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The Effects of the Alaskan Earthquake of March 27, 1964, on Ground Water in Iowa[1]

RONALD W. COBLE[2]

Abstract. The large Alaskan earthquake of March 27, 1964, affected all the major aquifers in Iowa. The effects included (1) seismic fluctuations of the water level; (2) turbid water; and (3) a permanent change in some water levels. A change in the porosity of the aquifers is postulated as an explanation for the permanent water-level changes.

INTRODUCTION

At 9:36 p.m. Iowa time (Central Standard) on March 27, 1964, a large earthquake occurred 80 miles east of Anchorage in south-central Alaska. This earthquake was one of the largest ever recorded on the North American continent; its magnitude was between 8.4 and 8.6 on the Richter Scale. The energy released by the shock was about three times as much as was released by the San Francisco earthquake of 1906, and more than 150 times the amount released by the Hebgen Lake, Montana, earthquake of 1959. Reports by Grantz and others (1964) and the U. S. Coast and Geodetic Survey (1964) describe the location and effects of the earthquake in Alaska. The effects of this quake in the United States and as far away as Puerto Rico are

[1]Approved for publication by the Director of the U.S. Geological Survey.
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summarized by Waller and others (1965). This paper describes the earthquake's effects on the aquifers in Iowa.

Earthquake Effects on Water Levels in Wells

The earth is an elastic solid and will transmit earthquake shock waves. An earthquake sets up three types of waves in the earth. In descending order of velocity, they are (1) longitudinal or compression waves (P waves) which travel within the earth and cause a back-and-forth movement of particles in the direction of the propagation of the wave; (2) transverse or shear waves (S waves) which also travel within the earth and cause the particles to move at right angles to the direction of wave propagation; and (3) surface waves (L waves) which are also transverse waves, but which instead of being transmitted within the earth are propagated along the surface. The various types of earthquake waves are discussed in detail by Richter (1958) and Hodgson (1964).

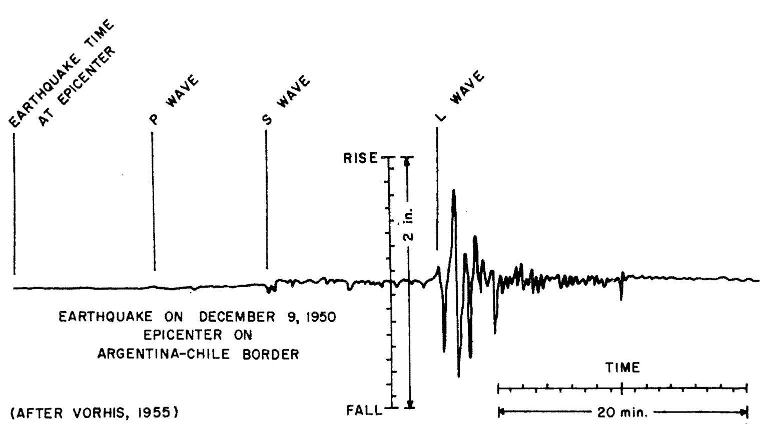

Figure 1. Seismic fluctuations in a well at Milwaukee, Wisconsin, caused by an earthquake with a magnitude of 8.3 4,800 miles away.

Figure 1 is a record of seismic fluctuations of the water level in an earthquake-sensitive well at Milwaukee, Wisconsin (Vorhis, 1955). All three types of earthquake waves may cause water levels to fluctuate; however, the greatest fluctuation is caused by the L waves, which alternately compress and dilate the aquifer. The recorder chart speed in figure 1 is about 240 times faster than that of the fastest recorders generally used by the Geological Survey and private industries. On the slower recorders the entire event would have been recorded as single line or a series of overlapping vertical lines that appear to be one thick ink mark, no wider than the crossbar of the "H" in the upper right-hand corner of Figure 1.

