

**Basic Seismological Characterization  
for  
Fremont County, Wyoming**

by

James C. Case, Rachel N. Toner, and Robert Kirkwood  
Wyoming State Geological Survey  
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**BACKGROUND**

Seismological characterizations of an area can range from an analysis of historic seismicity to a long-term probabilistic seismic hazard assessment. A complete characterization usually includes a summary of historic seismicity, an analysis of the Seismic Zone Map of the Uniform Building Code, deterministic analyses on active faults, “floating earthquake” analyses, and short- or long-term probabilistic seismic hazard analyses.

Presented below, for Fremont County, Wyoming, is an analysis of historic seismicity, an analysis of the Uniform Building Code, deterministic analyses of nearby active faults, an analysis of the maximum credible “floating earthquake”, and current short- and long-term probabilistic seismic hazard analyses.

**Historic Seismicity**

The enclosed map of “Earthquake Epicenters and Suspected Active Faults with Surficial Expression in Wyoming” (Case and others, 1997) shows the historic distribution of earthquakes in Wyoming. Over thirty magnitude 2.0 or intensity III and greater earthquakes have been recorded in Fremont County. These earthquakes are discussed below.

The first earthquake that was reported in Fremont County occurred on December 10, 1873. This earthquake, which was located in the southern part of the county near Atlantic City, was felt as an intensity III event at nearby Camp Stambaugh (Case, 1996). On January 22, 1889, an intensity III-IV earthquake was reported near Lander. An intensity IV earthquake also occurred in the Lander area on November 21, 1895. People reported that houses were jarred and dishes rattled (Case, 1996).

On August 11, 1916, an earthquake occurred in the Sand Draw/Gas Hills area. No damage was reported from this intensity III event, which was centered approximately 6 miles south of Jeffrey City (Reagor, Stover, and Algermissen, 1985).

Two earthquakes were reported in Fremont County in the 1920s. The first occurred on December 12, 1923, when an intensity V earthquake was detected approximately 3 miles west-northwest of Atlantic City (Humphreys, 1924). No significant damage was reported. This area experienced another non-damaging, intensity III earthquake on October 30, 1925.

Only one earthquake was reported in the county in the 1930s. On November 23, 1934, an intensity V earthquake was reported approximately 20 miles northwest of Lander. Residents in a 10-mile radius around Lander reported that dishes were thrown from cupboards and pictures fell from walls. Buildings in two business blocks were cracked, and the brick chimney of the Fremont County Courthouse was moved two inches away from the building. The earthquake was felt as far away as Rock Springs and Green River (Casper Tribune-Herald, November 25, 1934).

No earthquakes were reported in Fremont County in the 1940s, but several were reported in the county in the 1950s. On August 17, 1950, an intensity IV earthquake occurred approximately 2.5 miles south-southeast of Lander. It caused loose objects to rattle and buildings to creak (Murphy and Ulrich, 1952). Intensity II and intensity IV earthquakes occurred in the same area on January 11, 1954 (Reagor, Stover, and Algermissen, 1985) and December 13, 1955 (Murphy and Cloud, 1957), respectively. No damage was reported from either event. On August 22, 1959, an intensity IV earthquake was detected approximately 3.5 miles west-northwest of Atlantic City. No damage was associated with this earthquake. A few days later, an earthquake was recorded on August 25, 1959. This event, which was located just southeast of Fort Washakie, was later determined to be non-tectonic in origin.

On October 12, 1961, a small-magnitude earthquake was detected approximately 7 miles northwest of Pavillion (Reagor, Stover, and Algermissen, 1985). Two earthquakes were recorded in northern Fremont County on April 26, 1967. A magnitude 4.7 event and a magnitude 4.2 event occurred approximately 32 miles southwest and approximately 38 miles west-southwest of Thermopolis, respectively (Reagor, Stover, and Algermissen, 1985). No damage was associated with any of the earthquakes that occurred in the county in the 1960s.

Several earthquakes were reported in Fremont County in the 1970s. The first occurred on April 22, 1973, approximately 12 miles north of Jeffrey City. This magnitude 4.8, intensity V earthquake rattled dishes and disturbed pictures on walls in Jeffrey City (Casper Star-Tribune, April 24, 1973). A small earthquake occurred on June 14, 1973, approximately 8 miles east-northeast of Lander. This event was later determined to be the result of an explosion in the area. On March 25, 1975, a magnitude 4.8, intensity II earthquake was detected approximately 18 miles northwest of Jeffrey City. A mobile home located 35 miles southeast of Riverton was moved an inch off its foundation by this earthquake (Laramie Daily Boomerang, March 26, 1975). A magnitude 3.5 earthquake occurred on December 19, 1975, approximately 25 miles northeast of Jeffrey City (Reagor, Stover, and Algermissen, 1985). This earthquake did not cause any damage. Later that same month, on December 30, 1975, an earthquake of no specific magnitude

or intensity was recorded in eastern Fremont County, approximately 27 miles east-southeast of Riverton. No one reported feeling this event.

