

**Basic Seismological Characterization
for
Park County, Wyoming
(Exclusive of Yellowstone National Park)**

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 Park 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 in Park County

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. Twelve magnitude 2.5 and greater earthquakes have been recorded in Park County. These earthquakes are discussed below.

The first earthquake recorded in Park County occurred on February 2, 1920. This intensity III event was located in north-central Park County, approximately 18 miles northwest of Cody. Several people reported feeling it and hearing a rumbling sound (Humphreys, 1921).

On October 3, 1944, an intensity IV earthquake occurred in south-central Park County approximately 6 miles north of Pitchfork. Several people in Yellowstone National Park and the Flag Ranch reported feeling three distinct tremors that rattled dishes and canned goods, swung suspended objects, and even caused buildings to sway. “Subterranean sounds” were also reported from the Flag Ranch (Bodle, 1946).

Two earthquakes occurred in park County during the 1950s. The first was recorded on April 10, 1950, 18 miles north of Wapiti. This intensity IV event shook lamps, rattled loose objects, and caused buildings to creak (Murphy and Ulrich, 1952). On April 25, 1952, an intensity III earthquake occurred approximately 35 miles west-northwest of Clark near the Wyoming/Montana border. The earthquake lasted for a few seconds and was felt by only one person (Murphy and Cloud, 1954).

Four earthquakes occurred in Park County during the 1960s. All four were recorded in western Park County near the Yellowstone National Park border, but no one reported feeling the earthquakes (U.S.G.S. National Earthquake Information Center). The March 22, 1963 event was reported approximately 40 miles west-northwest of Clark in the extreme northwestern corner of Park County. On June 25, 1963, a magnitude 4.2 earthquake occurred 22 miles southwest of Valley. A magnitude 3.6 earthquake was recorded on May 15, 1965, approximately 22 miles southwest of Valley. Another magnitude 3.6 earthquake occurred 25 miles north-northwest of Wapiti on January 21, 1967.

On April 21, 1973, a magnitude 4.4 earthquake was recorded on the western edge of Park County approximately 36 miles west-northwest of Wapiti. People in the area reported feeling the earthquake (Coffman et al., 1975). On January 16, 1980, a magnitude 2.6 earthquake occurred 20 miles north-northwest of Wapiti. No one reported feeling this event (U.S.G.S. National Earthquake Information Center).

Most recently, two earthquakes occurred in Park County during the 1990s. A magnitude 3.6 earthquake was recorded on January 1, 1994, and a year later, a magnitude 3.7 earthquake was felt on January 17, 1995. The earthquakes had epicenters approximately 29 and 28 miles west-northwest of Wapiti, respectively. No damage was reported and nobody reported feeling either event (University of Utah Seismograph Station Epicenter Listings).

Regional Historic Seismicity

Park County is in close proximity to Yellowstone National Park, one of the most volcanically and seismically active regions in the United States. Many known active faults are exposed in the Yellowstone area and thousands of earthquakes have been recorded inside the Park boundaries since the late 1800s. The largest earthquake recorded in this region occurred on August 17, 1959. This magnitude 7.5, intensity X event occurred just outside of Yellowstone National Park, near Hebgen Lake in Montana. The event triggered a landslide that dammed the Madison River and created Earthquake Lake. Twenty-eight people lost their lives; most of them were buried in the campground located directly beneath the landslide. Numerous aftershocks, some as big as magnitude 6.5, occurred within or near Yellowstone National Park. The largest earthquake that occurred inside Yellowstone National Park boundaries was on June 30, 1975. This magnitude 6.4, intensity VII event caused landslides and large cracks in the ground.

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:

<u>Zone</u>	<u>Effective Peak Acceleration, % gravity (g)</u>
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.

Park County is primarily in Seismic Zone 2 of the UBC, although the far western portion of the county is in Seismic Zone 3. Since effective peak accelerations (90% chance of non-exceedance in 50 years) can range from 10%-20%g in Zone 2, and there has been some significant historic seismicity in the county, it may be reasonable to assume that an average peak acceleration of 15.0%g could be applied to the design of a non-critical facility located in the county if only the UBC were used. Such 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. Park County still uses the UBC, however, as do most Wyoming counties as of October 2002.



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 Park County, exclusive of Yellowstone National Park. As a result, no fault-specific analysis can be generated for Park 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, Park 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 Park 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 Park County ranges from approximately 5%g in the northeastern corner of the county to nearly 20%g in the western portion of the county. These accelerations are roughly comparable to intensity V earthquakes (3.9%g – 9.2%g), intensity VI earthquakes (9.2%g – 18%g), and intensity VII earthquakes (18%g – 34%g). Intensity V earthquakes can result in cracked plaster and broken dishes. Intensity VI earthquakes can result in fallen plaster and damaged chimneys. Intensity VII earthquakes can result in slight to moderate damage in well-built ordinary structures, and considerable damage in poorly built or badly designed structures. Chimneys may be broken. Cody would be subjected to an acceleration of approximately 6-7%g or intensity V.

