

OPEN-FILE REPORT 86-8

AN INTERPRETATION OF THE NOVEMBER 7, 1882
COLORADO EARTHQUAKE

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DEPARTMENT OF NATURAL RESOURCES
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ABSTRACT

On November 7, 1882 an earthquake rocked parts of Colorado, Wyoming, Utah, and Kansas. It was felt over 470,000 km², with a maximum reported Modified Mercalli intensity of VII. An isoseismal map for the main event and the felt area of an aftershock on November 8th, along with historic wave path and focusing considerations, suggest the epicenter was probably in north-central Colorado, perhaps in the northern Front Range or possibly southern Laramie Mountains. The felt area for the aftershock is in our opinion the most significant factor for defining the general epicentral location for the main earthquake. Earthquake magnitude is estimated at 6.2 ± 0.3 ML, based on felt area size. Similarities with the 1984 Laramie Mountains earthquake support an interpretation that the 1882 event probably occurred at a fairly great depth, perhaps 20 km or more. The possibility of there having been two earthquakes closely spaced in time at different locations was specifically addressed and no data supporting this theory was found.

INTRODUCTION

On November 7, 1882 at about 6:30 p.m. Denver time a relatively large earthquake occurred which was felt strongly in Colorado and Wyoming, at less intensity in Utah, and at one known location in Kansas. Numerous previous investigators have studied this earthquake. Heck (1938) suggested the tremor was felt over 28,000 km². Hadsell (1968) proposed the earthquake was centered just north of Denver, was felt over 1,200,000 km², and had a Richter magnitude of 5.0 ± 0.6 based on the maximum observed Modified Mercalli intensity (MMI) of VII and 6.7 ± 0.6 based on its felt area size. Coffman, von Hake, and Stover (1982) estimated the felt area size at 28,500 km² with a maximum intensity of V. According to Docekal (1970), the felt area was 285,000 km², while the maximum intensity was VII.

Dames & Moore (1981) collected and interpreted additional felt reports and estimated the felt area at 500,000 km², the magnitude (ML) at 6 1/2, and the maximum intensity at VIII. They placed the epicenter in northwest Colorado and suggested the Dudley Gulch graben as a possible causative fault. A summary of the Dames & Moore study was published by McGuire and others (1982). Oaks and others (1985) compared the 1882 quake with the 1984 Laramie Mountains earthquake and noted similarities in their felt areas and intensity distribution.

This earthquake was probably the largest to occur in Colorado during the period of historic record. A similar-sized event today could have significant impact on modern structures, possibly causing serious property damage and perhaps injury or death. Because of the potential effects of such an earthquake, and the varied interpretations regarding the magnitude, maximum intensity, epicentral location, and felt area size of this earthquake, the Colorado Geological Survey (CGS) undertook this investigation to clarify some of the mysteries surrounding this century-old earthquake.

Additional felt reports have been located by Oaks and Kirkham (1986) as part of the CGS investigation. These reports were discovered in newspapers, in unpublished local diaries, through interviews with knowledgeable individuals, and in manuscripts held by the National Archives in Washington, D.C.. MMI assignments are herein proposed for these newly discovered felt reports, and

intensity ratings for previously known accounts are re-examined and revised in some cases. An isoseismal map for this earthquake is presented based on our intensity assignments, along with descriptions of our interpretation as to the magnitude, maximum intensity, felt area size, and most probable epicentral location.

FELT REPORTS AND INTENSITY ASSIGNMENTS

Table one lists all currently known felt reports and the MMI rating assigned to each report. Also included in Table 1 is the source or reference for each felt report. Verbatim transcriptions of selected original accounts are contained in Appendix A. Only those original accounts which have not previously been assigned a MMI (i.e. new accounts from Oaks and Kirkham, 1986) value or those which our assigned MMI value differs from intensity ratings previously reported in earlier studies are included in Appendix A.

Please refer to Dames & Moore (1981) and Oaks and Kirkham (1986) for all other felt reports. All felt reports are plotted on Figure 1, along with their assigned MMI.