Four earthquakes were reported in the county in the 1980s. On January 28, 1980, a magnitude 2.8 earthquake was recorded in the northwestern part of the county, approximately 28 miles northwest of Dubois. This earthquake was not felt. A magnitude 3.1 earthquake occurred on September 4, 1980, approximately 15 miles west-southwest of Atlantic City. No damage was reported. A magnitude 3.2, intensity IV earthquake occurred in Fremont County on August 31, 1982. No significant damage was reported from this earthquake, which was centered approximately 10 miles southwest of Lander (Case, 1994). On November 3, 1984, a magnitude 5.1, intensity VI earthquake was detected approximately 10 miles northwest of Atlantic City. The earthquake was felt in Lander, Dubois, Atlantic City, and Casper. Residents in Lander and Atlantic City reported cracked walls, foundations, and windows (Casper Star-Tribune, November 4, 1984). This event was one of the largest earthquakes to occur in the southwestern quarter of the state. The last earthquake to occur in Fremont County in the 1980s took place on August 16, 1985. This magnitude 4.3, intensity IV event occurred approximately 25 miles southeast of Jeffrey City (Case, 1994). No damage was associated with this earthquake.

On August 7, 1991, a magnitude 3.5 earthquake was recorded in northern Fremont County, approximately 35 miles southwest of Thermopolis. Residents of Thermopolis reported feeling this non-damaging earthquake. Another non-damaging earthquake occurred on January 31, 1992, approximately 20 miles northwest of Lander (Case, 1994). Area residents reported feeling this magnitude 2.8 event (U.S.G.S. National Earthquake Information Center). On October 10, 1992, a magnitude 4.0, intensity III earthquake was detected approximately 22 miles east of Lander (Case, 1994). Again, people in the area felt this earthquake, but no damage was reported from it (U.S.G.S. National Earthquake Information Center). A magnitude 3.8, intensity III earthquake occurred near Bairoil on June 1, 1993, approximately 17 miles southeast of Jeffrey City (Case, 1994). No damage was reported. On August 22, 1993, a magnitude 3.1 earthquake was recorded in northwestern Fremont County, approximately 14 miles west-northwest of Dubois. No one reported feeling this earthquake. A magnitude 3.4 earthquake occurred approximately 11 miles southeast of Jeffrey City on December 11, 1996. Again, no damage was associated with this earthquake. This earthquake was followed by another non-damaging, magnitude 3.1 event on April 25, 1997. No one felt this earthquake that was centered approximately 10 miles south of Lander (U.S.G.S. National Earthquake Information Center). Lander city officials reported, however, that the earthquake may have caused a crack in the city's water tank, releasing 600,000 gallons of water. On July 21, 1999, another magnitude 3.1 earthquake occurred approximately 23 miles southeast of Lander. No one reported feeling this event (U.S.G.S. National Earthquake Information Center).

On August 19, 2000, an earthquake was reported approximately 25 miles west-northwest of Jeffrey City. Area residents reported feeling this magnitude 3.2 earthquake. Most recently, a magnitude 3.0 earthquake occurred on November 8, 2000, in northeastern Fremont County. This event was centered approximately 29.5 miles southeast of Thermopolis. No one reported feeling this earthquake (U.S.G.S. National Earthquake Information Center).

## Regional Historic Seismicity

Several earthquakes have also been reported near Fremont County. On February 13, 1928, an earthquake occurred in Hot Springs County, approximately 18 miles north-northwest of Shoshoni. The intensity IV earthquake was felt as three shocks in Thermopolis, and was “felt sharply” in Worland, Owl Creek, Gebo, Crosby, and Kirby. It was also strongly felt at a mine in the Copper Mountain mining district near Bonneville. Reports indicate that two men entered their mine when aftershocks were occurring and found that many of the mine props were so loose that they could be moved by hand (Heck and Bodle, 1930). On June 19, 1928, another intensity IV earthquake was reported in the area, with the epicenter located approximately 34 miles north-northwest of Shoshoni (Heck and Bodle, 1930). A single shock from this event was felt in Thermopolis, with sounds slightly preceding the earthquake.

