Basic Seismological Characterization
for
Carbon 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 Carbon 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 Carbon 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. Twenty-five magnitude 2.0 or intensity II and greater earthquakes have been recorded in Carbon County.

The first earthquake that was felt and reported in Carbon County occurred just southwest of Rawlins on March 28, 1896. The intensity IV earthquake shook for about two seconds. Residents of Rawlins reported that windows and dishes rattled and lamps swayed. The local newspaper also reported that "Several years ago a similar disturbance was felt here, but at that time it was considerably more severe" (The Rawlins Republican, April 3, 1896). The earlier earthquake may have been a November 7, 1882 event that occurred between Laramie and Estes Park, Colorado. Kirkham and Rogers (1985) report that the earthquake was felt as an intensity V event in Rawlins.

On March 10, 1917, another intensity IV earthquake was recorded approximately one mile northeast of Rawlins. The earthquake was felt as a distinct shock that caused wooden buildings to noticeably vibrate. Stone buildings were not affected by the event (Rawlins Republican, March 15, 1917).

The next two earthquakes in Carbon County occurred in the Medicine Bow area. The first was recorded on February 5, 1938, less than a mile southeast of Medicine Bow. The intensity III earthquake was felt as a slight shock in Medicine Bow (Neumann, 1940). On August 28, 1952, an intensity IV earthquake occurred in the same area. Area residents felt this event and reported buildings creaking and loose objects rattling (Murphy and Cloud, 1954).

Most of the earthquakes recorded in Carbon County occurred in the 1970's. A small earthquake of no assigned intensity or magnitude was detected on April 13, 1973, approximately 6 miles west of Hanna. No one reported feeling this event (Reagor, Stover, and Algermissen, 1985). On May 29, 1973, another earthquake of no specific magnitude or intensity occurred near the Ferris Mountains, approximately 21 miles northeast of Lamont. This earthquake was also not felt (Reagor, Stover, and Algermissen, 1985). Two more small earthquakes of no specific magnitude or intensity were recorded in Carbon County on May 30, 1973, and June 1, 1973. Again, no one felt these earthquakes, which were centered approximately 6 miles west of Hanna (Reagor, Stover, and Algermissen, 1985). On August 3, 1973, a magnitude 4.1 earthquake was recorded on the southeastern margin of Seminoe Reservoir, approximately 13 miles northwest of Hanna. A few days later, a magnitude 3.6 earthquake was recorded approximately 9 miles northwest of Hanna on August 10, 1973. Explosions were later identified as being the probable causes of the August 3 and August 10 earthquakes (Coffman and von Hake, 1975). A small earthquake of no assigned magnitude occurred approximately 11 miles northwest of Hanna on August 17, 1973. The U.S. Geological Survey did not report this event as explosion; however, the record was so weak that a definite origin is uncertain (Reagor, Stover, and Algermissen, 1985). A second earthquake of no specific magnitude or intensity occurred on August 17, 1973, approximately 9 miles west-northwest of Medicine Bow. No one reported feeling this event (Reagor, Stover, and Algermissen, 1985). On November 21, 1973, another earthquake resulting from a probable explosion was recorded on the western side of Seminoe Reservoir, approximately 20 miles north-northeast of Sinclair. No magnitude was assigned to the event (Coffman and von Hake, 1975). On December 26, 1973, a small earthquake of no specific magnitude or intensity was recorded approximately 29 miles north-northwest of Hanna. An explosion is thought to be the cause of this earthquake (Reagor, Stover, and Algermissen, 1985). On July 11, 1975, an earthquake occurred on the southeastern margin of Seminoe Reservoir, approximately 12 miles northwest of Hanna. Residents in Rawlins felt the earthquake as an intensity II event (Coffman and Stover, 1977). A magnitude 2.3, intensity V earthquake occurred on January 27, 1976, approximately 12 miles north of Rawlins. Many reports from the Park Drive area indicated that dishes were rattled, pictures fell from walls, lamps were knocked off tables, and one wall in a residence was reportedly cracked. Several people reported that they were thrown out of bed. (Daily Times, January 28, 1976). The last earthquake recorded in Carbon County in the 1970s occurred on March 3, 1977. This magnitude 4.2, intensity V earthquake occurred in the Sierra Madre Mountains, approximately 18.5 miles west-northwest of Encampment. Doors and dishes were rattled in southern Carbon County homes, but no significant damage was reported (The Laramie Daily Boomerang, March 6, 1977).

