Basic Seismological Characterization for Natrona County, Wyoming

by

James C. Case, Rachel N. Toner, and Robert Kirkwood
Wyoming State Geological Survey
January 2003

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 Natrona 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 Natrona 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 or intensity III and greater earthquakes have been recorded in Natrona County. These earthquakes are discussed below.

The first earthquake that occurred in Natrona County took place on December 10, 1873, approximately 2 miles south of Powder River. People in the area reported feeling the earthquake as an intensity III event. Two of the earliest recorded earthquakes in Wyoming occurred near Casper. On June 25, 1894, an estimated intensity V earthquake was reported approximately 3 miles southwest of Evansville. Residents on Casper Mountain reported that dishes rattled to the floor and people were thrown from their beds. Water in the Platte River changed from fairly clear to reddish, and became thick with mud due to the riverbanks slumping into the river during the earthquake (Mokler, 1923). An even larger earthquake was felt in the same area on November 14, 1897. This intensity VI-VII earthquake, one of the largest recorded in central and eastern Wyoming, caused considerable damage to a few buildings. As a result of the earthquake, a portion of the Grand Central Hotel was cracked from the first to the third story. Some of the ceilings in the hotel were also severely cracked. In another part of Casper, a person sitting in a chair was thrown to the floor (Mokler, 1923).

On October 25, 1922, an intensity IV-V earthquake was detected approximately 6 miles north-northeast of Barr Nunn. The event was felt in Casper; at Salt Creek, 50 miles north of Casper; and at Bucknum, 22 miles west of Casper. Dishes were rattled and hanging pictures were tilted near Salt Creek. No significant damage was reported at Casper (Casper Daily Tribune, October 26, 1922).

One of the first earthquakes recorded near Midwest occurred on December 11, 1942. The intensity IV-V event occurred approximately 14 miles south of Midwest. Although no damage was reported, the event was felt in Casper, Salt Creek, and Glenrock (Casper Tribune-Herald, December 12, 1942). On August 27, 1948, another intensity IV earthquake was detected approximately 6 miles north-northeast of Bar Nunn. No damage was reported (Casper Tribune-Herald, August 27, 1948).

In the 1950's, two earthquakes caused some concern among Casper residents. On January 23, 1954, an intensity IV earthquake occurred approximately 7 miles northeast of Alcova. Although this event did not result in any reported damage, one area resident reported that he thought that an intruder in the attic of his house had fallen down (Casper Tribune-Herald, January 24, 1954). On August 19, 1959, an intensity IV earthquake was recorded north of Casper, approximately 6 miles north-northeast of Bar Nunn. People in Casper reported feeling this event (Reagor, Stover, and Algermissen, 1985). It is uncertain if this earthquake actually occurred in the Casper area, as it coincides with the Hebgen Lake, Montana, earthquakes that initiated on August 17, 1959.

Only one earthquake was reported in Natrona County in the 1960s. On January 8, 1968, a magnitude 3.8 earthquake occurred approximately 10 miles north-northwest of Alcova. No damage was reported.

An earthquake of no specific magnitude or intensity occurred approximately 13 miles southeast of Ervay on June 16, 1973. No one felt this earthquake and no damage was reported.

No other earthquakes occurred in Natrona County until March 9, 1993, when a magnitude 3.2 earthquake was recorded 17 miles west of Midwest. No damage was reported. A magnitude 3.1 earthquake also occurred in the far northwestern corner of the county on November 9, 1999. No one reported feeling this earthquake that was centered approximately 32 miles northwest of Waltman.

Most recently, on February 1, 2003, a magnitude 3.7 earthquake occurred approximately 16 miles north-northeast of Casper. Numerous Casper residents felt this event. One person reported feeling two jolts in rapid succession.

Regional Historic Seismicity

Several earthquakes have also occurred near Natrona County. The first took place on August 11, 1916, in eastern Fremont County. No damage was reported from this intensity III event, which was centered approximately 39 miles southwest of Ervay (Reagor, Stover, and Algermissen, 1985).

On August 27, 1938, an intensity III earthquake was recorded in northern Albany County, approximately 45 miles southeast of Casper. No damage was associated with the event (Neumann, 1940).

A magnitude 4.7 earthquake occurred in southwestern Johnson County on June 3, 1965. No one reported feeling this event, which was centered approximately 17 miles northwest of Midwest (U.S.G.S. National Earthquake Information Center). On May 11, 1967, a magnitude 4.8 earthquake occurred in southwestern Campbell County, approximately 24 miles northeast of Edgerton. No one felt this earthquake and no damage was reported.