No earthquakes were reported in the region until the 1940s. On October 11, 1944, an intensity IV earthquake was reported in Hot Springs County, approximately 3 miles south of Thermopolis. Several landslides occurred as a result of the earthquake, and rocks fell onto the highway in Wind River Canyon. At Hot Springs State Park, there was a “caving of earth on the south rim of the large hot spring in the park” (Casper Tribune-Herald, October 13, 1944). Another intensity IV earthquake occurred in the same area on January 26, 1946. This event, which was felt for approximately ten seconds, rattled windows and dishes and clouded the water in Hot Springs State Park for a few days (Laramie Republican-Boomerang, January 29, 1946).

On January 23, 1950, an intensity V earthquake was felt near Hamilton Dome, approximately 39 miles north-northeast of Pavillion. Houses shook and dishes rattled in the Hamilton Done area, and the earthquake was felt in Thermopolis (Murphy and Ulrich, 1952). Another intensity V earthquake occurred approximately 3 miles south of Thermopolis on January 31, 1954 (Casper Tribune-Herald, February 2, 1954). No damage was reported from this event.

Several earthquakes were reported near Fremont County in the 1960s. A magnitude 4.3, intensity V earthquake occurred in southeastern Sublette County on February 25, 1963, approximately 25 miles west-northwest of Atlantic City. The earthquake was felt for over a minute in Atlantic City, and for approximately six seconds in the Lander and Hudson areas (Casper Star-Tribune, February 26, 1963). Windows, doors, and dishes were rattled in Fort Washakie as a result of the earthquake (von Hake and Cloud, 1965). On June 25, 1963, a magnitude 4.2 earthquake occurred in southwestern Park County, approximately 37 miles northwest of Dubois. No one reported feeling this earthquake (U.S.G.S. National Earthquake Information Center). On October 14, 1963, a magnitude 4.5 earthquake was recorded in northeastern Sweetwater County, approximately 30 miles southeast of Atlantic City. No damage was reported. An earthquake of no specific magnitude or intensity was recorded in northern Sublette County on December 18, 1967. No one reported feeling this earthquake, which was centered approximately 11.5 miles southwest of Dubois (U.S.G.S. National Earthquake Information Center). On November 15, 1968, a magnitude 3.9 earthquake was recorded in eastern Teton County, approximately 30 miles northwest of Dubois. No one reported feeling the earthquake (U.S.G.S. National Earthquake Information Center).

On December 8, 1972, a magnitude 4.1, intensity V earthquake was detected in Hot Springs County, approximately 28 miles northwest of Shoshoni. It caused two cracks in the ceiling of a new addition to a Thermopolis rest home (Laramie Daily Boomerang, December 9, 1972), and the floor in a local lumberyard sank a few inches (Casper Star-Tribune, December 9, 1972). The earthquake was felt in Kinnear, Pavillion, and the Riverton area, and was reportedly felt as far away as Craig, Colorado. A magnitude 4.0 earthquake was recorded in Hot Springs County on June 6, 1978, approximately 30 miles northeast of Shoshoni (Reagor, Stover, and Algermissen, 1985). No damage was associated with this earthquake. Another non-damaging earthquake occurred on November 9, 1983, in eastern Teton County. This magnitude 3.6, intensity III earthquake was centered approximately 30 miles northwest of Dubois. The U.S.G.S. National Earthquake Information Center reported that this event was felt. Several other earthquakes occurred in eastern Teton County during the 1990s, but most were not felt. On December 28, 1993, however, a magnitude 4.7 earthquake, intensity V earthquake occurred in Teton County, approximately 24.5 miles west-southwest of Dubois. The earthquake was felt in Jackson, Dubois, Hudson, Lander, and Rock Springs. Most reports indicated that the earthquake felt like a heavy truck passing by. A ranch near the epicenter reported swinging lights, but no damage.

