Basic Seismological Characterization for Converse 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 Converse 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 Converse 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 3.0 and greater earthquakes have been recorded in Converse County. These earthquakes are discussed below.

The first earthquake recorded in Converse County occurred on April 14, 1947. The earthquake had an intensity of V, and was felt near LaPrele Creek southwest of Douglas. The earthquake was felt by everyone in a ranch house, and by a few outdoors. Windows were rattled, chairs were moved, and buildings shook (Murphy, 1950).

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.

Two earthquakes occurred in Converse County in the 1980's. On November 15, 1983, a magnitude 3.0, intensity III earthquake occurred approximately 15 miles northeast of Casper in western Converse County. No damage was reported. On December 5, 1984, a non-damaging magnitude 2.9 earthquake occurred in the Laramie Range in southern Converse County.

Four earthquakes occurred in Converse County in the 1990's. On June 30, 1993, a magnitude 3.0 earthquake was located approximately 15 miles north of Douglas. No damage was reported. 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 December 13, 1993, another earthquake occurred approximately 8 miles east of Toltec. This non-damaging event had a magnitude of 3.5. Most recently, on October 19, 1996, a magnitude 4.2 earthquake was recorded approximately 15 miles northeast of Casper in western Converse County. No damage was reported, although the event was felt by many Casper residents.

Regional Historic Seismicity

Many earthquakes in the area have originated in the Laramie Range in southern Converse County and northern Albany County. The first earthquake recorded in this area occurred on August 27, 1938. This intensity III earthquake was recorded in northern Albany County near Marshall. No damage was associated with the event (Neumann, 1940).

As mentioned in the previous section, earthquakes have occurred in this region on August 21,1952, September 2, 1952, January 5, 1957, March 31, 1964, and January 15, 1978.

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. This 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.

The most recent earthquake event in the region occurred on April 13, 2000. This magnitude 3.3 earthquake was located 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:

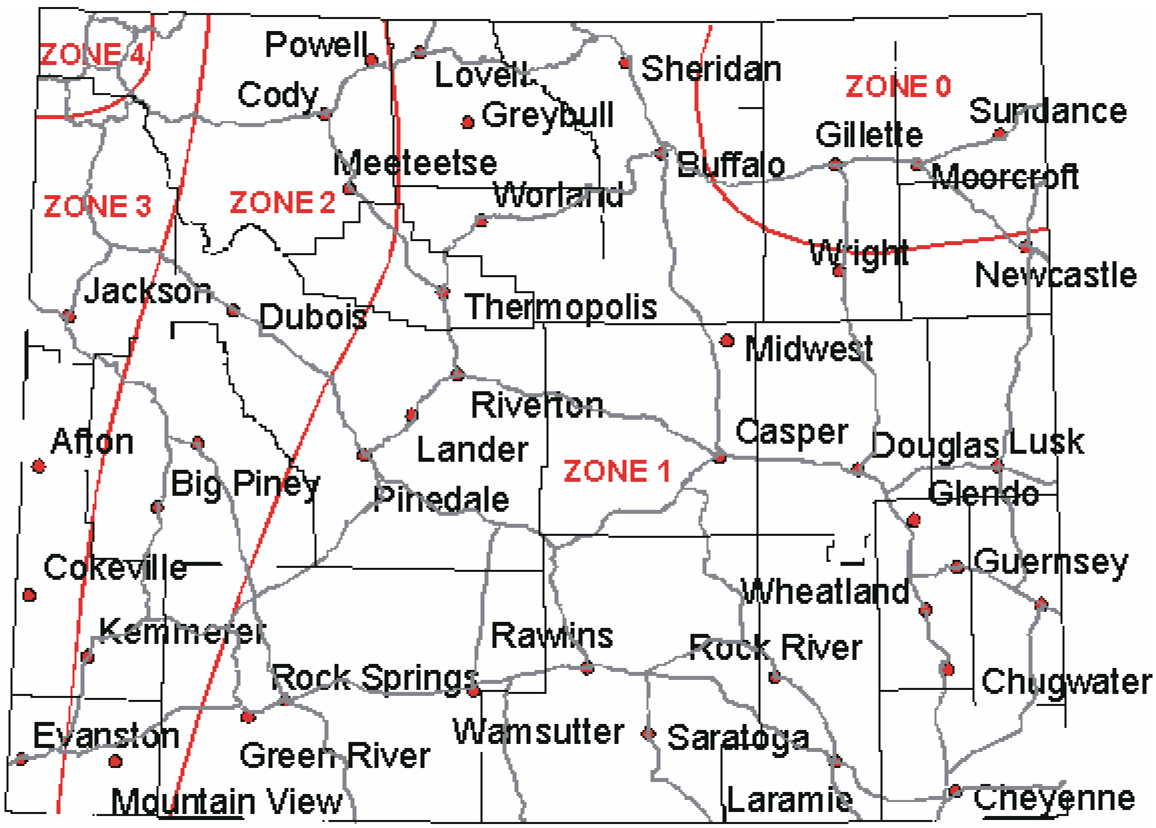

Figure 1. UBC Seismic Zone Map.