Several earthquakes were recorded in the region in the 1970s. The first occurred in Fremont County on April 22, 1973, approximately 28 miles southwest of Ervay. This magnitude 4.8, intensity V earthquake rattled dishes and disturbed pictures on walls in Jeffrey City (Casper Star-Tribune, April 24, 1973). On May 29, 1973, an earthquake of no specific magnitude or intensity occurred near the Ferris Mountains in Carbon County, approximately 23 miles southwest of Alcova. This earthquake was not felt (Reagor, Stover, and Algermissen, 1985). In December 1975, two earthquakes occurred in eastern Fremont County. A magnitude 3.5 earthquake occurred on December 19, 1975, approximately 13 miles west-southwest of Ervay (Reagor, Stover, and Algermissen, 1985). This earthquake did not cause any damage. Later the same month, on December 30, 1975, an earthquake of no specific magnitude or intensity was recorded approximately 24 miles northwest of Ervay. No one reported feeling this event. On June 6, 1978, a magnitude 4.0 earthquake was recorded in southeastern Hot Springs County, approximately 50 miles northwest of Waltman (Reagor, Stover, and Algermissen, 1985). No damage was associated with this earthquake.

On November 15, 1983, a magnitude 3.0, intensity III earthquake occurred in western Converse County, approximately 15 miles northeast of Casper. No damage was reported. In 1984, a series of earthquakes were recorded in northern Albany County. The most significant earthquake to occur in the area occurred on October 18, 1984. This magnitude 5.5, intensity VI event was centered approximately 44 miles southeast of Casper. It 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. A number of aftershocks occurred in the same area; the most significant were magnitude 4.5, intensity IV and magnitude 3.8 events 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.

Four earthquakes occurred near Natrona County in the 1990s. A magnitude 3.8, intensity III earthquake occurred near Bairoil in southeastern Fremont County on June 1, 1993. No damage was reported from this earthquake, which was centered approximately 41 miles south-southwest of Ervay (Case, 1994). On October 9, 1993, a magnitude 3.7, intensity IV earthquake occurred in northern Albany County, approximately 37 miles southeast of Casper. The earthquake was felt in Garrett. A magnitude 4.2 earthquake was recorded in western Converse County on October 19, 1996. Its epicenter was located approximately 15 miles northeast of Casper. No damage was reported, although many Casper residents reported feeling the earthquake. On December 11, 1996, a magnitude 3.4 earthquake occurred in Fremont County, approximately 38 miles south-southwest of Ervay. No damage was associated with this earthquake.

A magnitude 3.0 earthquake was recorded in northern Carbon County on February 1, 2000. No one reported feeling this event, which was centered approximately 22 miles south of Alcova (U.S.G.S. National Earthquake Information Center). On April 13, 2000, a magnitude 3.3 earthquake occurred in northern Albany County, approximately 39 miles southeast of Casper. No damage was reported. In 2000, two earthquakes occurred in northeastern Sweetwater County near the town of Bairoil (approximately 47-48 miles south-southwest of Ervay). A magnitude 4.00 event was recorded on May 26, 2000, and a magnitude 3.2 event was recorded four days later on May 30, 2000. People reported feeling both earthquakes (U.S.G.S. National Earthquake Information Center). Most recently, a magnitude 3.0 earthquake occurred on November 8, 2000, in northeastern Fremont County. This event was centered approximately 36 miles northwest of Waltman. No one reported feeling this earthquake (U.S.G.S. National Earthquake Information Center).

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.

Natrona 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 significant historic seismicity in the county, it may be reasonable to assume that an average peak acceleration of 7.5%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 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. Natrona County still uses the UBC, however, as do most Wyoming counties as of January 2003.

Deterministic Analysis Of Regional Active Faults With A Surficial Expression

A suspected active fault system called the Cedar Ridge/Dry Fork fault system is present in northwestern Natrona County and northeastern Fremont County. The 35-mile long Cedar Ridge fault comprises the western portion of the fault system, and the 15-mile long Dry Fork fault makes up the eastern portion. The only Pleistocene-age movement on the fault system was found in northeastern Fremont County (T39N R92W NE ¼ Section 10). A short scarp on the Cedar Ridge fault, approximately 0.8 miles long, was identified at that location. Since the entire fault system is approximately 50 miles long, and only one small active segment was discovered, Geomatrix (1988a) stated that the "age of this scarp and the absence of evidence for late Quaternary faulting elsewhere along the Cedar Ridge/Dry Creek fault suggest that this fault is inactive." As a result of this assessment, it is not possible to conduct a reliable deterministic analysis on the fault system; however, general estimates can be made.