Earthquake Effects on Ground Water in Iowa

The Alaskan earthquake caused the water levels to fluctuate in many wells in Iowa. The earthquake occurred at 9:36 p.m. Iowa time, and the L wave arrived in Iowa around 9:50 p.m.[3]

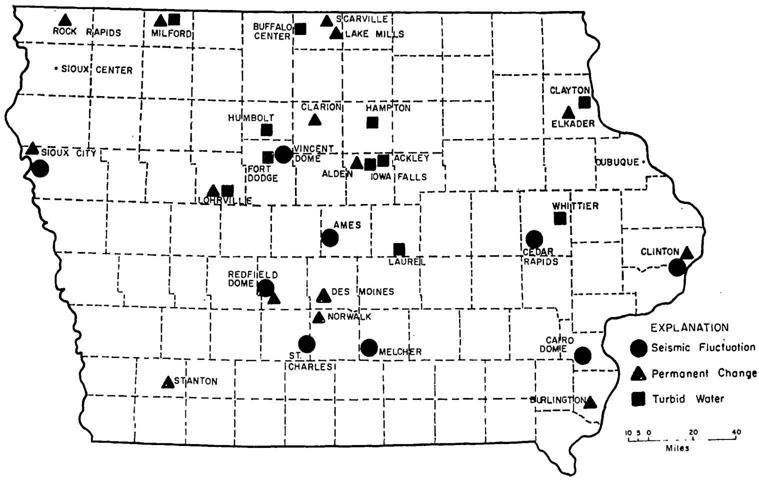

Figure 2. Locations of reported ground-water disturbances caused by the Alaskan earthquake.

The timing mechanisms on the water-level recorders on wells in Iowa are not precise enough to determine the exact minute that the earthquake affected the aquifers in the State, but there were many indications that something happened just before 10 p.m.

Aquifers in Iowa responded to the earthquake waves as shown by (1) the seismic fluctuations on some recorded charts; (2) turbid water in some wells and springs, probably caused by the disturbance and movement of silts, clays, and colloidal particles within the aquifers; and (3) a permanent change, either a rise or a fall, of the water level. These are summarized in Table 1 and Figure 2.

Seismic Fluctuations

The best record of a seismic fluctuation is shown on a recorder chart from an observation well in the Franconia Sandstone at Vincent Dome (Figure 3). A seismic fluctuation of 0.23 feet occurred just before 10 p.m. A series of smaller fluctuations

[3]Calculated to have arrived at Loras College Seismograph Station Dubuque, at 9:52 p.m. (personal communication from William Stauder, S. J., Saint Louis University).

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Summary of Ground-water Disturbances
Caused by the Alaskan Earthquake

Locality	Aquifer		Effect		
	System	Lithology	Seismic Fluctuation (feet)	Turbid Water	Water-level Change Lasting More Than One Week
Ackley				X	
Alden					Lowered
Ames	Quaternary	Sand & gravel	0.15		
Buffalo Center				X	
Burlington	Mississippian-Devonian	Carbonate			Lowered 2 ft.
	Ordovician	Sandstone			Lowered 1.8 ft.
Cairo Dome[1]	Silurian	Carbonate	1.2		
	Ordovician	Carbonate	10+		
Cedar Rapids	Silurian	Carbonate	.4		
Clarion					Raised
Clayton				X	
Clinton	Cambrian-Ordovician	Sandstone	*		Raised 15 ft. **
Des Moines	Cambrian-Ordovician	Sandstone			Raised 18 ft. **
Elkader	Cambrian-Ordovician	Sandstone			Raised 40 to 50 ft. **
Fort Dodge				X	
Hampton				X	
Humboldt	Mississippian	Carbonate		X	
Iowa Falls				X	
Lake Mills					Several reported lowered
					Several reported raised
Laurel	Mississippian	Carbonate		X	
Lohrville	Mississippian	Carbonate		X	Lowered 10 ft. **
Melcher	Quaternary	Sand & gravel	.05		
Milford				X	Lowered
Norwalk					Raised
Redfield Dome[2]	Ordovician	Carbonate	.5		
	Ordovician	Carbonate			Lowered 1 ft.
	Ordovician	Sandstone	1.25		
	Ordovician	Sandstone	.25		
	Cambrian	Sandstone			Lowered 1 ft.
Rock Rapids	Cretaceous	Sandstone			Raised 8 ft. **
St. Charles	Mississippian	Carbonate	1.1		
Scarville	Quaternary	Sand & gravel			Lowered 5 or 6 ft.
Sioux City	Cretaceous	Sandstone	2.5+*		Raised 5 ft. **
Stanton					Lowered 30 ft. in 2 days
					Raised 40 ft. after 7 days
Vincent Dome[2]	Cambrian	Sandstone	.23		
Whittier	Silurian	Carbonate		X	