Only one earthquake was recorded in Carbon County in the 1980s. On November 1, 1989, a magnitude 3.0 earthquake occurred in the Sierra Madre Mountains, approximately 12 miles west of Encampment. Residents of Saratoga reported feeling this earthquake (U.S. Geological Survey, 1989).

Several earthquakes occurred in Carbon County in the 1990s. On April 13, 1991, and April 19, 1991, magnitude 3.2 and magnitude 2.9 earthquakes, respectively, occurred near the center of Seminoe Reservoir. The April 13 event was centered approximately 22 northeast of Sinclair, and the April 19 event was centered approximately 24 miles northeast of Sinclair. On December 18, 1991, a magnitude 3.1 earthquake occurred southwest of Seminoe Reservoir, approximately 15 miles northeast of Sinclair. The last earthquake reported in the area occurred on August 23, 1993. This magnitude 3.0 earthquake, occurred near the center of Seminoe Reservoir, approximately 18 miles northwest of Hanna. No one reported feeling these Seminoe Reservoir area earthquakes (Case, 1994; U.S.G.S. National Earthquake Information Center). Two additional earthquakes were felt in Carbon County in the 1990's. On August 6, 1998, a magnitude 3.6 earthquake occurred approximately 13 miles north of Rawlins. Residents in Rawlins reported hearing a sound and then feeling a jolt. This non-damaging earthquake was also felt in Sinclair. A magnitude 4.3 earthquake occurred on April 5, 1999, approximately 29 miles north-northwest of Baggs. It was felt in Rawlins, Sinclair, Baggs, Wamsutter, and Rock Springs. Residents of Rawlins reported that pictures fell off walls. The most significant damage occurred between Baggs and Creston Junction, and at Wamsutter. The owner of a ranch house, located approximately 30 miles north of Baggs, reported that cinder block walls in the basement of the home cracked, separated, and may have to be replaced. A motel and associated residence in Wamsutter also suffered cracks in the cinder-block walls of the basement.

Most recently, 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 27 miles north-northwest of Hanna (U.S.G.S. National Earthquake Information Center).

Regional Historic Seismicity

Several earthquakes have also occurred near Carbon County. As previously mentioned, an earthquake occurred on November 7, 1882, between Laramie and Estes Park, Colorado. Residents in Rawlins reported feeling the earthquake as an intensity V event (Kirkham and Rogers, 1985).

On August 11, 1916, an earthquake was recorded in southeastern Fremont County, approximately 21 miles northwest of Lamont. No damage was reported from this intensity III event (Reagor, Stover, and Algermissen, 1985).

An intensity IV earthquake occurred in Albany County 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, approximately 34 miles northeast of Medicine Bow. No damage was associated with the event (Neumann, 1940).

On January 22, 1954, an earthquake was recorded in southwestern Albany County, approximately 42 miles east-southeast of Riverside. This intensity IV earthquake resulted in a very strong but brief shock felt in Jelm (Murphy and Cloud, 1956). On January 23, 1954, an intensity IV earthquake was detected in southern Natrona County, approximately 50 miles north of Hanna. 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 May 22, 1955, an intensity V earthquake in southwestern Albany County, approximately 42 miles east-southeast of Riverside, caused considerable concern. Many Jelm and Woods Landing 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 in the same area 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). On December 25, 1959, a magnitude 4.3, intensity V event was recorded approximately 38 miles southeast of Riverside. The earthquake 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. All Jelm residents felt the earthquake, with many reporting creaking walls (Eppley and Cloud, 1961).