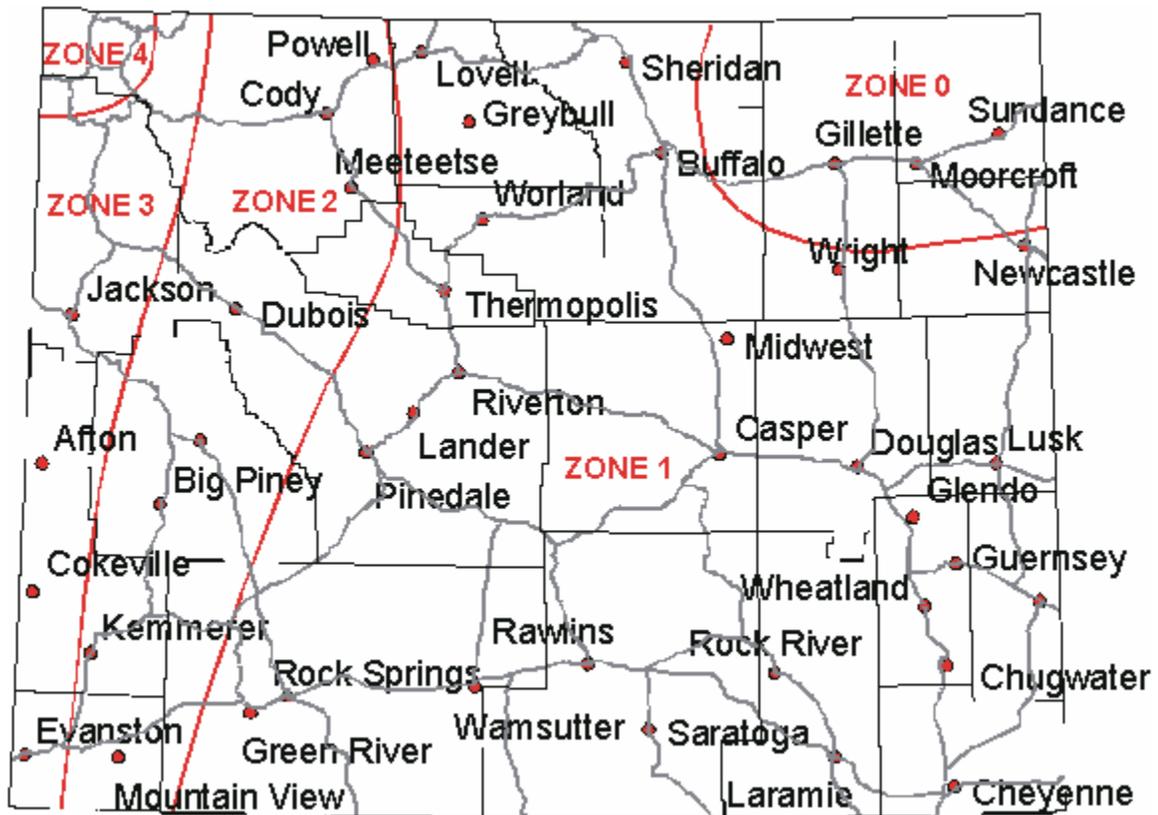
In 2000, two earthquakes were reported in northeastern Sweetwater County near the town of Bairoil. A magnitude 4.00 event was recorded on May 26, 2000, and a magnitude 3.2 event was recorded four days later on May 30, 2000. People reported feeling both earthquakes (U.S.G.S. National Earthquake Information Center). The most recent earthquake to occur near Fremont County took place on September 27, 2001, near the Fremont County-Teton County-Sublette County borders. Area residents reported feeling this magnitude 4.3 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:



**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.

Fremont County is in Seismic Zones 1 and 2 of the UBC. The southeastern two-thirds of the county is in Seismic Zone 1, and the northwestern third of the county is in Seismic Zone 2. Since effective peak accelerations (90% chance of non-exceedance in 50 years) can range from 5%g-20%g in these zones, and there has been some significant historic seismicity in the county, it may be reasonable to assume that an average peak acceleration of 10%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 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. Fremont County has not adopted the UBC or the IBC, although Lander and Riverton have adopted the codes.

**Deterministic Analysis Of Regional Active Faults With A Surficial Expression**

Fremont County has two known active fault systems and one suspected active fault system with a surficial expression within the county boundary. The known systems are the South Granite Mountain fault system and the Stagner Creek fault system. The suspected active fault is the Cedar Ridge/Dry Fork fault system.