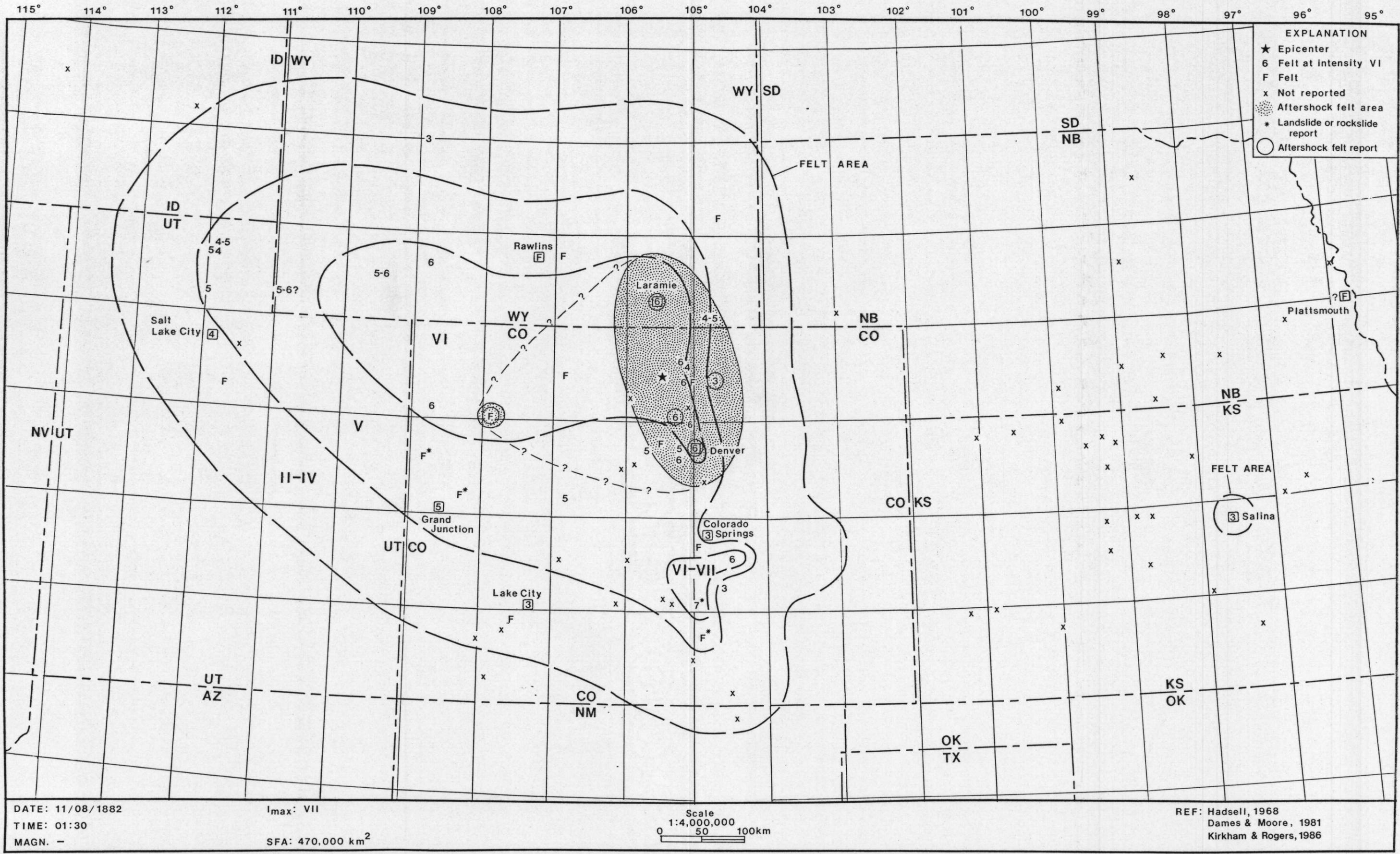


Figure 1. Isoseismal map for the 1882 Colorado earthquake. Stippled pattern is felt area of aftershock the next day. Date and time shown on the map is in Coordinated Universal Time.

Table 1. Intensity Assignments for the November 7, 1882 earthquake (modified from Dames & Moore (1981) and Oaks and Kirkham (1986)).

Location	Reference and Date	Intensity
<u>COLORADO</u>		
Animas Forks	Animas Forks Pioneer - 11/18 & 12/9	F
Aspen	The Aspen Times - 11/11	V
Boulder	Boulder County Herald - 11/8 University Portfolio - December, 1882	VI, AS
Central City	The Post - 11/18	F
Chico Creek	The Pueblo Daily Chieftain - 11/11	VI
Colorado Springs	The Weekly Gazette - 11/11	III
DeBeque Canyon	The Daily Sentinel (Grand Junction) - 7/11/1976 (see Oaks and Kirkham, 1986)	F *
Denver	The Daily Denver Times - 11/9 The Denver Republican - 11/8 The Denver Tribune - 11/8 The Queen Bee - 11/8 Rocky Mountain News - 11/8 War Dept., U.S. Signal Office, Monthly Meterological Report - November, 1882 Abstracts of Daily Journals - 11/7	VI, AS (ranges from IV-VII)
Fort Collins	Daily Evening Courier - 11/8 The Daily Express - 11/8 War Dept., U.S. Signal Service, Voluntary Observers's Meteorological Report - November, 1882	IV
Georgetown	The Colorado Miner - 11/11 Georgetown Courier - 11/9 Rocky Mountain News - 11/8 & 11/11	V
Golden	The Golden Globe - 11/11 Colorado Transcript - 11/8	V
Greeley	The Colorado Sun - 11/11	III, AS
Greenhorn Mtn. foothills	The Pueblo Daily Chieftan - 11/11	VII *
Grand Junction	Grand Junction News - 11/11 Haskell (1886)	V

La Porte	Daily Evening Courier (Ft. Collins) - 11/10	VI
Lake City	Silver World - 11/11	III
Louisville	The Daily Denver Times - 11/9	VI
	The Daily Express (Ft. Collins) - 11/11	
	Rocky Mountain News - 11/8	
Loveland	The Daily Express (Ft. Collins) - 11/11	F
Pueblo	The Pueblo Daily Chieftain - 11/11	III
Rangely	Diary of Charles Porter Hill - 11/7 (see Oaks and Kirkham, 1986)	VI
Steamboat Springs	Diary of Perry A. Burgess -11/7 (see Oaks and Kirkham, 1986)	F
Thompson	Daily Evening Courier (Ft. Collins) - 11/24	VI (VII?)
Turkey and Beaver Creeks	The Pueblo Daily Chieftain - 11/11	F
White River Agency (near Meeker)	Carbon County Journal (Rawlins, WY) - 11/18	F,AS
30 or 40 miles south of Pueblo Walsenburg area)	The Pueblo Daily Chieftain - 11/11	F *
Douglas Pass area	Grand Junction News - 11/18	F *
<u>UTAH</u>		
Hyrum	Salt Lake Daily Tribune - 11/11	IV
Logan	Cache Coin <u>in</u> Ogden Daily Herald - 11/9 Journal (Logan) <u>in</u> The Deseret Evening News (Salt Lake City) - 11/11	IV-V
Ogden	Ogden Daily Herald - 11/8	V
Provo City	The Territorial Enquirer - 11/8	F
Salt Lake City	The Deseret Evening News - 11/8 Salt Lake Daily Herald - 11/8 The Salt Lake Daily Tribune -11/9 Abstracts of Daily Journals - 11/7	IV
Wellsville	Cache Coin <u>in</u> Ogden Daily Herald - 11/9 Ogden Daily Herald 11/10	V

WYOMING

Cheyenne	The Cheyenne Daily Leader - 11/8 War Dept., U.S. Signal Office, Monthly Meteorological Report - November, 1882 Abstracts of Daily Journals - 11/7	IV-V
Evanston	The Uinta Chieftain - 11/11	V-VI?
Fort Fred Steele	Letter from A. Morton, Captain, U.S. Army to Assistant Adjutant General in Omaha, NE	F
Fort Laramie	U.S. Army, Records of Medical History of Post- November, 1882	F
Fort Washakie	The Cheyenne Daily Leader - 11/12 Fort Washakie Meteorological Register - November, 1882 Abstracts of Daily Journals - 11/17	III
Green River	Green River Gazette <u>in</u> Cheyenne Daily Sun - 11/15	V-VI
Laramie	Laramie Weekly Sentinel - 11/11	VI,AS
Point-of-Rocks	The Cheyenne Daily Leader - 11/8	VI
Rawlins	Carbon County Journal - 11/11 The Cheyenne Daily Leader - 11/8	F

KANSAS

Salina	War Dept., U.S. Signal Service, Voluntary Observer's Meteorological Record - November, 1882 (also noted by Rockwood, 1883)	III
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NEBRASKA

Plattsmouth	The Omaha Bee - 11/11 Plattsmouth Weekly Herald - 11/16	F ?
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AS indicates aftershock reported on 11/8/1882

* indicates landslide or rockslide reported

Table two Describes locations and newspapers examined by Dames & Moore (1981) or Oaks and Kirkham (1986) in which no local effects were reported. These locations are herein considered "not reported" localities. In many instances these newspapers carried accounts of the earthquake effects in other towns, but did not describe any local manifestations. "Not reported" localities cannot be definitively categorized as "not felt" locations. "Not reported" localities are designated on Figure 1 by the symbol "X".

