Basic Seismological Characterization for Albany County, Wyoming

by

James C. Case, Rachel N. Toner, and Robert Kirkwood
Wyoming State Geological Survey
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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 Albany 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. Over thirty magnitude 3.0 and greater earthquakes and hundreds of smaller earthquakes have been recorded in Albany County. Those earthquakes and one from Colorado are discussed below.

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 actually 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). As the earthquake occurred at 11:45 pm, a number of people were awakened by the shaking of their beds.

Three earthquakes occurred in Albany County in the 1930's. The first two occurred in the Laramie area, and the last occurred in northern Albany County. 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). This event was followed by another intensity IV earthquake 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). On August 27, 1938, an intensity III earthquake was recorded in northern Albany County. No damage was associated with the event (Neumann, 1940).

No earthquakes were recorded in Albany County in the 1940's, although many occurred in the 1950's. On January 20, 1954, an intensity V earthquake occurred approximately 12 miles north-northeast of Laramie. In Wyoming, the earthquake was felt in Laramie, Fox Park, Albany, Centennial, Jelm, Tie Siding, and Ryan Park. In Colorado, it was felt near Cowdrey. In fact, Murphy and Cloud (1956) estimated that the earthquake was felt over 2,000 square miles. In Laramie, a roaring noise was heard, and buildings shook and dishes fell from tables. One Laramie resident thought that the earthquake was an explosion, and alerted the local fire department. The local newspaper reported that stories "were getting more colorful by the hour" (The Laramie Republican and Boomerang, January 21, 1954). At Fox Park, a slow motion was observed by all residents. Doors and dishes were rattled, and a post supporting the roof of one house was shifted. At Albany, a rapid motion was felt, with furnishings shifted and windows rattled. The earthquake was reported to have been felt for two minutes at Albany. In Centennial, the earthquake was described as being similar to a heavy dynamite blast (Murphy and Cloud, 1956). In Jelm, a rapid motion that lasted for ten seconds was felt by all residents. An east-to-west motion was described in Jelm. At Tie Siding and Ryan Park, a slow motion was felt for a short period of time. In Cowdrey, Colorado, a rapid motion was felt for fifteen seconds, and hanging objects swung. A few aftershocks were reported in Fox Park and Jelm.

The rest of the 1950's-era earthquakes in Albany County occurred in the Fox Park, Jelm, and Woods Landing area. The first earthquake recorded in that area, an intensity IV event, occurred on January 22, 1954. The earthquake resulted in a very strong but brief shock felt in Jelm

(Murphy and Cloud, 1956). On May 22, 1955, an intensity V earthquake near Jelm and Woods Landing caused considerable concern. Many area residents reported hearing a loud rumbling noise, which was then followed by shaking. Dishes, windows, and cupboards were rattled in many cabins in the Woods Landing area. Reflecting the fears of the time, one Jelm resident thought that an atomic bomb had dropped on Denver. A group of fishermen camping near Woods Landing reported that they were rolled around in their tent. The earthquake was not felt in Laramie (The Laramie Republican and Boomerang, May 23, 1955; Murphy and Cloud, 1957). On August 6, 1958, an intensity IV earthquake near Fox Park was felt in Fox Park, Laramie, and Centennial. Windows rattled and dishes shook in Fox Park, and one Laramie resident thought there was an explosion in his basement (The Laramie Daily Boomerang, August 7, 1958). This earthquake was followed on August 15, 1958, by an intensity III event in the same general area. Residents in the Centennial area reported that buildings shook (The Laramie Daily Boomerang, August 15, 1958). In Fox Park, a light tremor was felt (Brazee and Cloud, 1960). The last earthquake recorded in the area occurred near Fox Park and Jelm on December 25, 1959. The magnitude 4.3, intensity V event was felt in Fox Park, Jelm, and Laramie. In Fox Park, slight cracks formed in a concrete block building under construction. Many residents of Fox Park felt the earthquake and described it as a pretty strong jolt. At Jelm, the earthquake was felt by all residents, with many reports of creaking walls (Eppley and Cloud, 1961).