Although there is no compelling reason to believe that the Dry Fork fault system is active, if it did activate as an isolated system, it could potentially generate a magnitude 6.7 earthquake. This is based upon a postulated fault rupture length of 15 miles (Wells and Coppersmith, 1994; Wong et al., 2001). A magnitude 6.7 earthquake on the fault system could generate peak horizontal

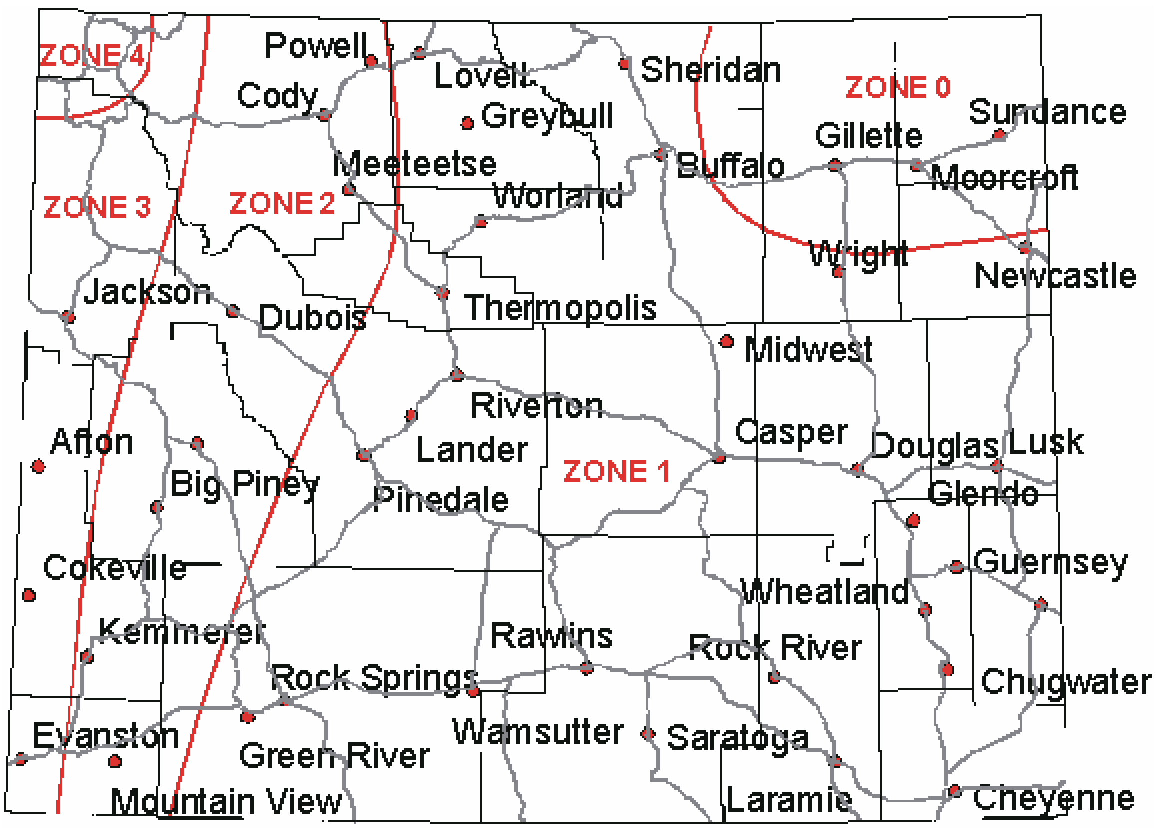

Figure 1. UBC Seismic Zone Map.

accelerations of approximately 1.9%g at Alcova, approximately 16%g at Arminto, approximately 2.0%g at Casper, approximately 2.3%g at Edgerton, approximately 5.7%g at Ervay, approximately 7.8%g at Hells Half Acre, approximately 14%g at Hiland, approximately 2.4%g at Midwest, approximately 4.4%g at Natrona, approximately 1.8%g at Pathfinder Reservoir Dam, approximately 7.2%g at Powder River, and approximately 11%g at Waltman, (Campbell, 1987). These accelerations would be roughly equivalent to intensity VI earthquakes at Arminto, Hiland, and Waltman, intensity V earthquakes at Ervay, Powder River, Hells Half Acre, and Natrona, and intensity IV earthquakes at Alcova, Casper, Edgerton, Midwest, and Pathfinder Reservoir Dam. Light damage could occur at Arminto, Hiland, and Waltman, and very light damage could be sustained at Ervay, Powder River, Hells Half Acre, and Natrona. No damage should occur at Alcova, Casper, Edgerton, Midwest, or Pathfinder Reservoir Dam. Again, there is no compelling reason to believe that the Dry Fork fault system is active.