On September 10, 1964, a magnitude 4.1 earthquake occurred in eastern Sweetwater County, approximately 30 miles west of Rawlins. One Rawlins resident reported that the earthquake caused a crack in the basement of his Happy Hollow home. No other damage was reported (The Daily Times, September 11, 1964). On November 24, 1966, a small earthquake with no specific intensity or magnitude occurred approximately 40 miles west-southwest of Rawlins. No one reported feeling this earthquake (Reagor, Stover, and Algermissen, 1985).

The only earthquake to occur near Carbon County in the 1970s occurred on April 22, 1973, in southeastern Fremont County, approximately 34 miles north-northwest of Lamont. This magnitude 4.8, intensity V earthquake rattled dishes and disturbed pictures on walls in Jeffrey City (Casper Star-Tribune, April 24, 1973).

No other earthquakes occurred in the region until October 18, 1984, when an earthquake in northern Albany County caused damage in Carbon County. The magnitude 5.5, intensity VI earthquake, which was centered approximately 38 miles northeast of Medicine Bow, 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 also slightly cracked by the earthquake. This 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.

A magnitude 3.8, intensity III earthquake occurred in southeastern Fremont County on June 1, 1993. No damage was reported from this event, which was centered approximately 7 miles northwest of Lamont (Case, 1994). On October 9, 1993, a magnitude 3.7, intensity IV earthquake occurred in eastern Albany County, approximately 39 miles north-northeast of Medicine Bow. The earthquake was felt in Garrett. A magnitude 3.4 earthquake occurred in southeastern Fremont County, approximately 14 miles northwest of Lamont on December 11, 1996. No damage was associated with this earthquake.

On April 13, 2000, a magnitude 3.3 earthquake occurred in northern Albany County, approximately 40 miles northeast of Medicine Bow. No damage was reported. Two earthquakes occurred in northeastern Sweetwater County in May 2000. A magnitude 4.0 event was recorded on May 26, 2000, approximately 5 miles southwest of Lamont. Four days later, on May 30, 2000, a magnitude 3.2 event was recorded in the same area. Area residents reported feeling both earthquakes (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.

Carbon County is primarily in Seismic Zone 1 of the UBC. Since effective peak accelerations (90% chance of non-exceedance in 50 years) can range from 5%g-10%g in these two zones, 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 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. Carbon County still uses the UBC, however, as do most Wyoming counties as of December 2002.

Deterministic Analysis of Regional Active Faults with a Surficial Expression

Carbon County contains an active fault system called the South Granite Mountain fault system, which should be included in a deterministic analysis. The South Granite Mountain fault system is composed of several northwest-southeast trending fault segments in southeastern Fremont County and northwestern Carbon County. 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