Table 2. "Not reported" locations for the November 7, 1882 earthquake (from Dames & Moore, 1981 and Oaks and Kirkham, 1986).

COLORADO

Breckenridge	Daily Journal
Castle Rock	The Castle Rock Journal
Durango	Durango Herald
Grand Lake	Grand Lake Prospector
Gunnison	Gunnison Daily Review Press
La Veta	The Huerfano Herald
Leadville	Leadville Daily Herald (note: several non-local newspapers reported that the earthquake was felt in Leadville)
Longmont	Longmont Ledger (note: non-local newspapers reported that the earthquake was felt in Longmont)
Montezuma	Montezuma Millrun
Rico	Dolores News
Rosita	The Sierra Journal
Saguache	Saguache Advance; Saguache Chronicle
Salida	Mountain Mail
Silver Cliff	The Daily Herald; The Weekly Herald
Trinidad	Trinidad Daily News; The Trinidad Democrat; Trinidad Weekly News

UTAH

Park City	The Park City Mining Record
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WYOMING

NONE

KANSAS

Atwood	Republican Citizen
Beloit	The Beloit Gazette
Bunker Hill	Bunker Hill Banner
Dodge City	Ford Country Globe; Dodge City Times
Garden City	The Irrigator
Great Bend	Arkansas Valley Democrat
Hays	The Star Sentinel
Hutchinson	Hutchinson Herald; Hutchinson News
Junction City	The Junction City Tribune
Kirwin	The Independent; The Kirwin Chief
La Crosse	La Crosse Chieftan
Lakin	Lakin Herald
Logan	Logan Enterprise
Manhattan	The Nationalist
Norton	Norton County Advance
Oberlin	Oberlin Herald
Phillipsburg	Phillipsburg Herald
Russell	The Russell Hawkeye
Stockton	The News; The Rooks County Record
Topeka	Daily Kansas State Journal
Wichita	Weekly Leader; The Wichita City Eagle; Wichita Daily Times; The Wichita Weekly Beacon

NEBRASKA

Arapahoe	Arapahoe Pioneer
Geneva	Filmore County Review
Hastings	The Gazette Journal
Lincoln	The Lincoln Daily News
Minden	Kearney County Gazette
Omaha	The Omaha Bee; The Omaha Daily Bee; The Omaha Weekly Herald
O'Neill	The Frontier
Ord	Valley County Journal
Sidney	Plainsleader-Telegraph

Red Cloud	Webster County Argus
St. Paul	The Phonograph

IDAHO

Blackfoot	The Blackfoot Register
Boise City	Idaho Tri-Weekly Statesman
Hailey	Wood River Times
Lewiston	The Lewiston Teller
Silver City	The Idaho Avalanche

NEW MEXICO

Albuquerque	Daily Democrat; The Albuquerque Review
Raton	The Raton Comet
Santa Fe	Santa Fe Daily New Mexican

The primary problem related to the study of older earthquakes is the lack of historical records to document the effects of an earthquake. In 1880 there were less than 200,000 people in Colorado, most of whom were in rural areas (Dames & Moore, 1981). Only Denver, Colorado Springs, Leadville, and Silver Cliff had populations over 4,000. The population of the probable epicentral area, north-central Colorado or southeast Wyoming was especially low. Relatively few newspapers were published daily in Colorado. Some of the weekly newspapers may have ignored the earthquake due to the time lag between the earthquake date and publication date.

Other problems that complicate the understanding of the November 7, 1882 earthquake have been described by Dames & Moore (1981). They include the following factors:

- 1) The earthquake occurred on a national election day just as the polls closed. The Democratic victory added to the excitement of the day and some editors cleverly related the two news items. Many people were in the streets near telegraph offices and may not have noticed the earthquake effects as readily as those in buildings. The

telegraph offices rapidly passed on news of the earthquake, allowing for possible confusion due to association of reported effects with perhaps a wrong locality.

- 2) Exaggeration in the newspapers also presents difficulties in accurately defining this event. A clear example of this is the numerous accounts of damaged plaster at the University of Colorado at Boulder. Some newspapers state that "plaster fell" or "plaster was shaken down" at the University. Others report "a large quantity of plaster...was thrown to the floor" or "the ceilings of the university were stripped of plaster". The record is set straight in the University Portfolio in December of 1882, when it reported "There is still some plastering on the ceiling of the University"... "The fact is that the building was shaken considerably, and some bits of plastering fell in the third story". Another probable example of exaggeration is illustrated by the account from near Douglas Pass in the Grand Junction News.
- 3) Some towns in the area were "booster oriented" and their newspapers tended to avoid subjects considered undesirable, such as earthquakes.
- 4) Hearsay reports consist of newspaper accounts in one town that describe the effects in another town. We utilize the technique of Dames & Moore (1981) to evaluate hearsay reports. If a hearsay report suggests a particular town felt the earthquake, but local newspapers from that town do not report the earthquake, then the location is considered to be a "not reported" locality. Such a situation exists for Leadville and Longmont.

If local newspapers were not published or if copies have not survived in archive repositories, then the town is assigned a MMI based on the reported effects in the non-local newspaper. Several felt reports fall into this category, and uncertainties in interpreting the earthquake may result from this aspect. An example of this is from Point-of-Rocks, Wyoming where no local report has been discovered because a newspaper was not published there in 1882. Non-local newspapers state that plaster fell at this location.

The remainder of this section describes selected felt reports and our rationale for assigning the MMI for that location. The description is organized by state and alphabetically by location.

BOULDER, CO: A small amount of plaster fell from the third floor of the University. The newspaper accounts suggest the quake was felt by a large number of residents. Previous investigators have rated Boulder at MMI V. We believe even a small amount of fallen plaster justifies a rating of VI.

DEBEQUE CANYON, CO: According to Mr. Al Looks (in Oaks and Kirkham 1986), a rockfall occurred in DeBeque Canyon during the earthquake. No intensity rating is assigned to this report. Rockfalls can develop at relatively low intensities, particularly in an area with unstable slopes like those in DeBeque Canyon.

Denver, CO: Felt reports from the Denver area vary with respect to location and the type of structure. The strongest shaking was reported in the downtown, northern, and western parts of the city. Most of this area is underlain by water-saturated alluvial deposits.