The South Granite Mountain fault system is 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 Seminole 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 6.7%g at Atlantic City, approximately 3%g at Ethete, approximately 34%g at Jeffrey City, approximately 4.5%g at Lander, approximately 2.1%g at Lysite and Pavillion, approximately 3.75%g at Riverton, and approximately 2.4%g at Shoshoni (Campbell, 1987). These accelerations would be roughly equivalent to an intensity VIII earthquake at Jeffrey City, intensity V earthquakes at Lander and Atlantic City, and intensity IV earthquakes at Ethete, Lysite, Pavillion, Riverton, and Shoshoni. Jeffrey City could sustain moderate to heavy damage, whereas very light damage could occur at Lander and Atlantic City. No damage should occur at Ethete, Lysite, Pavillion, Riverton, and Shoshoni. Dubois would be subjected to ground accelerations of less than 1.5%g, which should not cause any damage. Pipelines crossing the South Granite Mountain Fault System could 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 maximum credible earthquake for this fault system was determined to be a magnitude 6.75 event. A magnitude 6.75 earthquake originating on the Stagner Creek fault system could generate peak horizontal accelerations of approximately 64% at Boysen Dam, 1.6%g at Atlantic City, approximately 1.9%g at Dubois, approximately 4.4%g at Ethete, approximately 1.8%g at Jeffrey City, approximately 3%g at Lander, approximately 7.6%g at Lysite, approximately 9.4%g at Pavillion, approximately 6%g at Riverton, and nearly 18%g at Shoshoni. These accelerations would be roughly equivalent to intensity VIII at Boysen Dam, intensity VI earthquakes at Pavillion and Shoshoni, intensity V earthquakes at Ethete, Lysite, and Riverton, and intensity IV earthquakes at Atlantic City, Dubois, Jeffrey City, and Lander. An intensity VIII earthquake could cause moderate to heavy damage at Boysen Dam. An intensity VI earthquake could cause light damage at Pavillion and Shoshoni, and

intensity V earthquakes could cause very light damage at Ethete, Lysite, and Riverton. Atlantic City, Dubois, Jeffrey City, and Lander should not sustain any damage.

The Cedar Ridge/Dry Fork fault system is present in northeastern Fremont County and northwestern Natrona 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 (Wong et al., 2001). A magnitude 6.7 earthquake on the fault system could generate peak horizontal accelerations of approximately 2%g at Jeffrey City, approximately 10.3%g at Lysite, approximately 1.7%g at Pavillion, approximately 2.3%g at Riverton, and approximately 4.2%g at Shoshoni (Campbell, 1987). These accelerations would be roughly equivalent to an intensity VI earthquake at Lysite, an intensity V earthquake at Shoshoni, and intensity IV earthquakes at Jeffrey City, Pavillion, and Riverton. An intensity VI earthquake could cause light damage at Lysite, while an intensity V earthquake could cause very light damage at Shoshoni. No damage should occur at Jeffrey City, Pavillion, or Riverton. Atlantic City, Dubois, Ethete, and Lander would be subjected to ground accelerations of less than 1.5%g, which should not cause any damage. 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 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 (Wong et al., 2001). A magnitude 7.1 event could generate peak horizontal accelerations of approximately 2.5%g at Ethete and Jeffrey City, approximately 2.1%g at Lander, approximately 26.5%g at Lysite, approximately 3.1%g at Pavillion, approximately 4%g at Riverton, and approximately 8.8%g at Shoshoni, 30%g at the Burlington Resources Oil and Gas Company/Lost Cabin Gas Plant and approximately (Campbell, 1987). These accelerations would be roughly equivalent to an intensity VII earthquake at Lysite and the Lost Cabin Gas Plant, intensity V earthquakes at Riverton and Shoshoni, and intensity IV earthquakes at Ethete, Jeffrey City and Pavillion. Lysite could sustain moderate damage and very light damage could occur at Riverton and Shoshoni. No damage should occur at Ethete, Jeffrey City and Pavillion. Atlantic City and Dubois would be subjected to ground accelerations of less than 1.5%g, which should 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, Fremont 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 Fremont 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 accelerations 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 Fremont County ranges from approximately 6%g in the eastern and north-central portions of the county to nearly 20%g in the northwestern portion of the county. These accelerations are roughly comparable to intensity V earthquakes (3.9%g – 9.2%g), intensity VI earthquakes (9.2%g – 18%g), and intensity VII earthquakes (18%g – 34%g). Intensity V earthquakes can result in cracked plaster and broken dishes. Intensity VI earthquakes can result in fallen plaster and damaged chimneys. Intensity VII earthquakes can result in slight to moderate damage in well-built ordinary structures, and considerable damage in poorly built or badly designed structures, such as unreinforced masonry. Chimneys may be broken. Lander and Riverton would be subjected to accelerations of approximately 7-8%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 Fremont County ranges from 9%g in the north-central and northeastern portions of the county to 25%g in the far northwestern corner of the county. These accelerations are roughly comparable to intensity V earthquakes (3.9%g – 9.2%g), intensity VI earthquakes (9.2%g – 18%g), and intensity VII earthquakes (18%g – 34%g). Intensity V earthquakes can result in cracked plaster and broken dishes. Intensity VI earthquakes can result in fallen plaster and damaged chimneys. Intensity VII earthquakes can result in slight to moderate damage in well-built ordinary structures, and considerable damage in poorly built or badly designed structures, such as unreinforced masonry. Chimneys may be broken. Lander and Riverton would be subjected to accelerations of approximately 10-15%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 Fremont County ranges from approximately 16%g in the north-central portion of the county to over 20%g in the central and southern portions of the county to nearly 40%g in the far northwestern corner of the county. These accelerations are roughly comparable to intensity VI earthquakes (9.2%g – 18%g), intensity VII earthquakes (18%g – 34%g), and intensity VIII earthquakes (34%g-65%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. 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. Lander and Riverton would be subjected to accelerations of greater than 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 Fremont County analyses, unless the ground acceleration derived from the deterministic analyses on faults exceed the probabilistic analyses. This conservative approach is in the interest of public safety.