There is also no compelling reason to believe that the entire Cedar Ridge fault system is active. Based upon its fault rupture length of 35 miles, however, if the fault did activate it could potentially generate a maximum magnitude 7.1 earthquake (Wells and Coppersmith, 1994; Wong et al., 2001). A magnitude 7.1 event could generate peak horizontal accelerations of approximately 2.4%g at Alcova, approximately 17%g at Arminto, approximately 2.3%g at Casper, approximately 2.6%g at Edgerton, approximately 7.6%g at Ervay, approximately 8.5%g at Hells Half Acre, approximately 18%g at Hiland, approximately 2.7%g at Midwest, approximately 4.7%g at Natrona, approximately 2.3%g at Pathfinder Reservoir Dam, approximately 7.8%g at Powder River, and approximately 12%g at Waltman (Campbell, 1987). These accelerations would be roughly equivalent to an intensity VI-VII earthquake at Hiland, intensity VI earthquakes at Arminto and Waltman, intensity V earthquakes at Ervay, Natrona, and Powder River, and intensity IV earthquakes at Alcova, Casper, Midwest, Edgerton, Pathfinder Reservoir Dam. Hiland could sustain moderate to light damage, and light damage could occur at Arminto and Waltman. Very light damage could occur at Ervay, Natrona, and Powder River, but no damage should occur at Alcova, Casper, Midwest, Edgerton, Pathfinder Reservoir Dam.

The South Granite Mountain fault system is a known active fault system located in southeastern Fremont County and northwestern Carbon County. The fault system is composed of several west-northwest-trending faults that border the northern flanks of the Seminoe Mountains, Ferris Mountain, Green Mountain, and Crooks Mountain. Geomatrix (1988b) divided the South Granite Mountain fault system into five segments. The segments, from east to west, are the Seminoe Mountains segment, the Ferris Mountains segment, the Muddy Gap segment, the Green Mountain segment, and the Crooks Mountain segment. Geomatrix (1988b) discovered evidence of late-Quaternary faulting on the Ferris Mountains and Green Mountain segments of the fault system. They concluded that the Ferris Mountains segment was capable of generating a maximum credible earthquake of magnitude 6.5 – 6.75 with a recurrence interval of 5,000 to 13,000 years. They also concluded that the Green Mountain segment was capable of generating a maximum credible earthquake of magnitude 6.75 with a recurrence interval of 2,000 to 6,000 years (1988b). Geomatrix (1988b) did not find evidence of late-Quaternary movement on the Seminoe Mountains, Muddy Gap, and Crooks Mountain fault segments. These segments, however, may be extensions of the known active faults in the South Granite Mountain fault system. These segments should therefore be considered to be potentially active. Geomatrix (1988b) estimated the length of the Seminoe Mountains segment to be 22.5 miles (36 km). Such a fault length would result in a magnitude 6.85 earthquake if the entire length ruptured (Wells and Coppersmith, 1994). The length of the Crooks Gap fault segment was estimated to be 21.25 miles (34 km) (Geomatrix, 1988b). This fault length could generate a magnitude 6.86 earthquake if the entire length ruptured (Wells and Coppersmith, 1994). The Muddy Gap fault system is approximately 14.4 miles (23 km) in length (Geomatrix, 1988b). If the entire fault ruptured, a magnitude 6.66 earthquake could be generated (Wells and Coppersmith, 1994).

There are two approaches to doing a deterministic analysis on a segmented fault system such as the South Granite Mountain fault system. The first approach involves finding the shortest distance from the area of interest to a specific fault segment. A deterministic analysis is then applied to each individual fault segment. The second approach involves measuring the distance from the area of interest to the closest point on the fault system as a whole. An average magnitude is then used for activation anywhere along the entire fault. For the purposes of this report, the second, more conservative approach will be used. Because the active segments of the South Granite Mountain fault system have been assigned a maximum magnitude of 6.75, it may be reasonable to assume that a magnitude 6.75 earthquake could be generated anywhere along the length of the fault system. A magnitude 6.75 earthquake could generate peak horizontal accelerations of approximately 6.6%g in the Alcova area, approximately 2.5%g at Casper, approximately 4.6%g at Ervay, approximately 2.5%g at Hiland, Powder River, and Waltman, approximately 2.2%g at Arminto and Natrona, and approximately 9.4%g at Pathfinder Reservoir Dam (Campbell, 1987). These accelerations would be roughly equivalent to an intensity VI earthquake at Pathfinder Reservoir Dam, intensity V earthquakes at Alcova and Ervay, and intensity IV earthquakes at Arminto, Casper, Hiland, Natrona, Powder River, and Waltman. The Pathfinder Reservoir Dam could sustain some light damage and very light damage could occur at Alcova and Ervay. No damage should occur at Arminto, Casper, Hiland, Natrona, Powder River, and Waltman. Midwest and Edgerton would be subjected to ground accelerations of less than 1.5%g, which should also not cause any damage. Pipelines crossing the South Granite Mountain Fault System could also be damaged or ruptured if the segment activates.