At the electric light plant a bolt nearly 2.5 cm in diameter was snapped and another was bent, causing the lights to go off in Denver. This is the most significant reported damage in Denver, and could justify a MMI rating of VII. Other reports suggest intensities of IV to V. Rather than assign an intensity rating of IV-VII for Denver, we chose to rate it at VI.

GRAND JUNCTION, CO: A brief account of the earthquake was reported in the Grand Junction News. It states that "the buildings [which were log structures] moved and quaked as if they were being torn down and that hanging objects were put into motion at a lively rate", suggestive of intensity V shaking. The article also indicates that "our people were frightened by the shock". Previous investigators have assigned a MMI of VI to this report because of this statement, although no other evidence of intensity VI damage was reported. It is unclear whether this statement means all, many, or a few of "our people" were frightened by the earthquake. We rate the Grand Junction report at intensity V.

LA PORTE, CO: A house in La Porte shook until the timbers cracked. Although previous investigators assigned only an intensity of IV to this report, we believe the damage justifies an intensity VI rating.

LOUISVILLE, CO: The walls of the railroad depot were cracked in Louisville, indicative of intensity VI damage.

RANGELY, CO: An excerpt from the diary of C.P. Hill states "heard the roaring and thundering of some great noise. The ground shook and the trees bent. They said it was an earth tremor." We assign an intensity of VI to this account. The exact location of this report is uncertain. It is thought to have come from just east of Rangely along the White River.

STEAMBOAT SPRINGS, CO: An excerpt from the diary of Perry A. Burgess (in Oaks and Kirkham, 1986) describes a distinct earthquake in Steamboat Springs. No mention is made of any local damage. Unfortunately, no other accounts have been located for Steamboat Springs. Various descriptions of other earthquakes in northwest Colorado are included in Fitzpatrick (1974), but the 1882 quake is not mentioned. We do not assign a numerical intensity to the diary account.

THOMPSON, CO: The walls of a residence near Thompson were badly cracked during the earthquake and some walls were stripped of plastering. This account justifies at least an intensity VI rating and may, perhaps, indicate intensity VII damage.

DOUGLAS PASS AREA, CO (north of Grand Junction): An intriguing account of severe shaking was reported by a party of travelers at the head of Douglas Creek near Douglas Pass. They describe landsliding and rockfalls, and indicate the quake broke off trees and that it was difficult to stand.

Hadsell (1968) discounted this report because the only account of it that he uncovered was a second-hand version in a Denver newspaper. Dames & Moore (1981) discovered an original, eyewitness account in a Grand Junction newspaper and give considerable credence to this particular report.

We question the reliability of this account. There is little supporting evidence for the descriptions provided by these travelers. Their geographic

knowledge as described in the article is limited or incorrect. They state that their horses ran away during the night and that they were lost for nearly four days before finding their way out. If they were lost, they may well have been prone to exaggerate their recollections considerably. Their statement that this was not a "trumped up" story leads one to suspect that it may well be questionable.

Kirkham and Rogers (1985) have demonstrated that Grand Junction is an area sensitive to earthquake shaking. Well documented tremors have been felt more strongly or equally strong in Grand Junction than at their fairly distant epicentral locations. We believe that if the strong shaking described near Douglas Pass had occurred, Grand Junction should have reported equally strong or greater intensities. This very clearly did not happen during the 1882 earthquake.

Likewise, the report from near Rangely does not support an interpretation of there having been high intensity shaking at Douglas Pass. The Rangely report was only about 30 km north of Douglas Pass and was located on saturated alluvial deposits, yet it was only rated at intensity VI.

If the travelers were where they claimed to be and did feel the earthquake, much of the phenomenon they described could be a result of earthquake-induced landsliding. The Douglas Pass area is well known for its numerous large, highly active landslides that do not need seismic shaking for activation. It is widely recognized that landslides can be activated at relatively low intensities, suggesting the Douglas Pass report, if it is authentic, may indicate only MMI IV-V at this location.

B. K. Stover (1985) has studied slope stability problems in the Douglas Pass area and discovered abundant evidence of landsliding, much of which is extremely active. He describes large "landslide bowls" that serve as source areas for earth flows. This type of feature is probably the "immense crater or chasm, from which great volumes of smoke came pouring forth" referred to by the traveler's on Douglas Pass.

Our interpretation is supported by the fact that the travelers did not report the aftershock. If they were in or near the epicentral region or area of highest intensities, they should have felt the aftershock and would likely

have reported it. Because of the various discrepancies, we believe the Douglas Pass report should be rated only as a "felt" location. It is equally plausible to totally discount this report.

EVANSTON, WY: The accounts from Evanston, Wyoming were rated at MMI V-VI by previous investigators. An intensity V rating certainly is justifiable, but an assignment as high as VI is probably not reasonable. No definitive evidence of intensity VI shaking has yet been uncovered.

FORT LARAMIE, WY: Oaks and Kirkham (1986) discovered a felt report in the medical records of Fort Laramie, Wyoming. Although no precise intensity assignment can be made based on the brief description, it is an important account because of its geographic location in eastern Wyoming.

LARAMIE, WY: Numerous newspapers carried descriptions of the effects of the earthquake in Laramie, Wyoming. Plaster was cracked and glass windows were broken. A MMI of VI is assigned to this location.

POINT-OF-ROCKS, WY: Only hearsay reports are available for Point-of-Rocks, Wyoming. These indicate plastering fell off in buildings. A MMI of VI is assigned to this location, but it is recognized that these hearsay accounts may be misleading or exaggerated.

WELLSVILLE, UT: A few felt reports have been discovered for towns in Utah. All accounts have been rated at MMI IV or V, with the exception of the brief report from Wellsville. Dames & Moore (1981) assigned Wellsville an intensity V-VI based on a correspondent's report from the Cache Coin reprinted in an Ogden newspaper which indicates that people were frightened and ran from their houses. The original copy of the Cache Coin has not been located. This article fails to explain whether all, many, or only a few people were frightened and ran into the streets, and accordingly, we believe an intensity V rating is probably more valid.

SALINA, KS: Rockwood (1883) briefly mentioned that the earthquake was felt as far east as Salina, Kansas. The original reference to the Salina felt report was located in the National Archives by Oaks and Kirkham (1986). In

that no other towns in Kansas are known to have reported the earthquake, the shaking in Salina was probably only very light (MMI III) and may represent an isolated felt area.