Many of the earthquakes in the area have originated in the Laramie Range in northern Albany County and southern Converse County. The first earthquake recorded in the area occurred on August 27, 1938, as discussed previously. The intensity III earthquake, which was approximately located near Marshall, did not cause any damage (Neumann, 1940). On August 21,1952, an intensity IV earthquake occurred approximately 7 miles north-northeast of Esterbrook, in Converse County. It was felt by several people in the area, and was reportedly felt 40 miles to the southwest of Esterbrook (Murphy and Cloud, 1954). Three additional earthquakes have occurred in the same location as the August 21, 1952 event. The first, a small magnitude event with no associated magnitude or intensity, occurred on September 2, 1952. The second, an intensity III event, occurred on January 5, 1957. The most recent, an intensity IV event, occurred on March 31, 1964. No damage was reported for any of the events. On January 15, 1978, a magnitude 3.0, intensity III earthquake occurred approximately 3 miles northeast of Esterbrook, in Converse County. No damage was reported.

In the 1980's, there were a series of relatively significant earthquakes in northern Albany County that were felt over a wide area. On February 13, 1983, a magnitude 4.0, intensity IV event occurred approximately 6 miles southwest of Toltec. That non-damaging earthquake was felt in Laramie, Casper, Wheatland, and Medicine Bow (Laramie Daily Boomerang, February 15, 1983). 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. On June 12, 1986, a magnitude 3.0 earthquake occurred in the same general area.

In 1993, there were a series of non-damaging earthquakes recorded in Northern Albany and southern Converse Counties. On July 23, 1993, a magnitude 3.7, intensity IV earthquake occurred in southern Converse County, approximately 13 miles north-northwest of Toltec in northern Albany County. This event was felt as far away as Laramie. On October 9, 1993, a magnitude 3.7, intensity IV earthquake occurred approximately 9 miles north of Marshall. The earthquake was felt in Garrett. On December 13, 1993, another earthquake occurred approximately 8 miles east of Toltec. This non-damaging event had a magnitude of 3.5.

Only one magnitude 3.0 and greater earthquake has occurred in Albany County in the 2000's. On April 13, 2000, a magnitude 3.3 earthquake occurred in northern Albany County, approximately 2 miles southwest of Warbonnet Peak. 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:

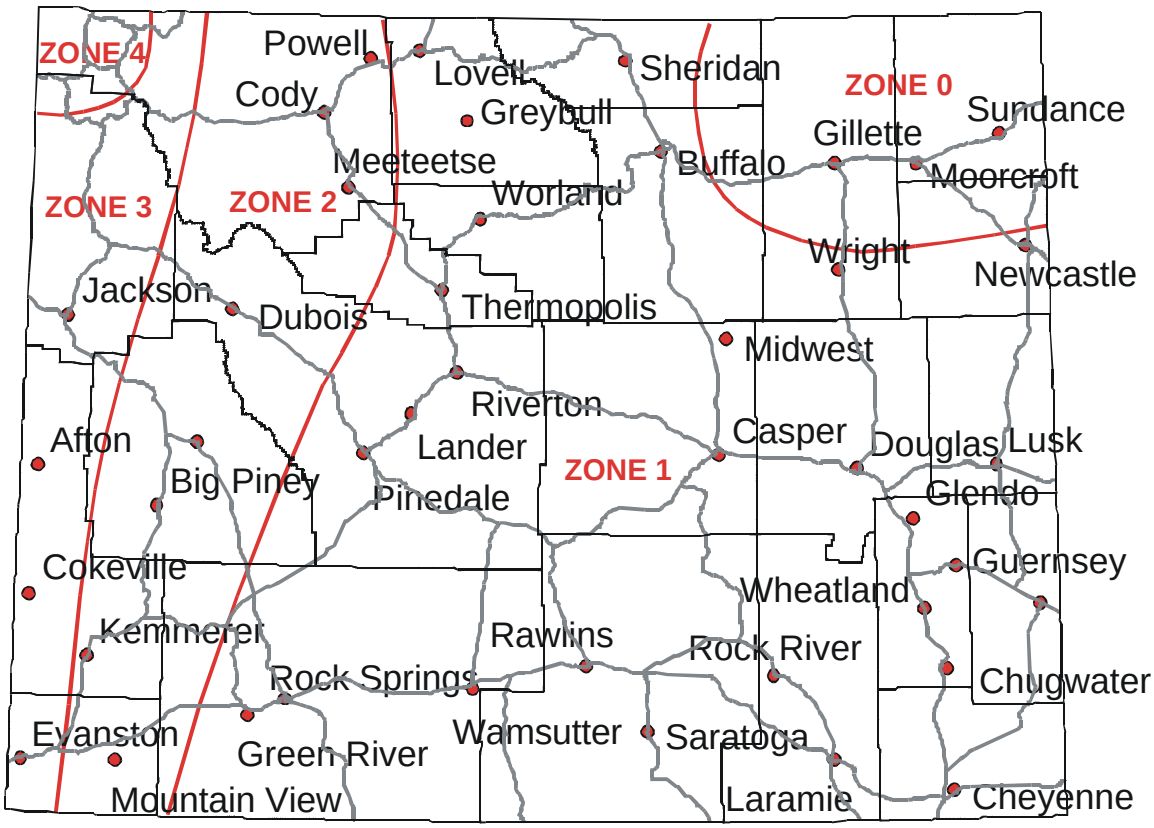

Figure 1. UBC Seismic Zone Map.

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.

Albany 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. Albany County still uses the UBC, however, as do most Wyoming counties as of October 2002.

Deterministic Analysis Of Regional Active Faults With A Surficial Expression

There are no known exposed active faults with a surficial expression in Albany County. As a result, no fault-specific analysis can be generated for Albany 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, Albany County was roughly classified as being in the "Faulted Laramide-Age Mountain Uplift" tectonic province. That province was assigned a "floating earthquake" with a 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 Albany 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 an 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 attached 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.

Based upon the 500-year map (10% probability of exceedance in 50 years) (Figure 2), the estimated peak horizontal acceleration in Albany County ranges from 3%g in the southeastern corner of the county to approximately 7%g in the northwestern corner of the county. Those 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. Laramie would be subjected to an acceleration of approximately 5%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 Albany County ranges from 6%g in the southeastern corner of the county to nearly 13%g in the northwestern corner of the county. Those accelerations are roughly comparable to intensity V earthquakes (3.9%g - 9.2%g) to intensity VI earthquakes (9.2%g -18.0%g). Intensity V earthquakes can result in cracked plaster and broken dishes. Intensity VI earthquakes can result in fallen plaster and damaged chimneys. Laramie would be subjected to an acceleration of approximately 7%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 Albany County ranges from 11%g in the southeastern corner of the county to over 21%g in the entire north central part of the county. Those accelerations are roughly comparable to intensity VI earthquakes (9.2%g – 18.0%g) to intensity VII earthquakes (18%g-34%g). 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. Laramie 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 Albany County analyses. This conservative approach is in the interest of public safety.