The Stagner Creek fault system is an east-west trending system located near Boysen Reservoir on the south flank of the Owl Creek uplift. Geomatrix (1988a) determined that the maximum length of the fault is 24 miles (38 km), with Quaternary-age displacement found along a 17 mile (27 km) segment of the fault between Mexican Pass and Tough Creek. The maxiumum credible earthquake was determined to be a magnitude 6.75 event with a recurrence interval of between 8,000 to 20,000 years (Geomatrix, 1988a). A magnitude 6.75 earthquake originating on the Stagner Creek fault system could generate peak horizontal accelerations of approximately 2.6%g at Ervay, approximately 3.2%g at Hiland, approximately 2.8%g at Arminto, approximately 2.5%g at Waltman, and approximately 1.9%g at Powder River. These accelerations would be roughly equivalent to intensity IV earthquakes, which should not cause any damage. Alcova, Casper, Midwest, Edgerton, Pathfinder Reservoir Dam, and Natrona would be subjected to ground accelerations of less than 1.5%g, which should also not cause any damage.

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, Natrona 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 Natrona County, would generate horizontal accelerations of approximately 15%g at the site. 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 included. 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 Natrona County ranges from approximately 5%g in the central portion of the county to greater than 6%g near the borders of the county. These 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. Casper and Midwest would be subjected to accelerations of 6%g and greater, or intensity V.

Based upon the 1000-year map (5% probability of exceedance in 50 years) (Figure 3), the estimated peak horizontal acceleration in Natrona County ranges from approximately 9%g in the central, south-central, and northwestern portions of the county to greater than 10%g in the northeastern, southeastern, and southwestern parts 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. Casper and Midwest would be subjected to accelerations of approximately 10%g or intensity VI.

Based upon the 2500-year map (2% probability of exceedance in 50 years) (Figure 4), the estimated peak horizontal acceleration in Natrona County ranges from approximately 14%g in the central portion of the county to greater than 20%g in the northeastern and southeastern corners of the county. These accelerations are roughly comparable to intensity VI earthquakes (9.2%g – 18%g) and 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, such as unreinforced masonry. Chimneys may be broken. Casper and Midwest would be subjected to accelerations of 18%g (intensity VI-VII) and 20%g (intensity VII), respectively.

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 Natrona 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, 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.