PLATTSMOUTH, NB: A confusing exchange of reports developed in Nebraska. The Omaha Bee stated "Plattsmouth felt an earthquake shock on Tuesday morning". The Plattsmouth Weekly Herald came back with a reply stating that "Plattsmouth felt it much more perceptibly, however, Tuesday night when the election returns began to roll in on us". The initial article placed the quake at the wrong time, while the second account is unclear. An earthquake may actually have been felt in Plattsmouth, or it may have been an attempt at satire. Because of this, we rate this report as a questionable "felt" locality.

FELT REPORTS FOR THE NOVEMBER 8, 1882 AFTERSHOCK

A critical aspect in the understanding of this earthquake is the aftershock on the morning of November 8th. The most reliable and numerous felt reports of the aftershock are clustered along the Denver-Laramie corridor. The towns of Boulder, Denver, Greeley, and Laramie all reported the aftershock. Persons in Laramie awake at the time of the aftershock claimed "it was quite as distinct as the first". The Carbon County Journal contains a one sentence summation of a letter from a resident at the White River Agency near Meeker stating that the aftershock was also felt at that location. Unfortunately, the original letter or a copy of it has not been discovered.

If the report from the White River Agency and the reports from Denver to Laramie are included in a single felt area (see Figure 1), then the aftershock would have been felt over about 61,000 km². Another reasonable interpretation might contour the Denver, Boulder, Greeley, and Laramie felt reports in one area, while showing the report from near Meeker as an isolated felt report, in a manner similar to the Salina, Kansas report for the main shock.

INTERPRETATION OF INTENSITY DATA

Preparation of a detailed isoseismal map for most pre-instrumental seismic events for which felt data are available is generally a rather difficult

task. The available felt reports for the November 7, 1882 earthquake are no exception in that they also present a complex and confusing picture. Moderate intensities in the V,VI, and VII range are reported from a large area, while no clear area of higher intensity damage is apparent. This may be due to an absence of population or felt reports in maximum intensity areas, or it may result from another phenomenon. It is also possible that higher intensity shaking did not occur during the earthquake.

Another difficult aspect of the interpretation is the occurrence of highly varied intensities in close geographic proximity with no obvious explanation. A vivid example of this developed in the Pueblo area. The town of Pueblo reported only MMI III, while surrounding locations ranged up to intensity VII. Another example has been noted in the Fort Collins area. The town of Fort Collins has been assigned intensity IV, yet the nearby towns of Thompson and La Porte experienced MMI VI or possibly even VII.

No matter how the data are contoured, a clearly defined area with high MMI cannot be distinguished. Figure 1 presents our most reasonable version of an isoseismal map for this earthquake. An epicentral area could be selected almost anywhere in north-central Colorado, northwest Colorado, or possibly even southeast Wyoming, if only the isoseismal map for the main shock is considered. However, we believe that data from the aftershock on November 8th provides the most incisive information for constraining the location of the major event.

An intriguing aspect of the felt data is that existing accounts could fit a pattern of there having been two or even three nearly simultaneous earthquakes. One event could have centered in the north Denver or north-central Colorado area, a second in northwest Colorado or northeast Utah, while a third might have been centered in the Wet Mountains. In that there is no known historical precedent for such a phenomenon, we believe the preferred interpretation is that we are dealing with only a single earthquake. In addition, in the historical research for this report a special effort was made to ascertain if there was any confirmation of the multiple earthquake theory. None was found.

A number of factors help to narrow the probable epicentral area. The felt area for the November 8th aftershock is indicated by the screen pattern on

Figure 1. It seems reasonable to assume that the epicenter of the main quake must be within this region. Therefore, the epicenter seems most likely to have been in north-central Colorado or possibly southeast Wyoming. The northern Front Range or southern Laramie Mountains should be considered as possible epicentral locations. Oaks and others (1985) agree with this interpretation. If the brief account from the White River Agency is considered an outlying felt report, the main aftershock felt area is restricted to an even narrower region. The aftershock reports from Laramie suggest it was nearly as strong at those localities as the main shock. It is perhaps significant to note that neither Grand Junction, any Utah cities, the travelers near Douglas Pass, nor the Hill family near Rangely mention an aftershock.

Another phenomenon to consider when analyzing the 1882 earthquake is the reported occurrence of earthquake lights described in reports by Dames & Moore (1981) and Oaks and Kirkham (1986). In Cheyenne, Wyoming an electrical disturbance or flash lit up the sky. An account from Colorado states "they saw jets of flame rushing from Long's Peak". Such phenomena are thought to occur near the epicentral area and may be due to fault movement (Richter, 1958; Lockner and others, 1983).

As previously mentioned, the Grand Junction area has been shown to be especially sensitive to seismic shaking (Kirkham and Rogers, 1985). If an earthquake felt over 470,000 km² was centered in northwestern Colorado and severe shaking occurred in the Douglas Pass area, it is reasonable to anticipate that Grand Junction would report effects at least as strong as the Douglas Pass area. It is well documented that Grand Junction did not experience high intensities during the 1882 quake (Oaks and Kirkham, 1986). An article in the Daily Sentinel on 11/14/01, which states that the November 13, 1901 earthquake centered in Utah was felt more distinctly in Grand Junction than any previous event, supports this interpretation. The 1901 Utah earthquake generated only intensity V shaking in Grand Junction.

Another factor to consider is the felt effects reported during more recent earthquakes (Kirkham and Rogers, 1985). None of the historic western slope earthquakes have been felt in the Front Range urban corridor from Pueblo to as far north as Cheyenne or Laramie, nor in Kansas. Two of the Rocky Mountain

Arsenal events on August 9 and November 27, 1967, however, were felt throughout the area from Pueblo to Cheyenne and Laramie, and as far west as Glenwood Springs. If one would modify these more recent events by slightly increasing the magnitude, moving the epicentral location to the northwest about 90 km, and increasing the hypocentral depth, it is fairly easy to visualize an earthquake that could generate the general intensity pattern of the 1882 earthquake.

Insight into this difficult to understand earthquake is also provided by the October 18, 1984 Laramie Mountains, Wyoming earthquake. This event was magnitude 5.3 mb, 5.1 MS, and 5.5 ML, was felt over 287,000 km², and probably occurred at a depth of around 20 km (Stover, 1985; Langer and others, 1985). An isoseismal map for this event is similar in certain aspects to isoseismal map for the 1882 quake (Figure 2). The earthquake was felt over a relatively large area and the epicentral area did not report high intensities. It was felt as far west as Salt Lake City and eastward into Nebraska, South Dakota, and Kansas. The greatest damage reported from this earthquake occurred in Golden, Colorado, although the damage there may have been due in part to poor construction practices and were accentuated by the ground motion. Comparative analyses by Oaks and others (1985) reveal marked similarities in the intensity patterns of the two quakes. The anomalous reports in the Pueblo vicinity during the 1882 earthquake are not readily explained by the 1984 Laramie Mountains earthquake. However, Kirkham and Rogers (1985) describe apparent wave path and focusing effects associated with the Rocky Mountain Arsenal earthquakes that result in somewhat higher intensity reports in the Pueblo area than would be anticipated.