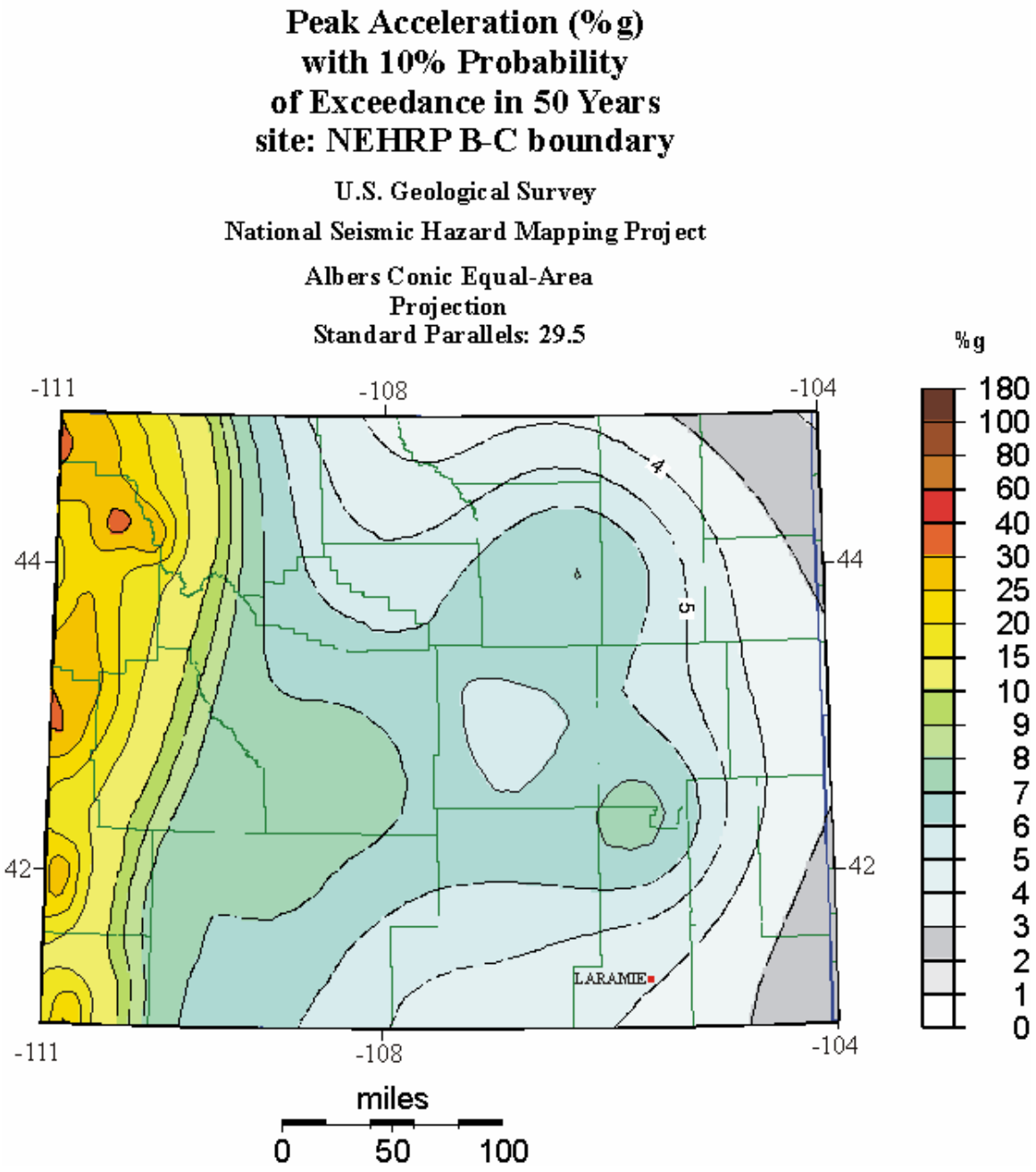

Figure 2. 500-year probabilistic acceleration map (10% probability of exceedance in 50 years).