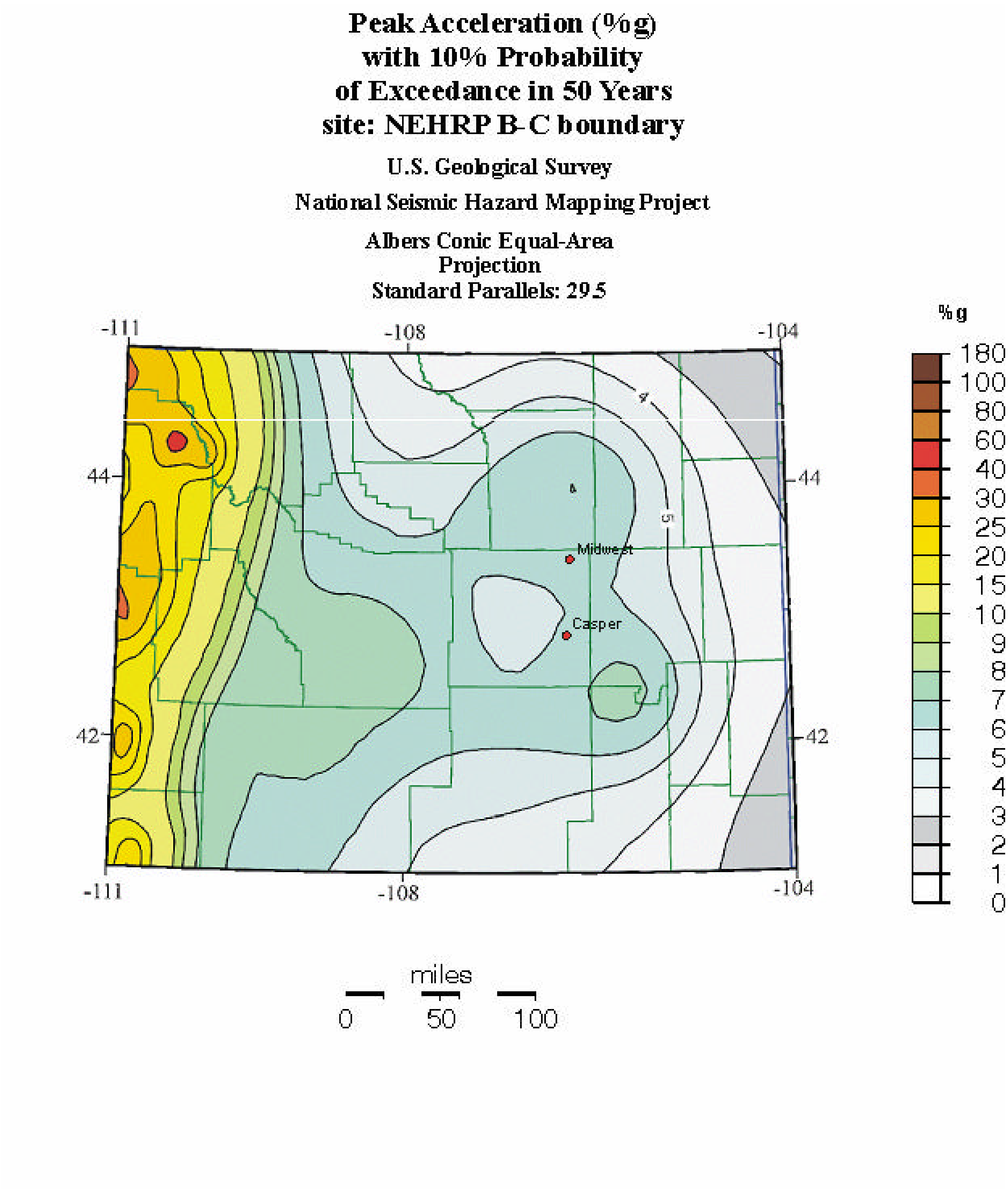

Figure 2. 500-year probabilistic acceleration map (10% probability of exceedance in 50 years).

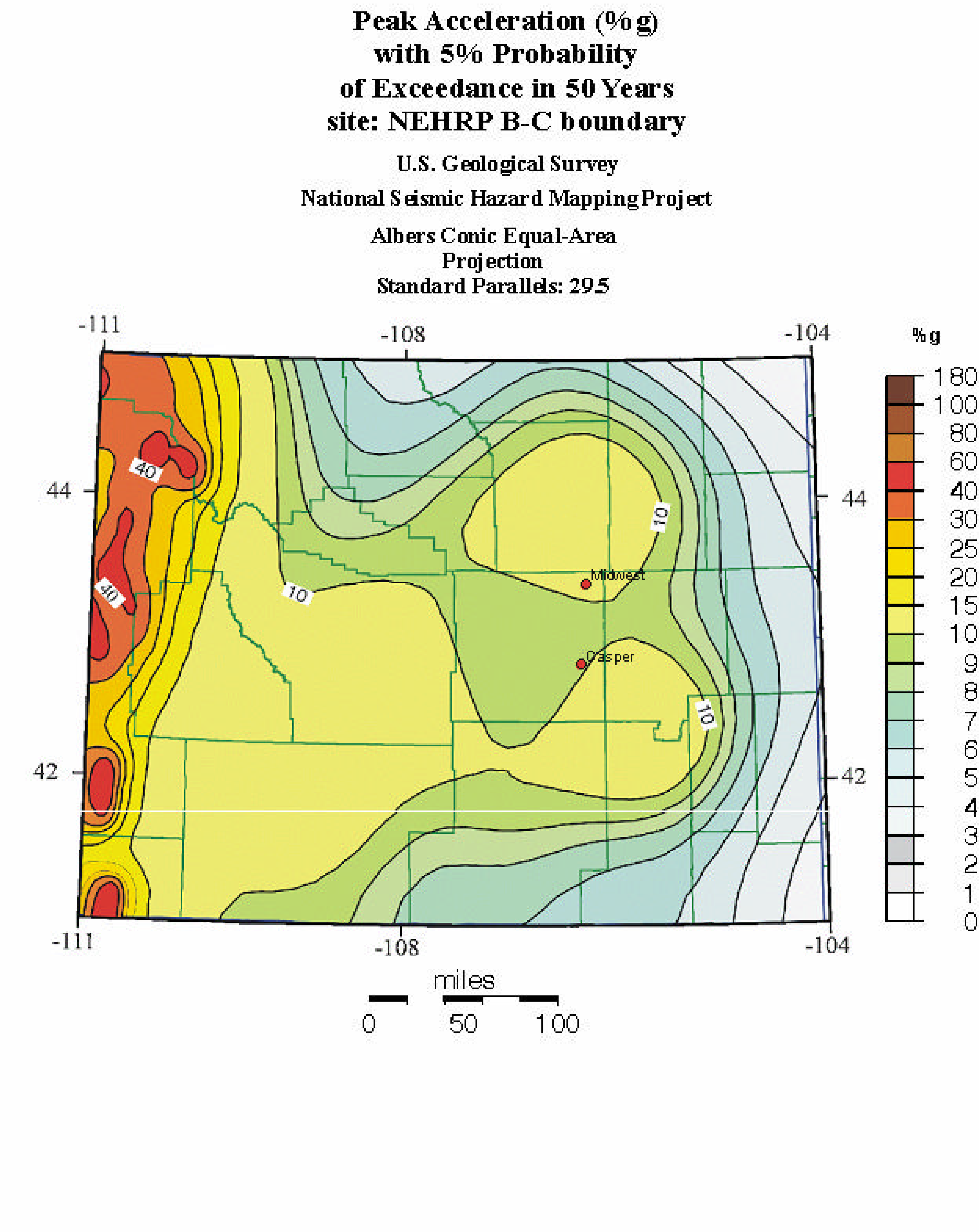

Figure 3. 1000-year probabilistic acceleration map (5% probability of exceedance in 50 years).