Based upon the 1000-year map (5% probability of exceedance in 50 years) (Figure 3), the estimated peak horizontal acceleration in Park County ranges from 6%g in the northeastern corner of the county to approximately 30%g in the western part of the county. These accelerations are roughly comparable to intensity V earthquakes (3.9%g – 9.2%g), intensity VI earthquakes (9.2%g – 18%g), and intensity VII earthquakes (18%g – 34%g). Intensity V earthquakes can result in cracked plaster and broken dishes. Intensity VI earthquakes can result in fallen plaster and damaged chimneys. Intensity VII earthquakes can result in slight to moderate damage in well-built ordinary structures, and considerable damage in poorly built or badly

designed structures, such as unreinforced masonry. Chimneys may be broken. Cody would be subjected to an acceleration of approximately 8-9%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 Park County ranges from approximately 8%g in the northeastern corner of the county to over 40%g in the southwestern corner of the county. These accelerations are roughly comparable to intensity V earthquakes (3.9%g – 9.2%g), intensity VI earthquakes (9.2%g – 18%g), intensity VII earthquakes (18%g – 34%g), and intensity VIII earthquakes (34%g – 65%g). Intensity V earthquakes can result in cracked plaster and broken dishes. Intensity VI earthquakes can result in fallen plaster and damaged chimneys. Intensity VII earthquakes can result in slight to moderate damage in well-built ordinary structures, and considerable damage in poorly built or badly designed structures, such as unreinforced masonry. Chimneys may be broken. Intensity VIII earthquakes can result in considerable damage in ordinary buildings and great damage in poorly built structures. Panel walls may be thrown out of frames. Chimneys, walls, columns, factory stacks may fall. Heavy furniture may be overturned. Cody would be subjected to an acceleration of approximately 12%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 Park 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).

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, sloped 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.