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.

Converse 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. Converse County still uses the UBC, however, as do most Wyoming counties as of September 2002.

Deterministic Analysis Of Regional Active Faults With A Surficial Expression

There are no known exposed active faults with a surficial expression in Converse County. As a result, no fault-specific analysis can be generated for Converse 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, Converse 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 Converse 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 Converse County ranges from 4%g in the northeastern portion of the county to greater than 7%g in the southwestern portion of the county. These accelerations are roughly comparable 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 V earthquakes can result in cracked plaster and broken dishes. Douglas would be subjected to an acceleration of approximately 6%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 Converse County ranges from 7%g in the northeastern part of the county to greater than 10%g in the southwestern 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. Douglas would be subjected to an acceleration of approximately 10 - 11%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 Converse County ranges from 11%g in the northeastern corner of the county to over 20%g in the southwestern quarter of the county. Those accelerations are roughly comparable to intensity VI earthquakes (9.2%g – 18.0%g) to intensity VII earthquakes (18.0%g – 34.0%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. Douglas would be subjected to an acceleration of approximately 20%g or intensity VII.

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 Converse County analyses. This conservative approach is in the interest of public safety.

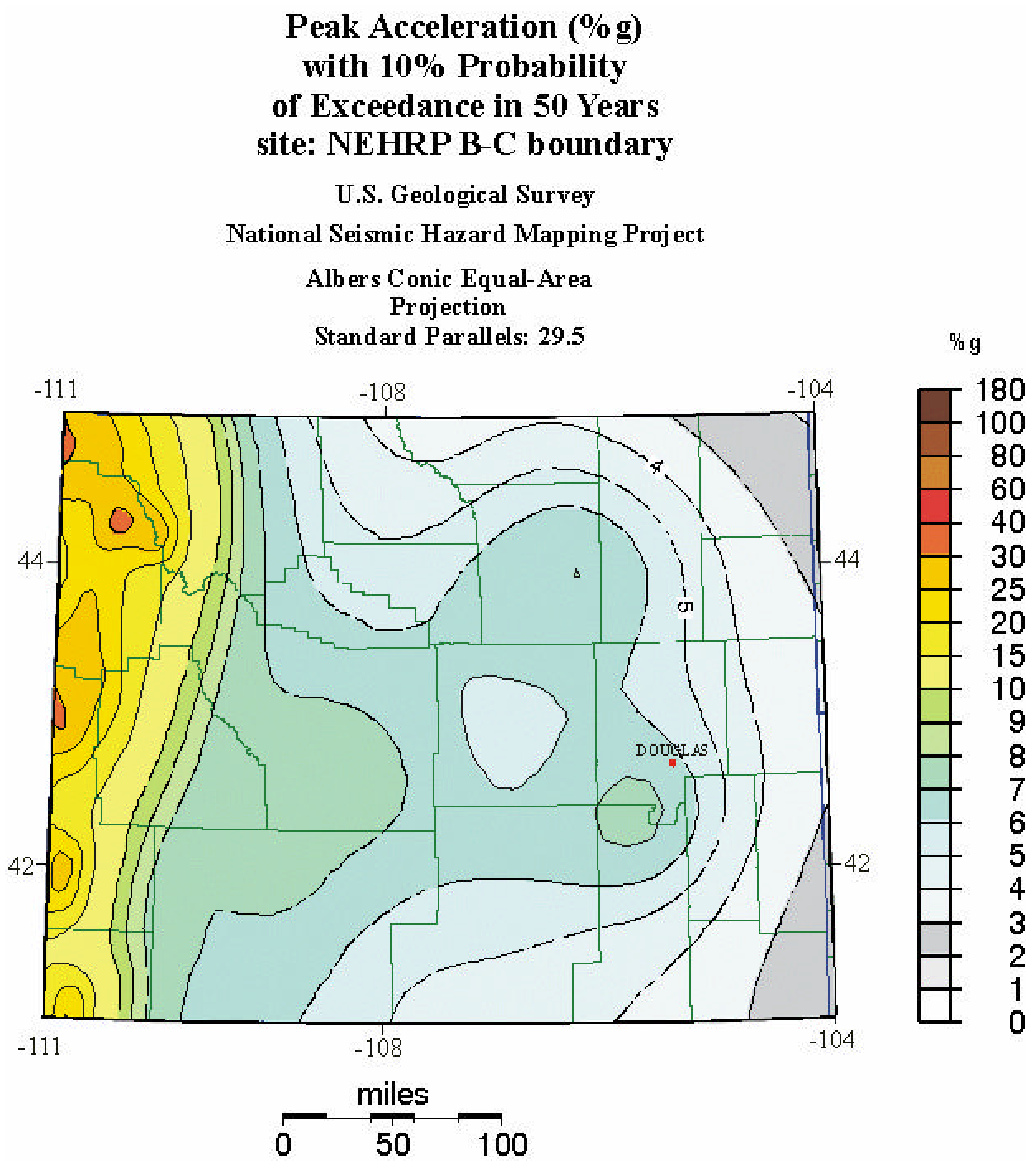

Figure 2. 500-year probabilistic acceleration map (10% probability of exceedance in 50 years).

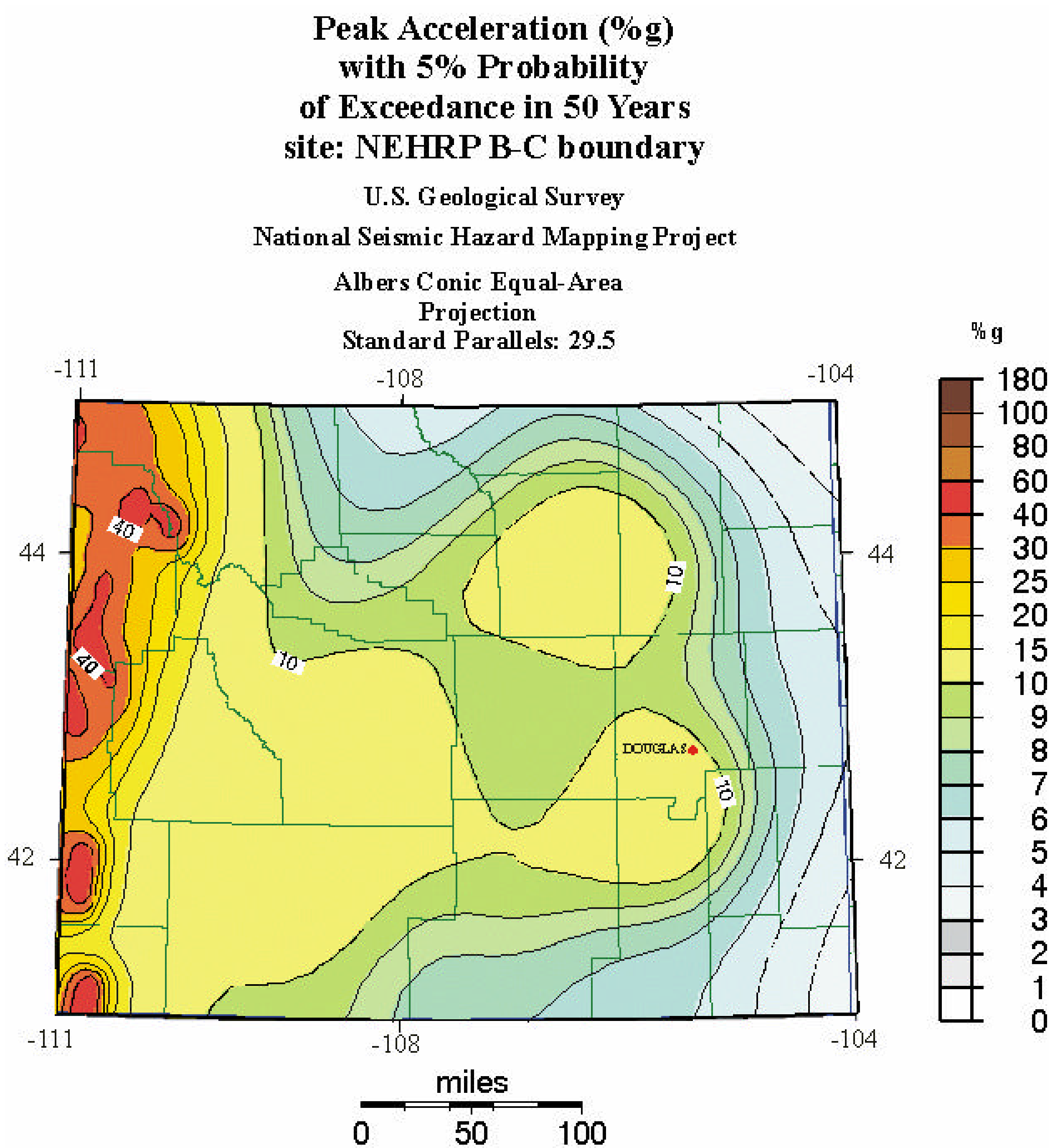

Figure 3. 1000-year probabilistic acceleration map (5% probability of exceedance in 50 years).