* Pumping rate fluctuated
** Known to have lasted more than 7 months
1. Data from Natural Gas Pipeline Company of America
2. Data from Northern Natural Gas Company

were recorded after the main one. Many of these can be matched with some aftershocks; however, many aftershocks were not recorded.

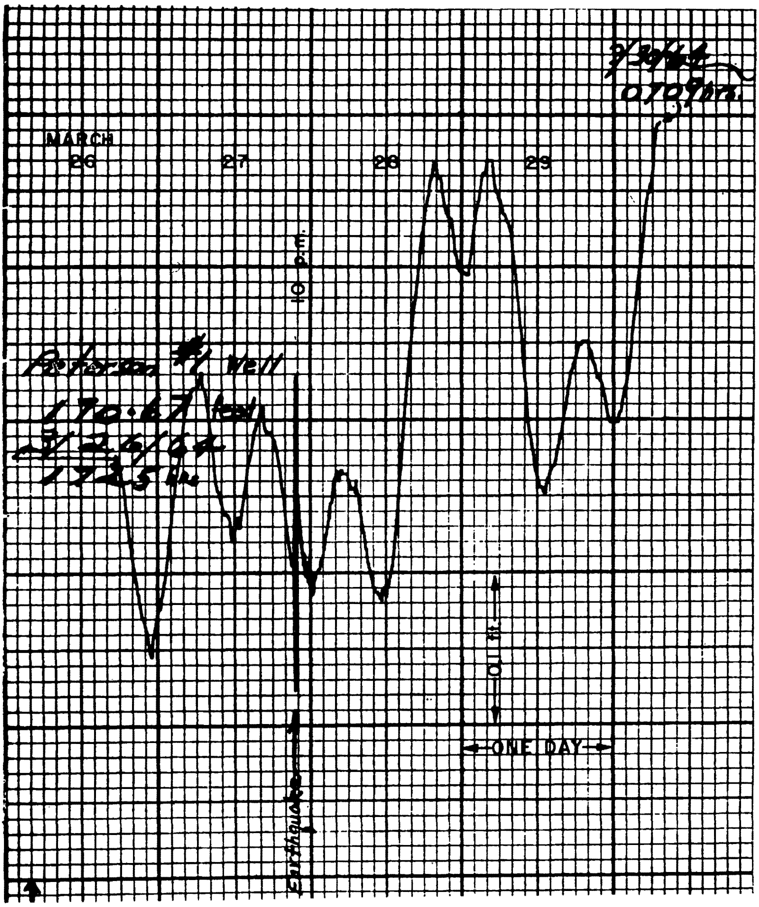

Figure 3. Seismic fluctuations in a well at Vincent Dome.

At Redfield Dome, the water levels for several different aquifers showed various types and amounts of seismic fluctuations (Figure 4). In this same area two of the four observation wells in the St. Peter Sandstone showed a seismic fluctuation; the other two showed no effect. Why some wells are affected and others are not is yet to be determined.