We believe the previously cited factors point to a probable epicentral location for the 1882 earthquake in north-central Colorado, possibly in the northern Front Range or southern Laramie Mountains. We assign a geographic location of 40 1/2° N and 105 1/2° W for the event, but recognize that this may be in error by one-half degree or more. The hypocentral depth of this event was probably about 20 km or more.

All existing data relating magnitude to felt area size for Colorado and other Rocky Mountain region earthquakes is presented in Kirkham and Rogers (1985).

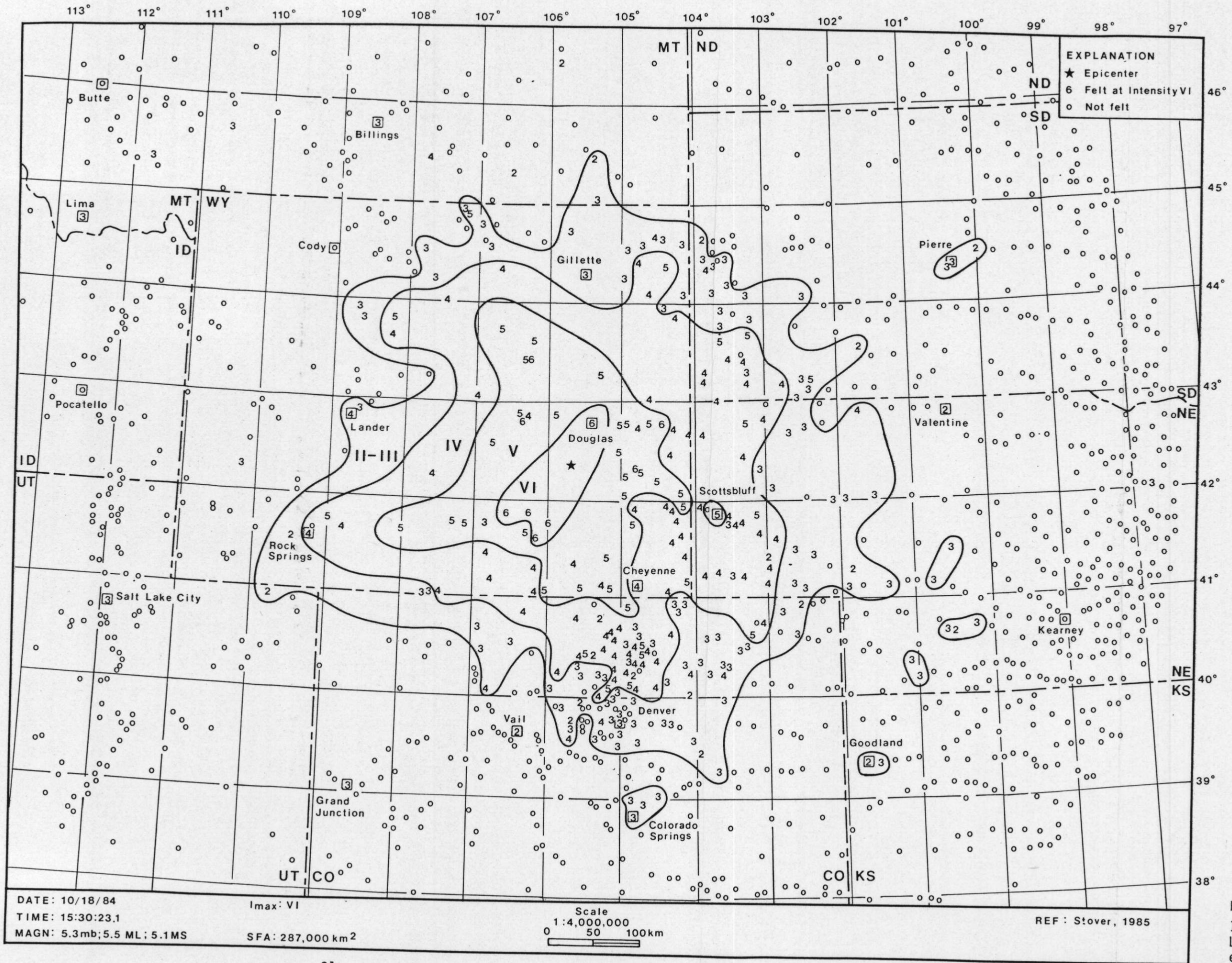


Figure 2.
 Isoseismal map for the 1984
 Laramie Mountains, Wyoming
 earthquake.

Based on a felt area of 470,00 km² and the data presented by Kirkham and Rogers (1985), the magnitude of the 1882 earthquake is estimated at 6.2 ± 0.3 ML.

POSSIBLE CAUSATIVE STRUCTURE

Dames & Moore (1981) suggested the Dudley Gulch graben as a possible causative structure for the 1882 earthquake. The authors of this paper, along with Mr. Rahe Junge, made a field inspection of the Dudley Gulch graben and found no geologic or geomorphic evidence of Holocene or late Quaternary movement on the graben. A bison skull and a charcoal-filled fire pit were discovered in unfaulted alluvial deposits in Ryan Gulch approximately 2.7 m below the land surface along the trend of the fault. The charcoal yielded a carbon-14 date of 1,230 ± 60 years before present, as determined by the U.S. Geological Survey. In that the alluvial deposits are not displaced by the Dudley Gulch graben, it is certain that surface rupture did not occur on this part of the graben on November 7, 1882. Furthermore, the Dudley Gulch graben was thoroughly studied by Eckert (1982), who found no evidence of historic or recent movement of the graben. These elements make it very unlikely that the Dudley Gulch graben was the causative structure for the 1882 earthquake.

The authors have not yet identified the causative structure for the November 7, 1882 earthquake. In that the earthquake may have been fairly deep, it is possible that no surface displacement occurred during the earthquake, in which case it will be very difficult or impossible to precisely define the causative structure. It is perhaps significant that the causative structure for the 1984 Laramie Mountains earthquake has not yet been located, even though a concerted effort was made by USGS personnel (G. L. Snyder, pers. comm., 1986).