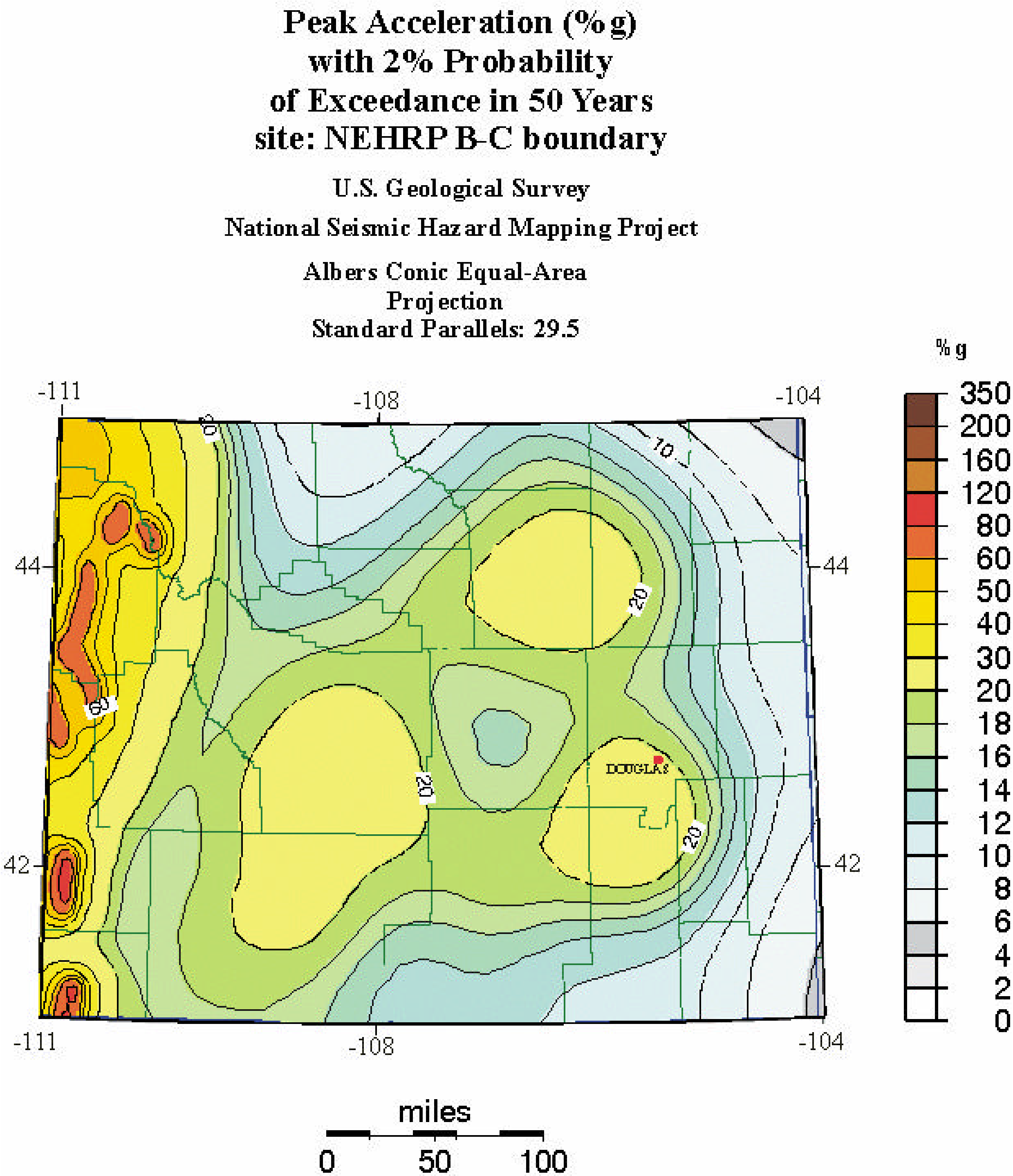

Figure 4. 2500-year probabilistic acceleration map (2% probability of exceedance in 50 years).

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).

Summary

There have been twenty-nine historic earthquakes with magnitudes greater than 3.0 recorded in or near Converse County. Because of the limited historic record, it is possible to underestimate the seismic hazard in Converse 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 Converse County.

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

Intensity VII Earthquake Areas

Boxelder
Douglas
Glenrock
Orin
Orpha
Rolling Hills

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

Bill
Lost Springs
Shawnee

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.

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., 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.

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.

Neumann, F., 1940, United States earthquakes 1938: U.S. Department of Commerce, Coast and Geodetic Survey Serial No. 629, 59 p.

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.