The seismic fluctuation was so rapid in observation wells in the Dakota Sandstone at Sioux City and the Ordovician dolomites at Cairo Dome, that the recorder pens became disengaged from the float pulley mechanism. At Sioux City, the waterplant operator could feel air moving in and out of the well casing as the water level fell and rose. He noted that this "sucking and blowing" of air, which gradually increased in intensity and then slowly diminished, lasted 5 to 10 minutes.

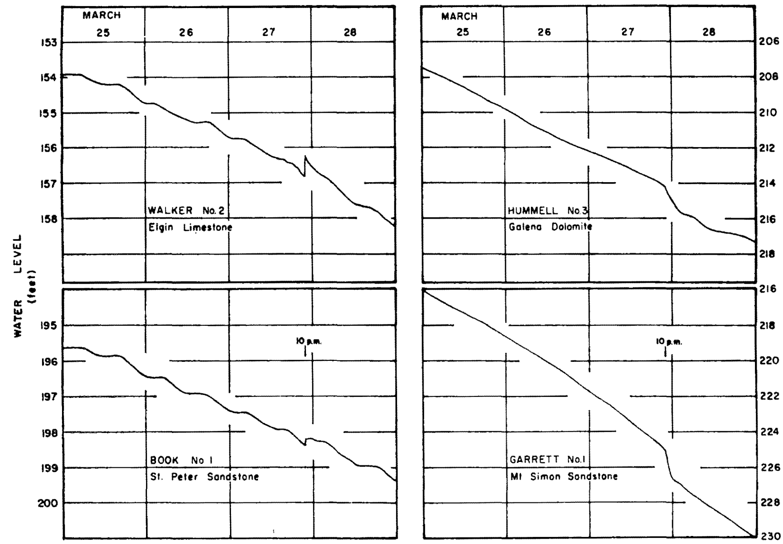

Figure 4. Water-level fluctuations at Redfield Dome.

Turbid Water

Several wells produced turbid water after the earthquake. The water usually became clear after a few hours or a few days of normal pumping. Similarly, water from several springs, the water supply for Humbolt, also became turbid. These springs, located on the bank of the West Fork of the Des Moines River, flow from limestones of Mississippian age. This water had always contained less than 5 ppm (parts per million) of suspended matter. On the morning of March 28, the turbidity was between 70 and 80 ppm. Nearby, water from several small springs in the riverbed was observed to be red, brown, and blackish-brown. The turbidity diminished on March 30, but increased again after a few rainy days during the first part of April. It did not completely disappear for another 2½ weeks.

Permanent Water-Level Changes

In several localities the ground-water levels seem to have been permanently changed. At Sioux City the water level in an observation well in the Dakota Sandstone rose 6 feet and remained high for at least the rest of the year (Figure 5). At Rock Rapids, 75 miles north of Sioux City, the water level in another well in the Dakota Sandstone rose 8 feet. A third well in the same aquifer at Sioux Center, which is almost midway between Sioux City and Rock Rapids, showed no seismic fluctuation or permanent change.