CONCLUSION

The November 7, 1882 earthquake was felt over 470,000 km² in Colorado, Wyoming, and Utah, at a single known locality in Kansas, and possibly at one location in Nebraska. It is probably the largest earthquake to affect Colorado during the 118-year period of record. A maximum MMI rating of VII has been assigned to this event based on known felt reports. Earthquake magnitude is estimated at 6.2 ± 0.3 ML.

An area somewhere in north-central Colorado or southeast Wyoming, perhaps in the northern Front Range or southern Laramie Range, is hypothesized as the probable epicentral location, based primarily on the concentration of higher intensities of the main quake and the distribution of felt reports for the aftershock. It is probable that the earthquake occurred at a depth greater than most Rocky Mountain events, possibly at a depth of 20 to 25 km, and that no or only very minor surface faulting may have resulted. The causative fault or source of the 1882 earthquake has not yet been determined, but will be the topic of continuing interest and future investigation by the Colorado Geological Survey and others.

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APPENDIX

SELECTED REPORTS OF THE NOVEMBER 7, 1882 EARTHQUAKE

Only those reports that are herein published for the first time or those for which our intensity assignments differ from previously published assignments are listed. Please refer to Hadsell (1968), Dames & Moore (1981), Oaks and Kirkham (1986), and McGuire and others (1982) for descriptions of all other reports.

Boulder, Colorado

BOULDER COUNTY HERALD

November 8, 1882

Vol. 3, No. 222

Erratic Earthquake--Two Distinct Shocks Felt in Boulder.

Mother earth seemed to rejoice last evening at the grand political revolution and for joy shook with laughter. At about 6:30 o'clock, when but a few votes were left uncast, the gods knew what the results would be and communicated the news to earth when the earthquake shock took place. A large number of Boulderites felt it. The waves seemed to go from east to west. Houses swayed and rocked, dishes rattled, and many people were startled. No damage, as far as is heard from, was done near Boulder except at the University where a large quantity of plastering in the third story was thrown to the floor. Another shock was felt this morning at about five o'clock. The shock last night was felt in Denver, Golden and Longmont.

Boulder, Colorado

UNIVERSITY PORTFOLIO

December, 1882

Vol. 4, No. 2

We rise to make a correction. There is still some plastering on the ceiling of the University. Now earthquakes do not occur very often

in this region, and we believe in making the most of such rare phenomena, but when people begin tumbling plastering about our ears, we object.

The fact is that the building was shaken considerably, and some bits of plastering fell in the third story. This was telephoned downtown and from there to Denver, appearing in the papers next morning. From these the story growing at every step, was copied throughout the State until at last we read the ceilings at the University were stripped of plaster! In Boulder, two or three weeks after the earthquake, we heard the statement that only about forty yards had fallen.

It is any wonder that the rising generation is inclined to be skeptical? Why, people have formed such a habit of exaggeration-to put it mildly-that they cannot trust themselves. In repeating a story they cannot tell whether they draw it mostly from fact, memory or imagination.

Denver, Colorado

THE DENVER TRIBUNE

November 8, 1882

Vol. XVI, No. 312

DAMAGING EFFECTS OF THE EARTHQUAKE

The earthquake Tuesday evening not only created a sensation but did some damage. It was observed by a few pedestrians who were not particularly interested in the election returns that the electric lights were suddenly extinguished at half past 6. Among the observers was Superintendent Runkle. He went immediately to the electric light building at the foot of Twenty-first street and found that an accident had occurred to the machinery. From the driving pulley of engine there is a connection of shafting five inches in diameter and divided into sections of 12 feet. These sections are connected by large iron bolt screws nearly an inch in diameter. At the instant of the earthquake shock one of those bolts was snapped in twain and the other bent out of shape. The whole machinery was

thrown out of gear, and it became necessary to stop the machinery at once. Mr. Runkle is of the opinion that the upheaval which caused the earthquake ran east and west and centered about his establishment and the residency of Mr. Birke Cornforth. It was ascertained yesterday that the shock was so severe in the northern portion of the city that many families ran from their houses.

Fort Collins, Colorado

War Department, U.S. Signal Service

VOLUNTARY OBSERVER'S METEOROLOGICAL RECORD (described in Oaks and Kirkham, 1986)

November, 1882

-CASUAL PHENOMENON-

7th earthquake 6:28 p.m.[sic]

Lasting only a few seconds.

Was felt all over town.

Shook books from wall shelves in our house.

Observer-Agricultural College

Grand Junction, Colorado

HISTORY OF MESA COUNTY, by C.W. Haskell (1886)

The election passed off quietly, with a majority in favor of the local Republican ticket. It was on this day of election that a perceptible earthquake shock was felt through the valley, and, indeed, through the entire State. A party camped on Douglas Creek, stated that they saw huge rocks tumble down the mountain side during this shock, and afterwards saw large volumes of smoke, with a sulphurous smell, emerge from crevices newly opened in the ground.

Grand Junction, Colorado

THE SUNDAY MAGAZINE OF THE DAILY SENTINEL, Grand Junction

July 11, 1976

(same information in Oaks and Kirkham (1986) based on an interview with Al Looks).

A "perceptible" earthquake shock was felt through the valley on the first general election day. The 1882 shock dumped large rocks down canyon walls and was said to be felt as far distant as Denver. Highway I-70 [now] cuts across the bottom of an escarpment made by this quake in DeBeque Canyon. It was called Hogback Canon in 1882. Minor quakes have been felt on a few occasions since.

Grand Junction, Colorado

GRAND JUNCTION NEWS

November 11, 1882

Vol. 1, No. 3

On Tuesday night, about seven o'clock, our people were frightened by the shock of an earthquake, those who were in their houses experienced the shock the most, the buildings moved and quaked as if they were being torn down, and things that were hanging up any where, were put in motion at a lively rate.

Grand Junction, Colorado

GRAND JUNCTION NEWS

November 18, 1882

Vol. 1, No. 4

THE EARTHQUAKE

No one in Grand Junction who felt the shock of the earthquake on Tuesday night, the 7th of this month, would have thought that the crater or opening that was made in the earth, was as near to us as

fifty miles, but it is a fact, as the following account will show. Mr. J.W. Yard, one of the men who saw the crater, immediately after the shock, gives us the following:

"You see there were three of us in the party, Allen Rice, Thomas Charleston and myself, on our way from the Ouray Indian agency, going to Leadville; we had gone along the range of what is called Crest of Roan, or Book Plateau mountains, until we got to the head of Vaccination creek, or the North Fork of Douglass creek. It was getting late and feeling tired, we began to look around for a camping ground. We found a suitable place in a small gulch, and turned our horses loose, made a fire and got our supper. It was about 7 o'clock, and we were all sitting around the fire, talking and smoking. We had noticed a very strong smell of sulphur when we entered the gulch-just as if it was being burned-and could not account for it.