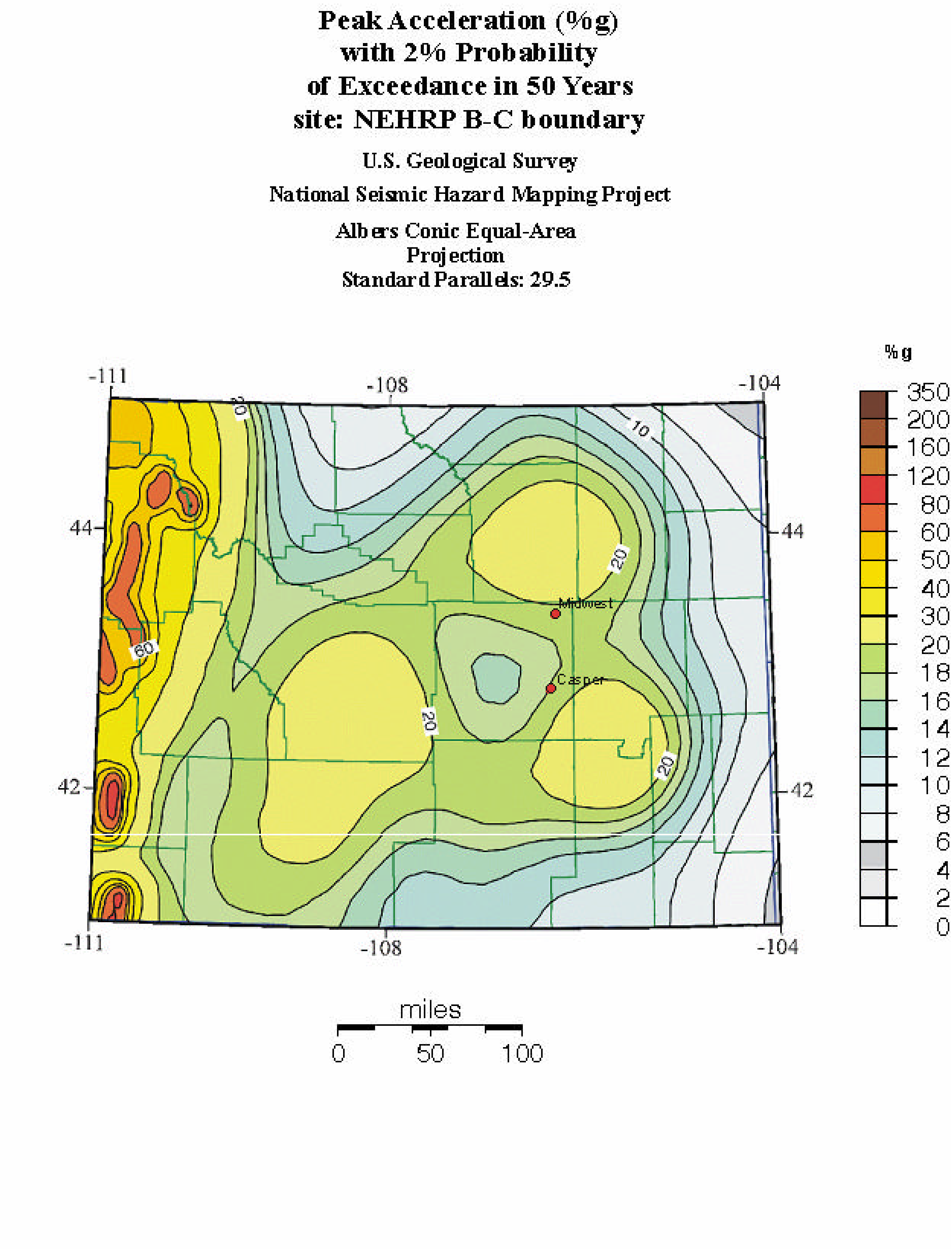

Figure 4. 2500-year probabilistic acceleration map (2% probability of exceedance in 50 years).