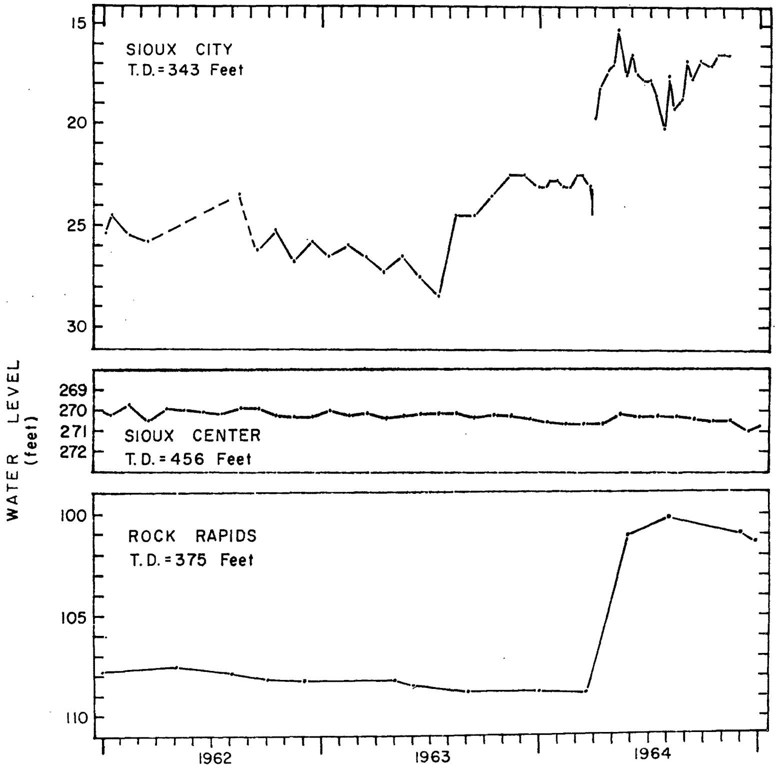

Figure 5. Water levels in the Dakota Sandstone in northwest Iowa.

Limestone of Mississippian age yields water to the municipal well at Lohrville. The nonpumping water level had been 97 to 98 feet below the land surface for more than a year before the quake (Figure 6). On March 28 the water level had dropped 3 feet, and after 1½ months the total drop was 10 feet below the

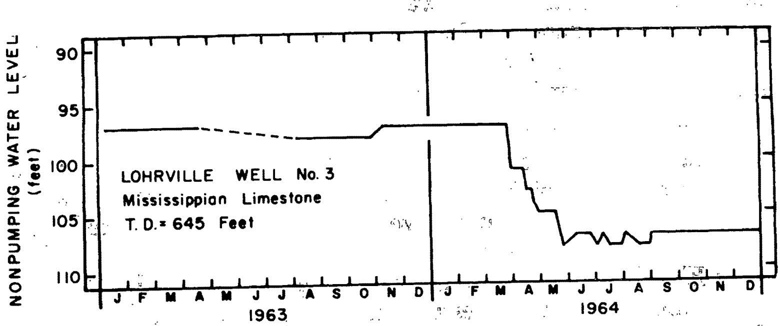

Figure 6. The water level dropped 10 feet at Lohrville.

original level. This lower level persisted throughout the rest of the year.

The water level in a well in the St. Peter and Jordan Sandstones at the Ford Motor Co. plant in Des Moines rose 18 feet (from 101 to 83 feet) after the earthquake. The level was still high in March 1965. The town of Elkader has several wells that produce water from the St. Peter-Prairie du Chien-Jordan interval. Shock waves from the Alaskan earthquake affected all of them in the same manner—the water levels which had been dropping steadily for at least two years rose 40 to 50 feet and have remained high (Figure 7). In the city of Clinton, adequate

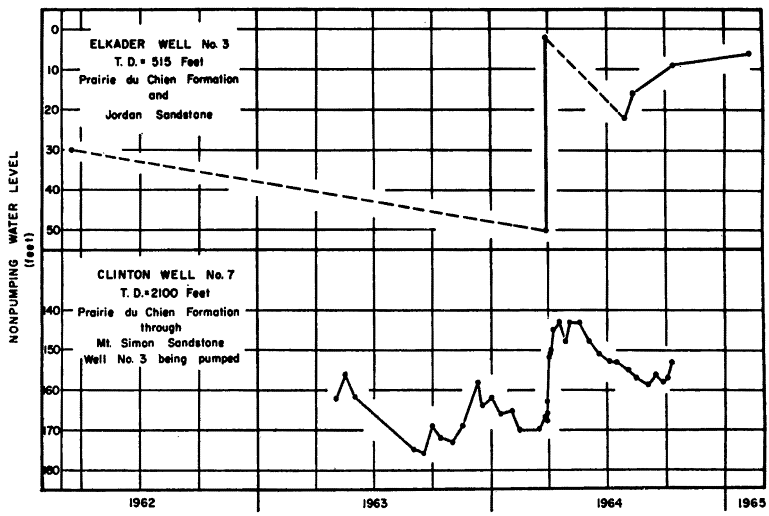

Figure 7. Water levels rose in wells at Elkader and Clinton.

records are available for two of the wells which produce water from the Prairie du Chien-Mt. Simon interval. Immediately after the initial shock, the water level rose over 20 feet in city well No. 7 (Figure 7). Seismic fluctuation was inferred in city wells Nos. 3 and 7 as pumping-rate recorders showed a total fluctuation of over 1 percent just at 9:55 p.m.