All of a sudden the earth began to shake and roll. I looked over to Tom and said: "What's the matter?" At the same time I started to get on my feet, but could not stand.

Tom called to me and said: "Let's go on top of the hill."

"This is the best place for us!" I said. "We might as well die here as anywhere."

In the mean time, great rocks, came rolling down the mountain side, and trees were broken off by the shock.

The feelings that came over us while the earth was trembling and pulling was like that of sea-sickness.

After the shock had subsided I ran on the mountain, and there, about a mile and a half to the north, gaping wide open, was an immense crater or chasm, from which great volumes of smoke came pouring forth. I immediately called Tom and Al to witness it, and we resolved to go over and look at it more thoroughly in the morning.

Next morning it was snowing, and our horses having ran away during the night, in our search for them we got lost, and wandered nearly four days, before we found our way out.

This is not a 'trumped up' story but a fact, and anyone who will take the trouble to ride over there, will see the crater, just as we saw it."

LaPorte, Colorado

DAILY EVENING COURIER(Fort Collins)

November 10, 1882

Vol. 1, No. 142

OUR LAPORTE LETTER

Last Tuesday evening, about six o'clock, Mr. Jacob Flowers felt the shock of an earthquake, which shook his house until the timbers cracked. LOCAL.

Rangely, Colorado

FROM THE DIARY OF CHARLES PORTER HILL (reprinted in local history by the Meeker History Book Committee of the Rio Blanco Historical Society, 1978, This is What I Remember, Rio Blanco Historical Society, Meeker, CO; also described in Eckert, 1982 and Oaks and Kirkham, 1986; location thought to be a few kilometers east of Rangely along the White River.)

November 7, 1882

They finally made it to the river and it took them three days to get from Wolf Creek to the place they wanted to stop. When they got there, it was late in the day, so they made camp and heard the roaring and thundering of some great noise. The ground shook and the trees bent. They said it was an earth tremor. This was November 7, 1882. Next day the three men started to build a cabin.

Steamboat Springs, Colorado

FROM THE DIARY OF PERRY A. BURGESS (Buddy Werner Memorial Library, Local History Collection, Steamboat Springs, CO; also described in Oaks and Kirkham, 1986)

November 7, 1882

Am sick nearly all day. Went to election in afternoon. At 7 p.m. we had a distinct shock of an earthquake which lasted several seconds.

Thompson, Colorado

DAILY EVENING COURIER (Fort Collins)

November 24, 1882

Vol. 1, No. 154

THOMPSON TALK from the REPORTER

We learn from Theo. Chubbuck that the walls of his residence on the farm were badly cracked, and in several places the plastering was entirely stripped from the walls by the late earthquake shock. This is the only instance where any damage was sustained through that cause in this section of country, so far as heard from.

Logan, Utah

OGDEN DAILY HERALD

November 9, 1882

Vol. 11, No. 163

Page 3, Column 4

CACHE COIN - A Distinct shock of earthquake was felt here and at Wellsville, about 6 o'clock, last evening. It appeared to be much more severe at the latter place than the former, as it is reported that people were so badly frightened as to run from their houses into the street.

Peter Spike, Logan, Nov. 8th.

Salt Lake City, Utah

THE DESERET EVENING NEWS

November 11, 1882

Vol. XV, No. 300

The Earthquake In Cache--The late earthquake shock was quite strong through Cache Valley. The JOURNAL (Logan) says, about its effects in that town:

"The earthquake shock of last Tuesday evening was felt by a number of citizens. It occurred at a few minutes past six o'clock, and frightened several persons. One lady was seated at a table writing, but for some seconds was compelled to pause; another lady living on Third Street not far from Z.C.M.I. was playing the organ, when the instrument was so violently shaken that she thought some one was behind it. The chandeliers in the upper story of Cardon and Thatcher's building swung at least a foot from their normal position by the rocking of the building. In another case an aged lady was quite frightened by the tremor."

Fort Laramie, Wyoming

U.S. ARMY, RECORDS OF MEDICAL HISTORY OF POST (described in Oaks and Kirkham, 1986)

November, 1882

Earthquake--a slight shock of earthquake felt November 7th 6:30 p.m. lasting about a minute shaking lamps and loose articles and rocking buildings without doing any damage. The shock was reported from numerous points in the territory and further south and east by H.V. Paulding, Asst. Surgeon, Post Surgeon.

Fort Washakie, Wyoming

FORT WASHAKIE METEOROLOGICAL REGISTER (described in Oaks and Kirkham,
1986)

November 7, 1882

Light earthquake at 6:12 p.m. lasted about 1/2 a minute

Wm. H. Arthur (?)

Asst. Army Surgeon

Fort Washakie, Wyoming

ABSTRACTS OF DAILY JOURNALS (described in Oaks and Kirkham, 1986)

November 7, 1882

Three distinct shocks of an earthquake were experienced at 6:12 p.m. Each shock hardly continued more than two or three seconds and the entire noise ceased almost as soon as it began. The motion seemed to pass from West to East. The lamps and other small articles vibrated from west to east. No damage was done though the walls of nearly every building in the Post were more or less disturbed. No aurora. Observer- A.M. [or F.M.?] Ambler.

Salina, Kansas

War Department, U.S. Signal Service (described in Oaks and Kirkham, 1986)

VOLUNTARY OBSERVERS METEOROLOGICAL RECORD

November, 1882

- CASUAL PHENOMENA-

7TH. Earthquake 6:55 p.m. SE to NW waves 3-time not to exceed 6 seconds. Same feeling noted by 6 persons - in second story of Brick [sic] building... , perceptible rolling motion to a long table at which was seated Board of Election - swing Chandelier same as if started by same person. Observer - Ino. H. Gibson.

Plattsmouth, Nebraska
THE OMAHA BEE (Omaha)
November 11, 1882
Twelfth Year, No. 125

State Jottings

Plattsmouth felt an earthquake shock on Tuesday morning.

Plattsmouth, Nebraska
PLATTSMOUTH WEEKLY HERALD
November 16, 1882
Volume XVIII

WE FELT IT

Plattsmouth felt an earthquake shock on Tuesday morning - OMAHA BEE.

Plattsmouth felt it much more perceptibly, however, Tuesday night when the election returns began to roll in on us.