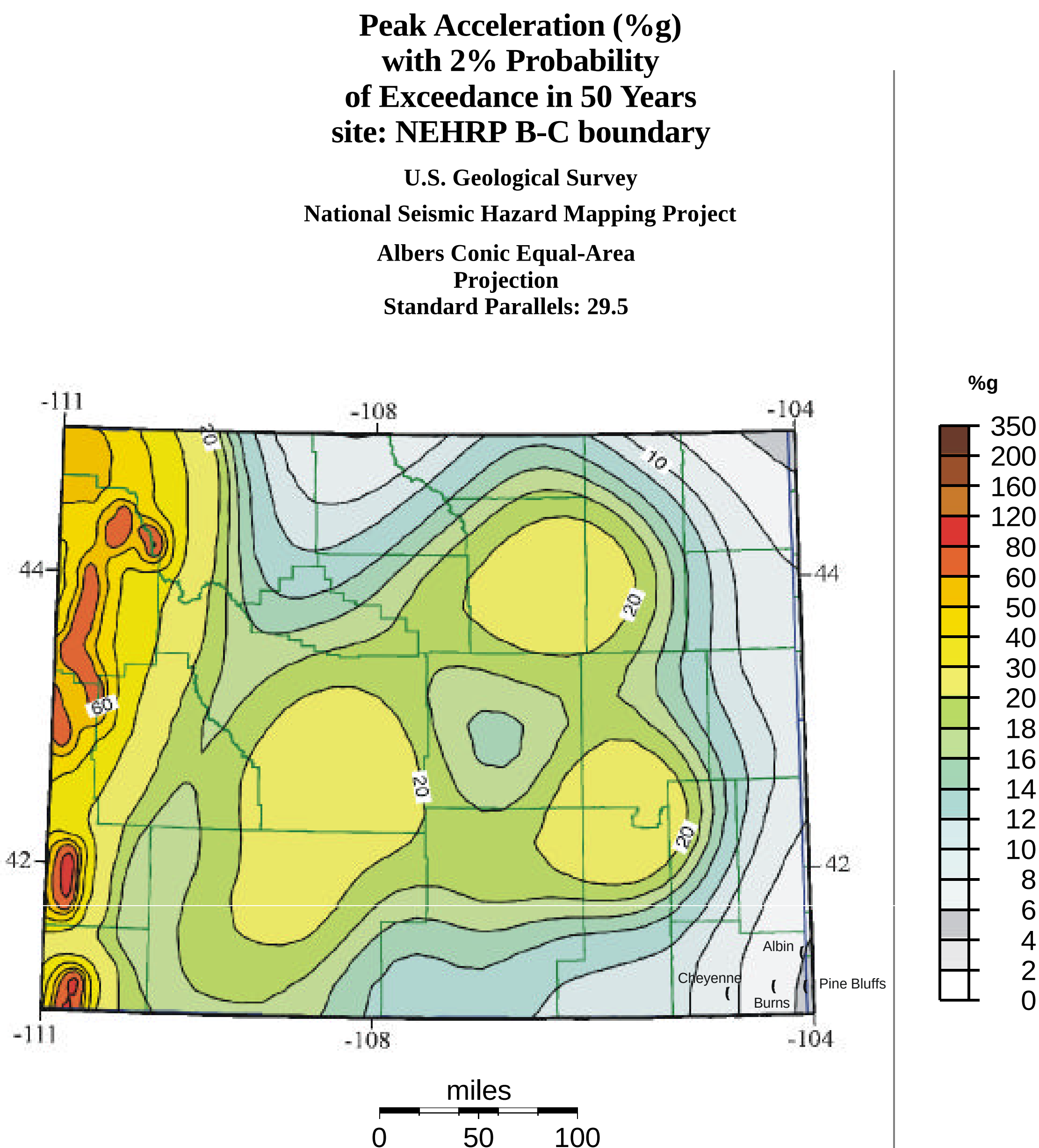

Figure 4. 2500-year probabilistic acceleration map (2% probability of exceedance in 50 years).

Summary

There have been seven historic earthquakes recorded in or near Laramie County. Because of the limited historic record, it is possible to underestimate the seismic hazard in Laramie 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 Laramie 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 southeast to the northwest. More specifically, the probability-based worst-case scenario could result in the following damage at points throughout the county:

<u>Intensity VI Earthquake Areas</u>

Cheyenne
Federal
Horse Creek
Warren Air Force Base

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

<u>Intensity V Earthquake Areas</u>

Albin
Burns
Carpenter
Egbert
Hillsdale
Pine Bluffs

In intensity V earthquakes, dishes and windows can break and plaster can crack. Unstable objects may overturn. Tall objects such as trees and power poles can be disturbed.

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