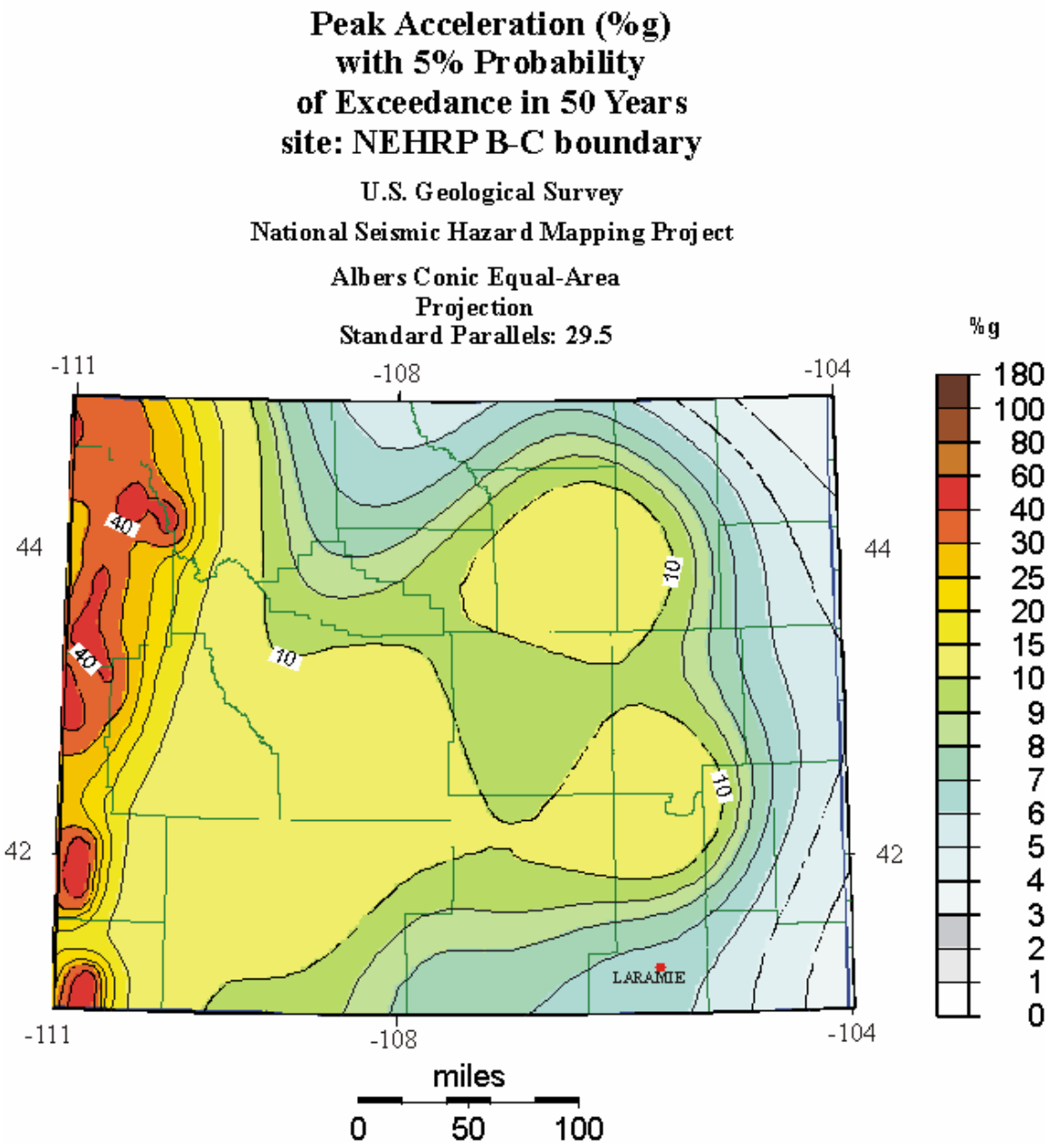

Figure 3. 1000-year probabilistic acceleration map (5% probability of exceedance in 50 years).