**Table 1:**

Modified Mercalli Intensity	Acceleration (%g) (PGA)	Perceived Shaking	Potential Damage
I	<0.17	Not felt	None
II	0.17 – 1.4	Weak	None
III	0.17 – 1.4	Weak	None
IV	1.4 – 3.9	Light	None
V	3.9 – 9.2	Moderate	Very Light
VI	9.2 – 18	Strong	Light
VII	18 – 34	Very Strong	Moderate
VIII	34 – 65	Severe	Moderate to Heavy
IX	65 – 124	Violent	Heavy
X	>124	Extreme	Very Heavy
XI	>124	Extreme	Very Heavy
XII	>124	Extreme	Very Heavy

Modified Mercalli Intensity and peak ground acceleration (PGA) (Wald, et al 1999).

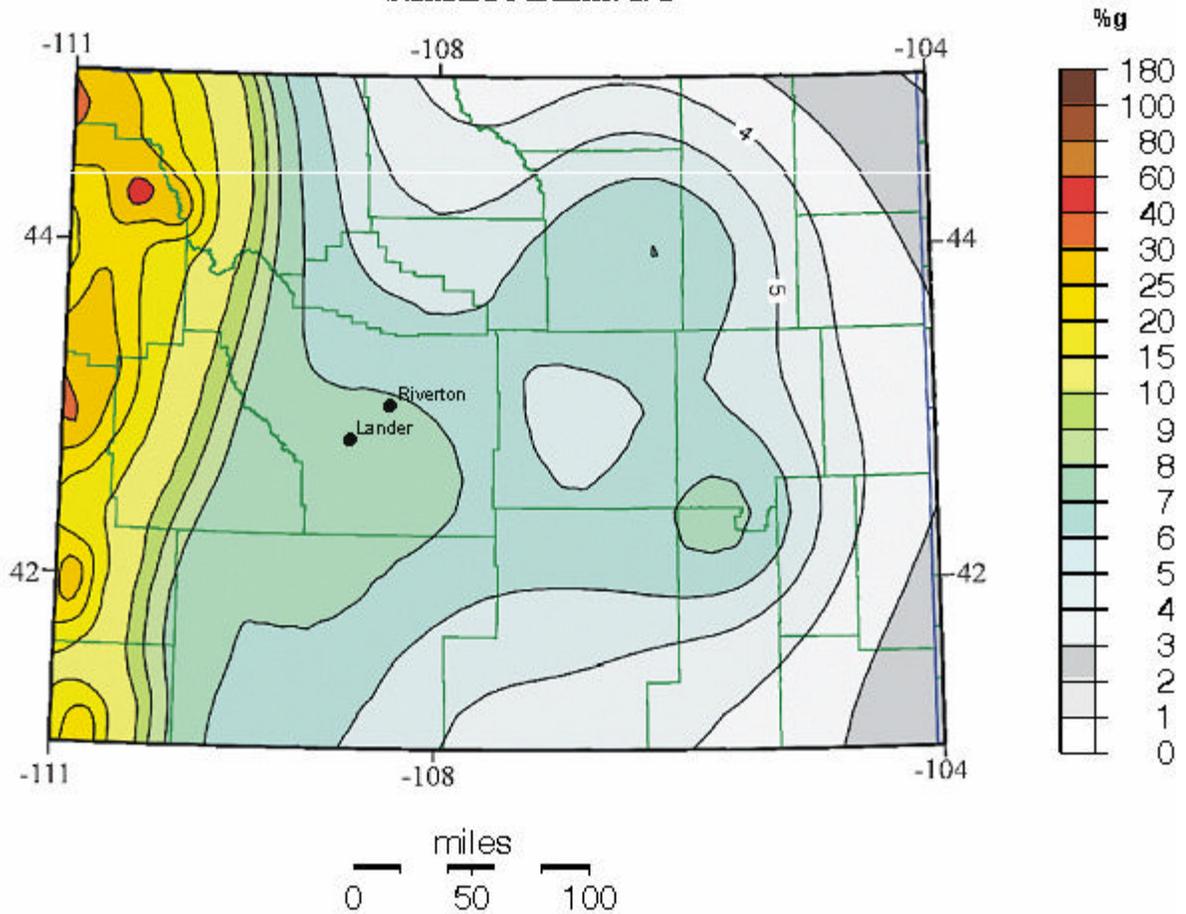
## Abridged Modified Mercalli Intensity Scale