Summary

There have been over forty historic earthquakes of magnitude 2.5 or intensity III and greater recorded in or near Natrona County. Because of the limited historic record, it is possible to underestimate the seismic hazard in Natrona County if historic earthquakes are used as the sole basis for analysis. Earthquake and ground motion probability maps and specific fault analyses give a more reasonable estimate of damage potential in Natrona 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 central to the northeast and southeast areas of the county. More specifically, the probability-based or fault activation-based worst-case scenario could result in the following damage at points throughout the county:

Intensity VII Earthquake Areas

Casper
Edgerton
Midwest
Bar Nunn
Mills
Evansville
Hiland
Ervay

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

Alcova
Arminto
Natrona
Powder River
Waltman

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

References

Algermissen, S.T., Perkins, D.M., Thenhaus, P.C., Hanson, S.L., and Bender, B.L., 1982, Probabilistic estimates of maximum acceleration and velocity in rock in the contiguous United States: U.S. Geological Survey Open File Report 82-1033, 99 p., scale 1:7,500,000.

Campbell, K.W., 1987, Predicting strong ground motion in Utah, *in* Gori, P.L., and Hays, W.W., editors, Assessment of regional earthquake hazards and risk along the Wasatch front, Utah, Volume 2: U.S. Geological Survey Open File Report 87-585, pp. L1-L90.

Case, J.C., 2000, Probability of damaging earthquakes in Wyoming: Wyoming State Geological Survey, Wyoming Geo-notes No. 67, p. 50-55.

Case, J.C., 1996, Historical seismicity of northeastern and east-central Wyoming: Wyoming State Geological Survey Wyoming Geo-notes Number 51, pp. 50-55.

Case, J.C., 1997, Historical seismicity of south-central and southeastern Wyoming: Wyoming State Geological Survey Wyoming Geo-notes Number 56, pp. 54-59.

Case, J.C., Larsen L.L., Boyd, C.S., and Cannia, J.C., 1997, Earthquake epicenters and suspected active faults with surficial expression in Wyoming: Wyoming State Geological Survey Geologic Hazards Section Preliminary Hazards Report 97-1, scale 1:1,000,000.

Case, J.C., 1994, Geologic Hazards in Wyoming Earthquakes in Wyoming, 1991-1993: Wyoming State Geological Survey Wyoming Geo-notes Number 41, pp. 49-53.

Case, J.C., 1993, Geologic Hazards in Wyoming: Wyoming State Geological Survey Wyoming Geo-notes Number 40, pp. 46-48.

Geomatrix Consultants, Inc., 1988a, Seismotectonic evaluation of the northwestern Wind River Basin: Report prepared for the U.S. Bureau of Reclamation, Contract No. 6-CS-81-07310, 116 p.

Geomatrix Consultants, Inc., 1988b, Seismotectonic evaluation of the Wyoming Basin geomorphic province: Report prepared for the U.S. Bureau of Reclamation, Contract No. 6-CS-81-07310, 167 p.

McGrew, L.W., 1961, Structure of Cenozoic rocks along the northwestern margin of the Julesburg Basin, southeastern Wyoming (abstract): Geological Society of America, Rocky Mountain Section, Annual Meeting Program, Laramie, Wyoming, May 11-13, 1961, p. 22.

Mokler, A.J., 1923, History of Natrona County, Wyoming, 1888-1922; true portrayal of the yesterdays of a new county and a typical frontier town of the middle west; fortunes and misfortunes, tragedies and comedies, struggles and triumphs of the pioneers: R.R. Donnelloy & Sons, Co., Chicago, 477 p.

Murphy, L.M., and Cloud, W.K., 1954, United States earthquakes 1952: U.S. Department of Commerce, Coast and Geodetic Survey Serial No. 773, 112p.

Reagor, B.G., Stover, C.W., and Algermissen, S.T., 1985, Seismicity map of the State of Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF-1798, Scale 1:1,000,000.

Stover, C.W., 1985, Preliminary isoseismal map and intensity distribution for the Laramie Mountains, Wyoming, earthquake of October 18, 1984: U.S. Geological Survey Open File report 85-137, 9 p.

Wald D.J., Quitoriano V., Heaton T.H., Kanamori H., 1999, Relationships between Peak Ground Acceleration, Peak Ground Velocity and Modified Mercalli Intensity in California: Earthquake Spectra, v. 15, no. 3, 557-564.

Wells, D.L., and Coppersmith, K.J., 1994, New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement: Bulletin of the Seismological Society of America, Vol. 84, No. 4, pp. 974-1002.

Wong, I., Dober, M., Fenton, C., 2001, Probabilistic Seismic Hazard Analyses Alcova, Glendo, Guernsey, Kortes, Pathfinder, and Seminoe Dams: Report prepared by URS Greiner Woodward Clyde for the U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado.

U.S.G.S. National Earthquake Information Center: http://wwwneic.cr.usgs.gov/