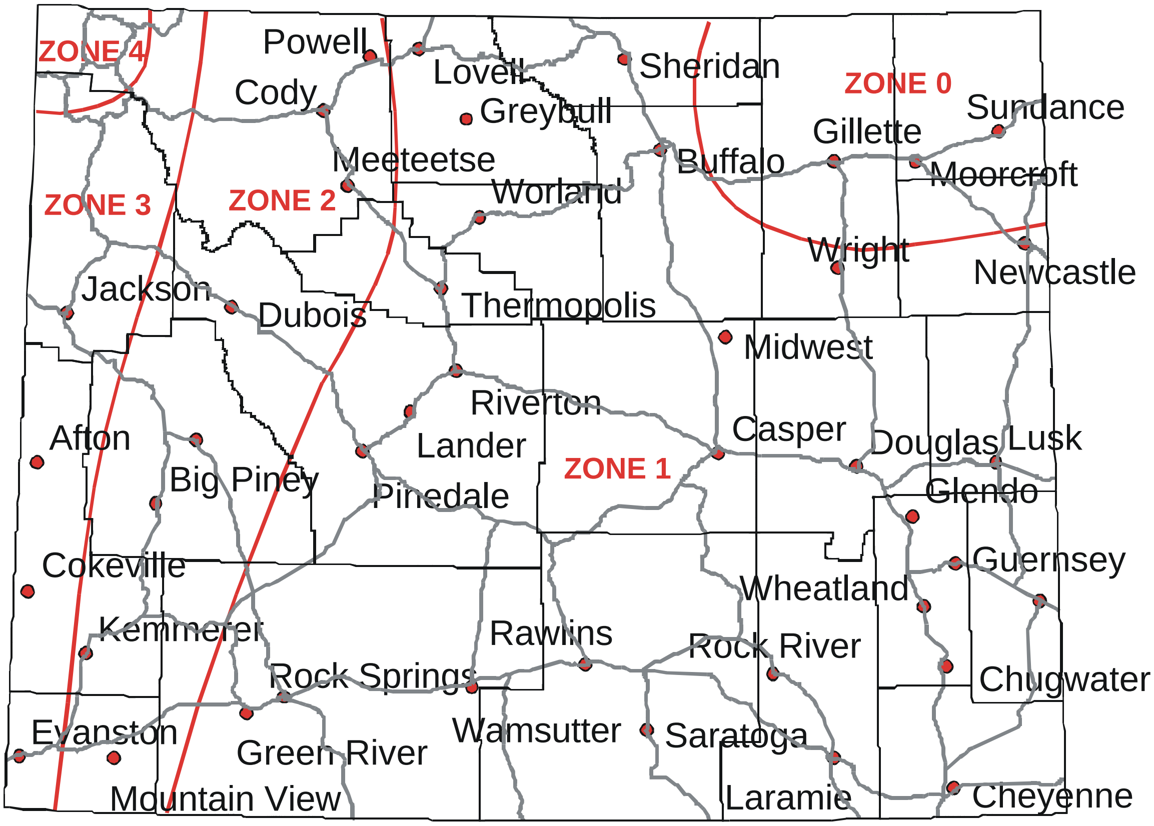

Figure 1. UBC Seismic Zone Map.

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. They 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 3.1%g at Arlington, approximately 4.5%g at Elk Mountain, approximately 1.8%g at Encampment and Riverside, approximately 9.4%g at Hanna, approximately 21%g at Lamont, approximately 4.9%g at Medicine Bow, approximately 5%g at Rawlins, approximately 3%g at Saratoga, approximately 5.1%g at Sinclair, approximately 45%g at Seminoe Reservoir Dam, and approximately 9.4%g at Pathfinder Reservoir Dam (Campbell, 1987). These accelerations would be roughly equivalent to an intensity VIII earthquake at Seminoe Reservoir Dam, an intensity VII earthquake at Lamont, intensity VI earthquakes at Hanna and Pathfinder Reservoir Dam, intensity V earthquakes at Elk Mountain, Medicine Bow, Rawlins, and Sinclair, and intensity IV earthquakes at Arlington, Encampment, Riverside, and Saratoga. Seminoe Reservoir Dam could sustain moderate to heavy damage whereas moderate damage could occur in Lamont. Hanna and Pathfinder Reservoir Dam could sustain light damage and Elk Mountain, Medicine Bow, Rawlins, and Sinclair could sustain very light damage. No damage would occur Arlington, Encampment, Riverside, and Saratoga.