A permanent change in water levels implies a change in the physical properties of the aquifers. A logical assumption is that the porosity and thickness of the aquifers have decreased where the water levels rose, and have increased where they fell. This change need not be large, even where the level went up 50 feet, as at Elkader. Such a change would require only a change of 22 psi in the hydrostatic pressure in the aquifer. Considering only the Jordan Sandstone, which is 100 feet thick near Elkader, and assuming that it has a porosity of exactly 15 percent, the compression of the water would have to be only in the order of 1.5 x 10^{-5} feet to raise the pressure 20 psi (computed from the tables of Keenan and Keys, 1936). This amount of compression would decrease the thickness of the aquifer from 100.000000 feet to 99.999985 feet and the porosity of the aquifer from 15.000000 percent to 14.999985 percent. These computations take into account only the compression of the water. If the sandstone itself were compressed, as it probably would be, the thickness of the aquifer would be decreased somewhat more than 1.5 x 10^{-5} feet. This decrease in porosity is extremely small and can be considered insignificant with respect to the productivity of the aquifers. No change has been noted in the specific capacities of wells at either Elkader, Clinton, or Lohrville.

Summary

A large earthquake can cause significant effects in groundwater levels in areas that are nearly 3,000 miles away from the epicenter. This is illustrated by the effects that occurred in Iowa following the Alaskan earthquake of March 27, 1964; most of these, however, are of a temporary nature.

In Iowa, sharp seismic fluctuations of water levels were evident for a short time after the quake. The water in some wells and springs became turbid, but soon was clear again.

The only permanent changes were the lowering or raising of the water levels in some wells. These changes in water level are thought to be the result of permanent compression or expansion of the aquifer and its contained water. A change in aquifer thickness and porosity need be of only a very small magnitude to raise the water level as much as 50 feet, which was the greatest change noted. No change was noted in the specific capacities of any wells.

Acknowledgments

Thanks are given to Mr. Robert R. Miller of the Northern Natural Gas Co. for his help in procuring records from the Vincent and Redfield Domes, and to Mr. William Clark of the Natural Gas Pipeline Company of America for permission to use data from Cairo Dome. The courteous assistance given by the water superintendents at Sioux City, Humbolt, Lohrville, Elkader, and Clinton is gratefully acknowledged, as is that of Reverend William Stauder of Saint Louis University for his assistance with the seismograph record and calculations for the station at Dubuque.

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A Study of the Structure and Associated Features of Sheep Mountain Anticline Big Horn County, Wyoming[1]

GARY D. JOHNSON, LARRY J. GARSIDE ,ALBERT J. WARNER

Abstract. A study was made of the joint sets developed within two stratigraphic units of significantly different ages in the Sheep Mountain region, Bighorn County, Wyoming, in an attempt to determine if any pre-Laramide orogeny existed in the area. The field methods used and the relationships exhibited between joint sets are discussed. From the data presented, no significant support of the premise is concluded.

INTRODUCTION

The Problem

It is generally accepted that a study of regional tectonic elements such as folds, faults, and joints will suggest genetic connections with the standard stress-strain distribution patterns. If an area under study is not too complex, the type, relative age, and direction of diastrophic forces may be proposed.

The goals of this study were two-fold:

1) To describe the tectonic and geologic setting of the area surrounding Sheep Mountain Anticline, Bighorn County, Wy-

[1] Funds for this study were made available through a grant from the National Science Foundation.