**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

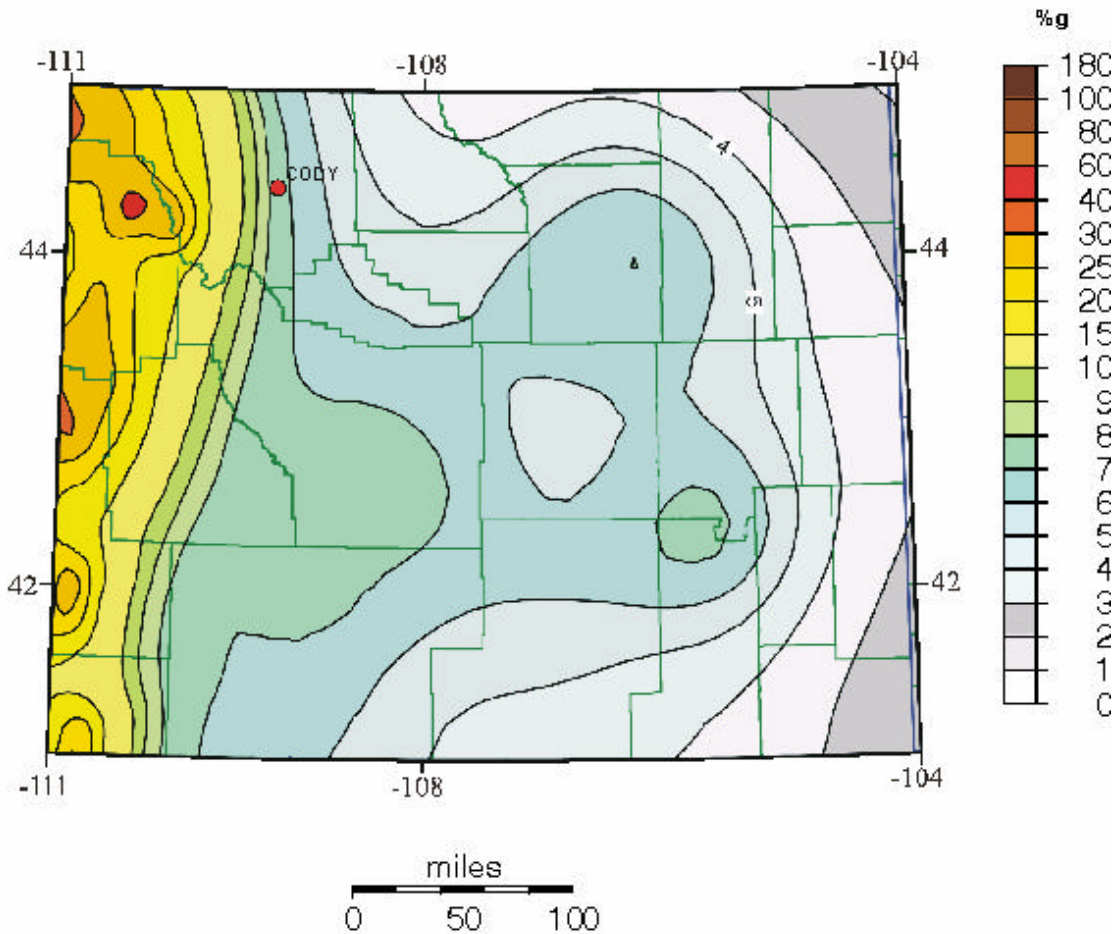


Figure 2. 500-year probabilistic acceleration map (10% probability of exceedance in 50 years).

**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

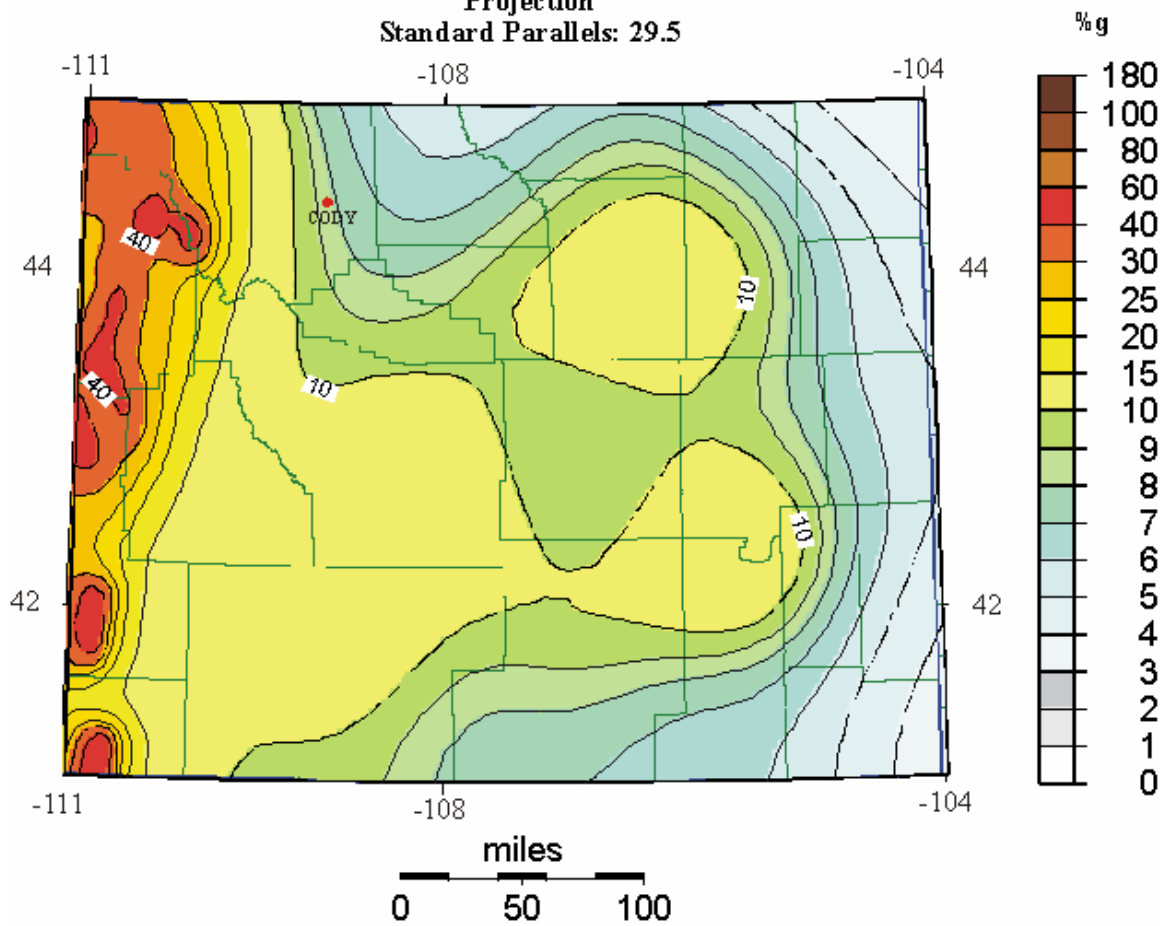


Figure 3. 1000-year probabilistic acceleration map (5% probability of exceedance in 50 years).