Several other active fault systems exist in southwestern Wyoming, including the Chicken Springs, Bear River, Rock Creek, and Grey’s River fault systems. The Bear River, Rock Creek, and Grey’s River fault systems are too far away to cause damage in Carbon County. If the Chicken Springs fault system in Sweetwater County activates, however, Carbon County could be affected. The Chicken Springs fault system is composed of a series of east-west trending segments in the northeastern corner of Sweetwater County. In 1996, the Wyoming State Geological Survey investigated the Chicken Springs fault system for the U.S. Nuclear Regulatory Commission and the Kennecott Uranium Company. The most recent activation on the system appears to be Holocene in age. Reconnaissance-level studies indicated that the fault system is capable of generating a magnitude 6.5 earthquake (Shepherd Miller, 1996). A magnitude 6.5 earthquake on the Chicken Springs fault system would generate peak horizontal accelerations of approximately 1.85%g at Hanna, approximately 18.5%g at Lamont, approximately 4.8%g at Rawlins, approximately 1.6%g at Saratoga, approximately 3.9%g at Sinclair, approximately 3.4%g at Seminoe Reservoir Dam, and approximately 2.6%g at Pathfinder Reservoir Dam (Campbell, 1987). These accelerations would be roughly equivalent to an intensity VII earthquake at Lamont, intensity V earthquakes at Rawlins and possibly Sinclair, and intensity IV earthquakes at Hanna, Saratoga, Sinclair, Pathfinder Reservoir Dam, and Seminoe Reservoir Dam. An intensity VII event at Lamont would have the potential to cause moderate damage. Rawlins and possibly Sinclair (if felt as an intensity V earthquake) could sustain very light damage, and no damage would occur at Hanna, Saratoga, Sinclair (if felt as an intensity IV earthquake), Pathfinder Reservoir Dam, and Seminoe Reservoir Dam.

A number of unmapped faults also exist in the Washakie Basin area in southern Sweetwater and Carbon Counties. Further field investigation is necessary to determine if any of these faults should be deemed active.

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, Carbon 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 Carbon 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 Carbon County ranges from approximately 4%g in the southern and southeastern portions of the county to over 6%g in the northern part 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. Rawlins and Saratoga would be subjected to accelerations of approximately 5-6%g and 5%g, respectively, or intensity V.

Based upon the 1000-year map (5% probability of exceedance in 50 years) (Figure 3), the estimated peak horizontal acceleration in Carbon County ranges from 6%g in the southeastern corner of the county to over 10%g in the northeastern and northwestern corners of the county. These accelerations are roughly comparable to intensity V earthquakes (3.9%g – 9.2%g) to 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. Rawlins and Saratoga would be subjected to accelerations of approximately 9-10%g (intensity V-VI) and 8%g (intensity V), respectively.

Based upon the 2500-year map (2% probability of exceedance in 50 years) (Figure 4), the estimated peak horizontal acceleration in Carbon County ranges from approximately 11%g in the southeastern corner of the county to over 20%g in the northeastern portion 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. Rawlins and Saratoga would be subjected to accelerations of approximately 17-18%g (intensity VI-VII) and 14-15%g (intensity VI), 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 Carbon 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.