### Intensity value and description:

- I** Not felt except by a very few under especially favorable circumstances.
- II** Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
- III** Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing automobiles may rock slightly. Vibration like passing of truck. Duration estimated.
- IV** During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing automobiles rocked noticeably.
- V** Felt by nearly everyone, many awakened. Some dishes, windows, and so on broken; cracked plaster in a few places; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
- VI** Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight.
- VII** Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars.
- VIII** Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed.
- IX** Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
- X** Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, sloped over banks.
- XI** Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
- XII** Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into the air.

**Peak Acceleration (%g)  
with 10% Probability  
of Exceedance in 50 Years  
site: NEHRP B-C boundary**

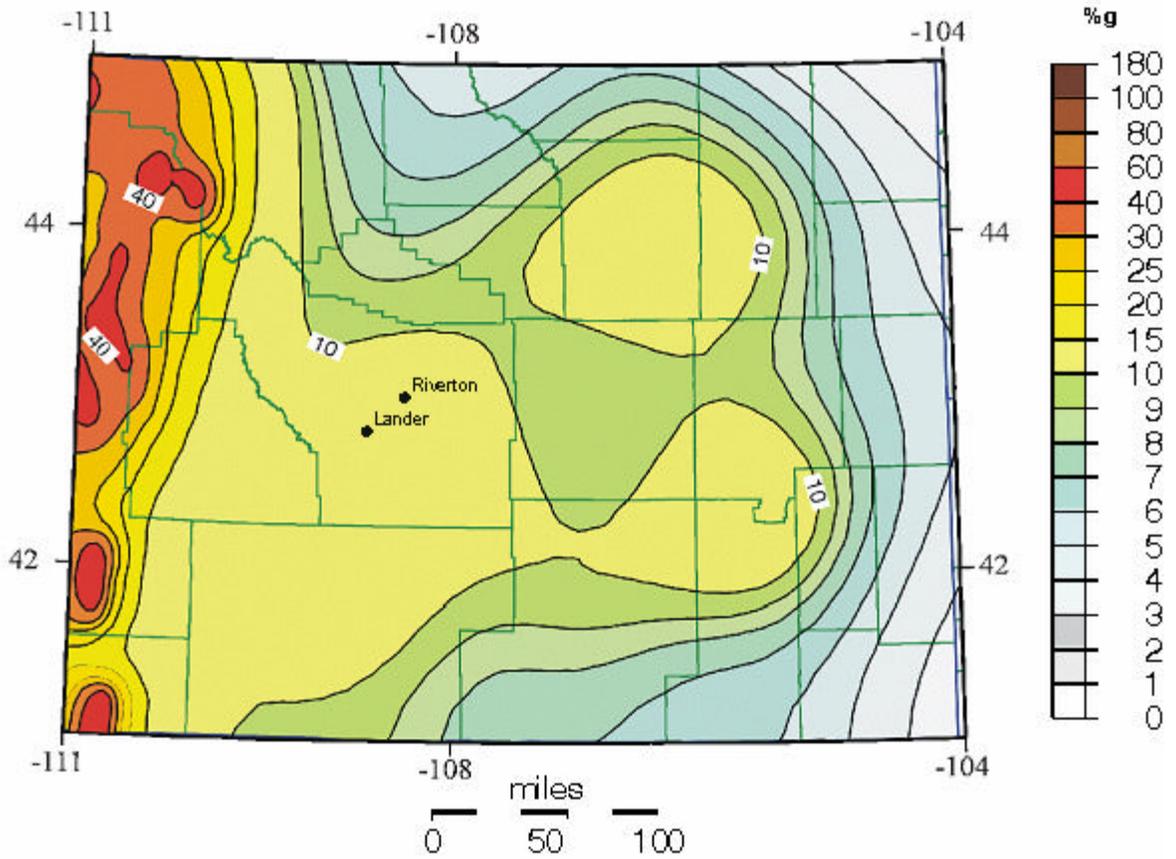
U.S. Geological Survey  
National Seismic Hazard Mapping Project  
Albers Conic Equal-Area  
Projection  
Standard Parallels: 29.5