**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

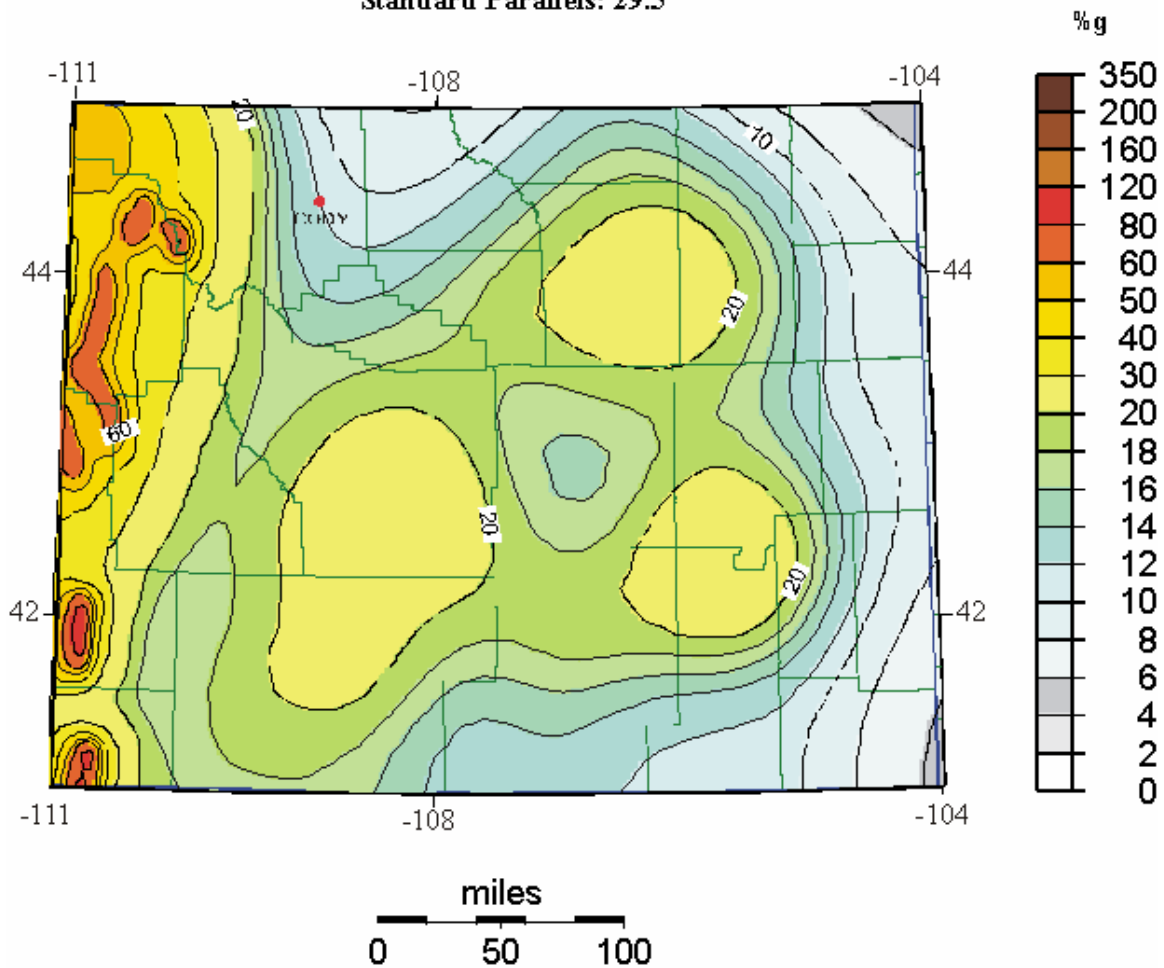


Figure 4. 2500-year probabilistic acceleration map (2% probability of exceedance in 50 years).

Summary

There have been twelve historic earthquakes with a magnitude greater than 2.5 recorded in Park County. Because of the limited historic record, it is possible to underestimate the seismic hazard in Park 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 Park 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 west. More specifically, the probability-based worst-case scenario could result in the following damage at points throughout the county:

Intensity VII Earthquake Areas

Valley
Wapiti

In intensity VII earthquakes, damage is negligible in buildings of good design and construction, slight-to-moderate in well-built ordinary structures, considerable in poorly built or badly designed structures such as unreinforced masonry buildings. Some chimneys will be broken.

Intensity VI Earthquake Areas

Clark
Cody
Elk Basin
Garland
Meeteetse
Pitchfork
Powell

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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