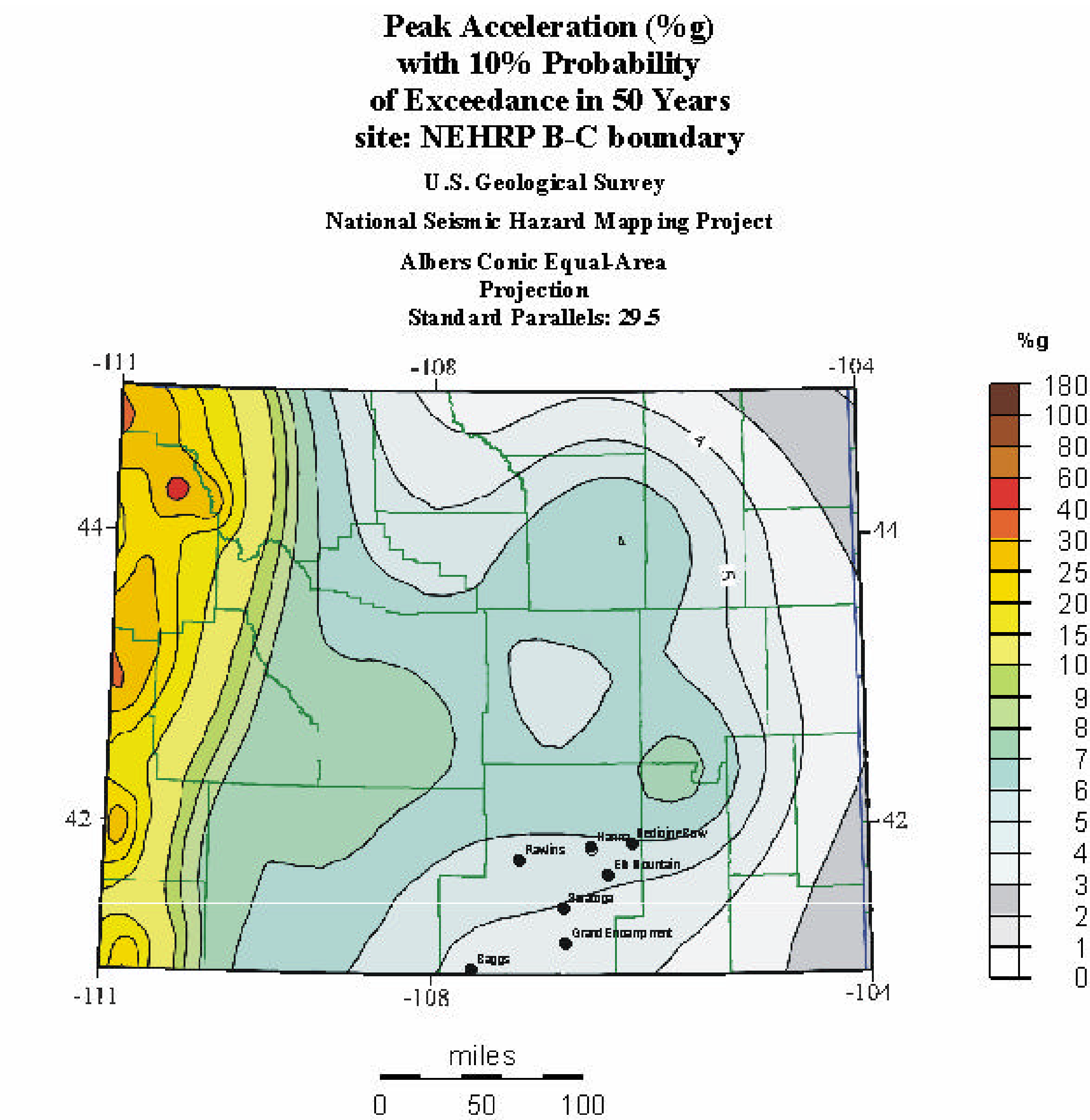

Figure 2. 500-year probabilistic acceleration map (10% probability of exceedance in 50 years).