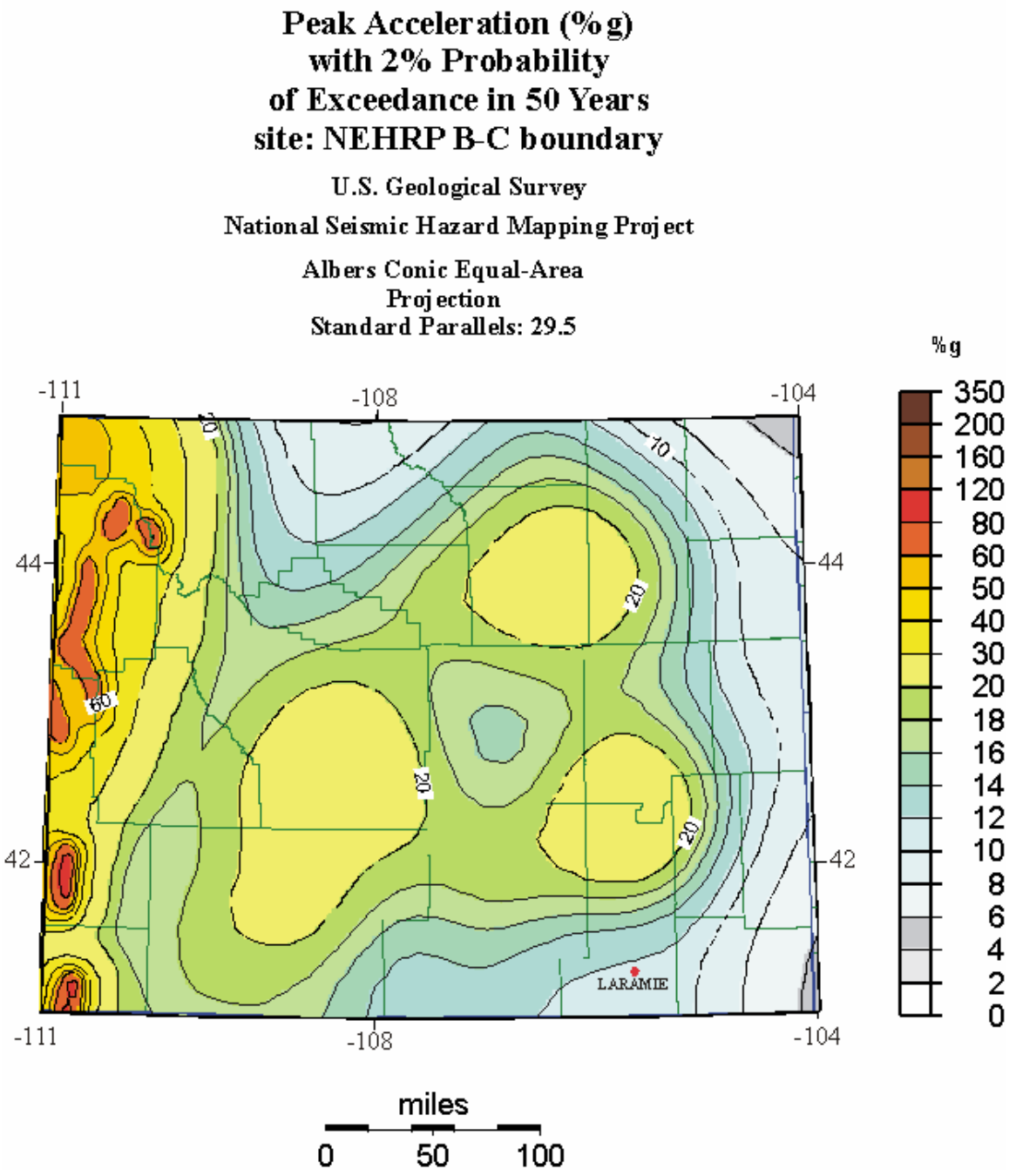

Figure 4. 2500-year probabilistic acceleration map (2% probability of exceedance in 50 years).

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 over thirty historic earthquakes with magnitudes greater than 3.0 recorded in or near Albany County, with the largest being a magnitude 6.2-6.5 event in 1882 between Laramie and Estes Park, Colorado. Because of the limited historic record, it is possible to underestimate the seismic hazard in Albany 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 Albany 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 north-northwest. More specifically, the probability-based worst-case scenario could result in the following damage at points throughout the county:

Intensity VII Earthquake Area

Toltec area
Esterbrook area
Marshall
Rock River

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

Laramie area
Jelm
Fox Park
Centennial
Albany
Woods Landing
Bosler
Buford
Tie Siding

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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