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

**Peak Acceleration (% g)  
with 5% Probability  
of Exceedance in 50 Years  
site: NEHRP B-C boundary**

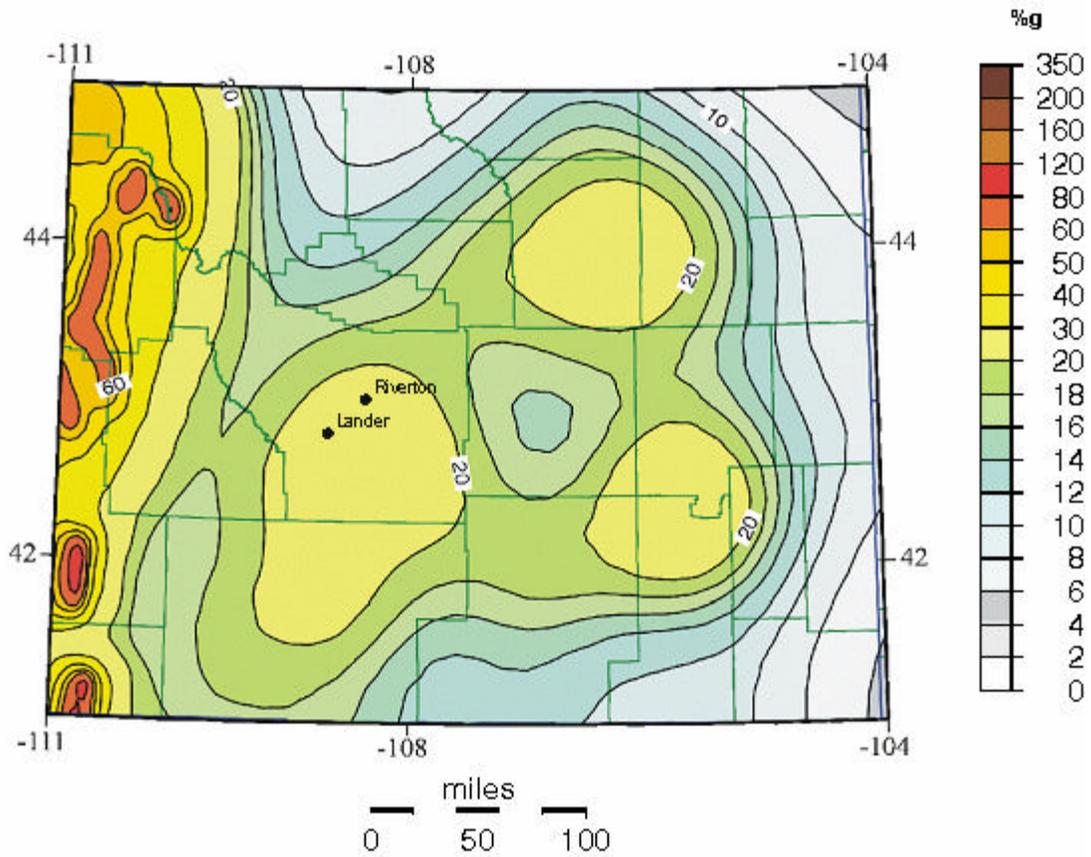
U.S. Geological Survey  
National Seismic Hazard Mapping Project  
Albers Conic Equal-Area  
Projection  
Standard Parallels: 29.5



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

**Peak Acceleration (%g)  
with 2% Probability  
of Exceedance in 50 Years  
site: NEHRP B-C boundary**

U.S. Geological Survey  
National Seismic Hazard Mapping Project  
Albers Conic Equal Area  
Projection  
Standard Parallels: 29.5



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

## Summary

There have been numerous historic earthquakes with magnitudes greater than 2.0 or intensity III and greater recorded in or near Fremont County. Because of the limited historic record, it is possible to underestimate the seismic hazard in Fremont 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 Fremont County.

Current earthquake probability maps that are used in the newest building codes suggest a scenario that would result in light to heavy damage to buildings and their contents, with damage increasing from the north-central to the northwest and south. More specifically, the probability-based or fault activation-based worst-case scenario could result in the following damage at points throughout the county:

### Intensity VIII Earthquake Areas

Jeffrey City

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.

### Intensity VII Earthquake Areas

Atlantic City	Hudson	Morton
Arapahoe	Kinnear	Pavillion
Boysen Dam	Lander	Riverton
Dubois	Lost Cabin	Shoshoni
Ethete	Lost Cabin Gas Plant	South Pass City
Fort Washakie	Lysite	St. Stephans
Gas Hills	Moneta	

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

Burris  
Crowheart

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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