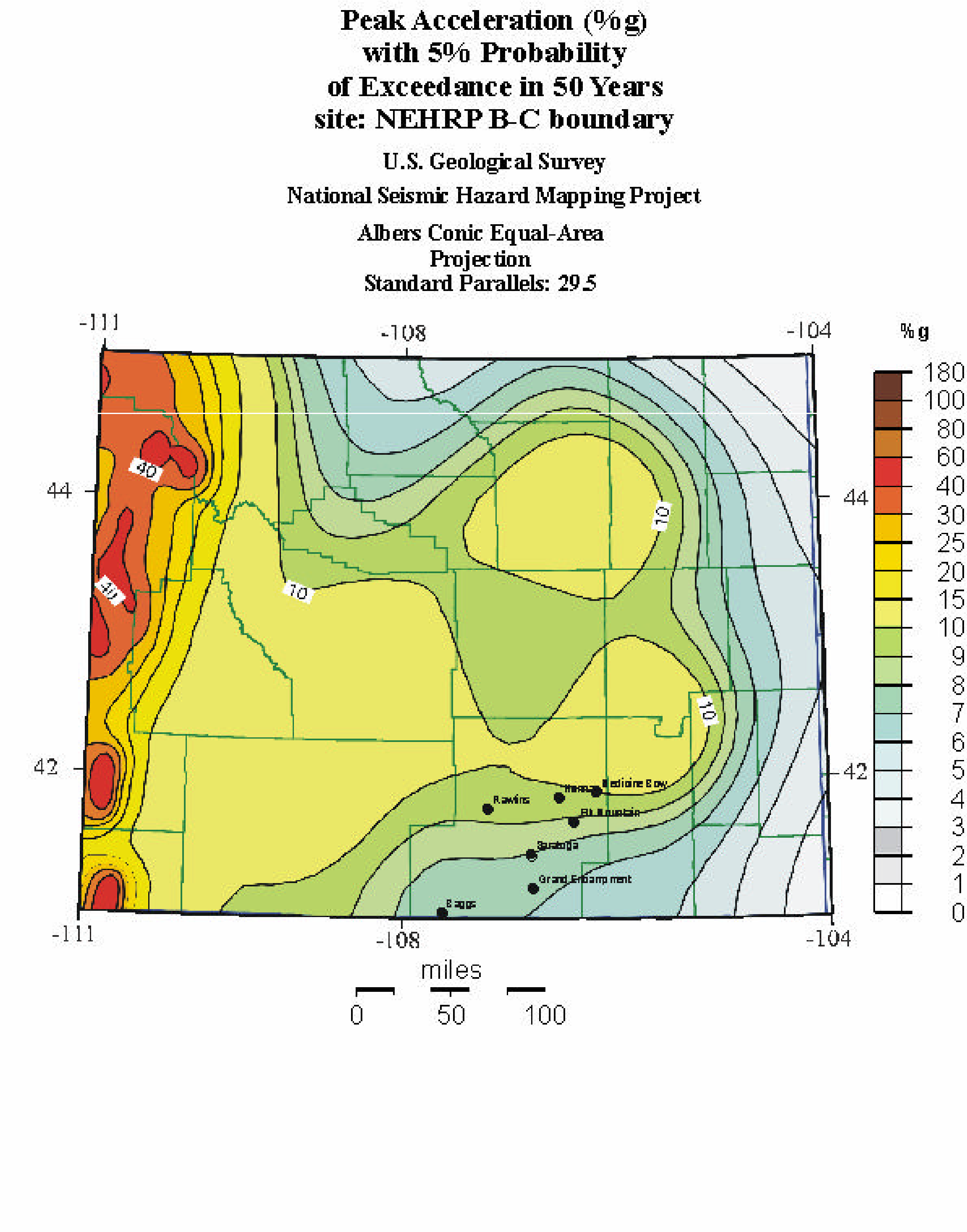

Figure 3. 1000-year probabilistic acceleration map (5% probability of exceedance in 50 years).

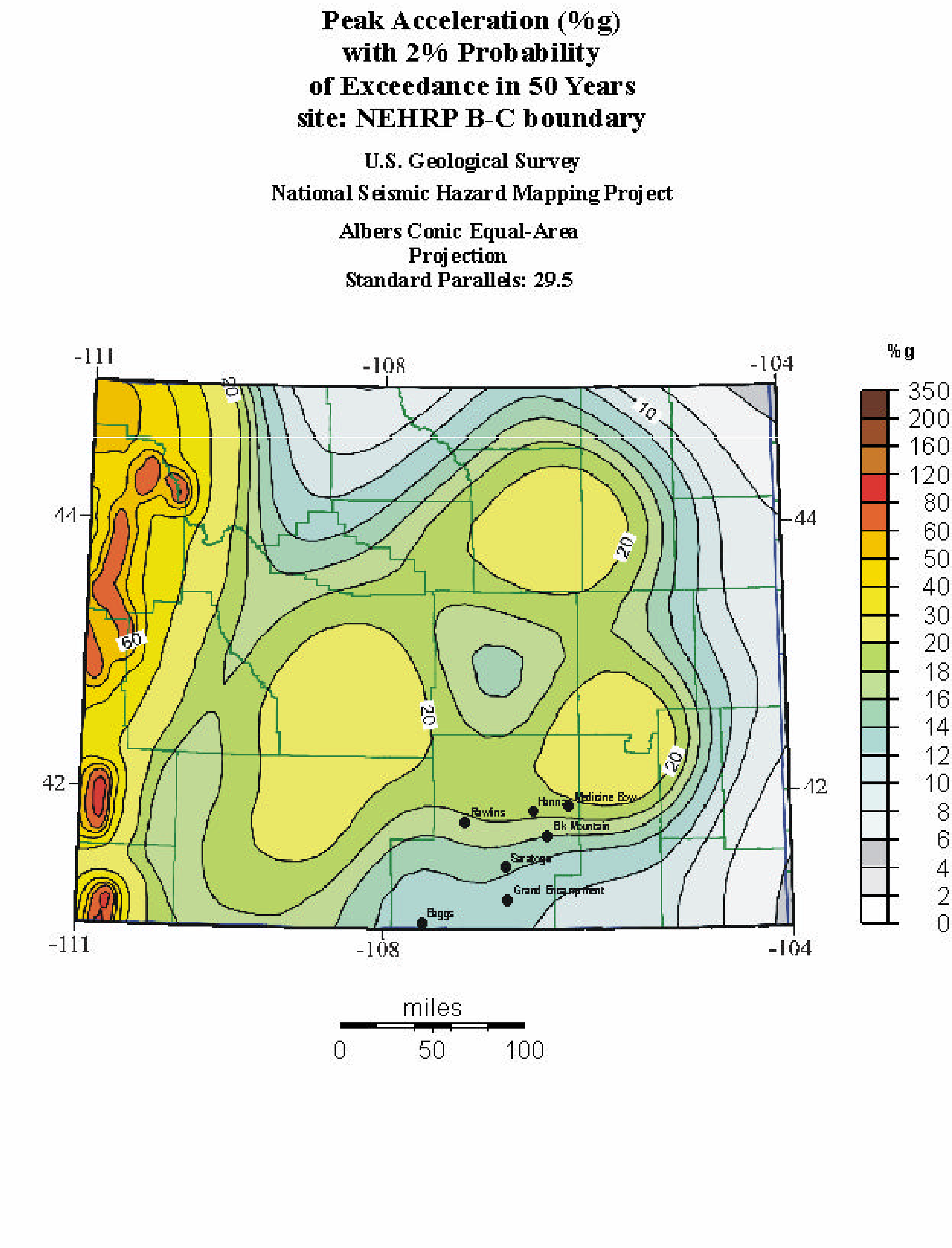

Figure 4. 2500-year probabilistic acceleration map (2% probability of exceedance in 50 years).

Summary

There have been over fifty historic earthquakes with a magnitude greater than 2.0 recorded in or near Carbon County. Because of the limited historic record, it is possible to underestimate the seismic hazard in Carbon 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 Carbon 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 northeast. More specifically, the probability-based or fault activation-based worst-case scenario could result in the following damage at points throughout the county:

<u>Intensity VIII Earthquake Areas</u>

Seminoe Reservoir Dam

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.

<u>Intensity VII Earthquake Areas</u>

Elmo
Hanna
Lamont
Medicine Bow
Rawlins
Sinclair
Walcott

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.

<u>Intensity VI Earthquake Areas</u>

Arlington
Baggs
Dixon
Elk Mountain
Encampment
McFadden
Pathfinder Reservoir Dam
Riverside
Saratoga
Savery

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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