

"No displacements could be seen in the fractures that cut bed-rocks. Several open fractures cut Monument Rock, which is composed of quartzite. The quartzite has been greatly brecciated and



FIGURE 9.—Mud cones developed along fractures about one-eighth mile west of Kosmo. Utah earthquake.



FIGURE 8.—Fault scarp north of Kosmo showing how opposite sides of scarp fit together. Utah earthquake.

recemented. Several inches of banded travertine occurs along one of the fractures which stands open for a distance of from 12 to 18 inches. This fracture strikes about north 20° east and has a ver-

"Most of the fractures from which water flowed trend northerly. The principal exception is the fracture about 200 feet south of Kosmo which trends north 70° west and has a nearly vertical dip. This fracture is situated at the edge of a terrace about 6 feet high.

"In places large holes formed around the springs due to caving of the soft material through which the water flowed. Two such holes were formed in the salt flats immediately northeast of Monument Rock. These holes had diameters of from 8 to 10 feet on March 16, 1934, and about one-half second-foot of water was flowing from one of them. Less water flowed from the other. Prof. Reed Bailey states that one of these holes was 37 feet deep.



FIGURE 11.—Water issuing from fault on salt flat northeast of Kosmo. Utah earthquake.

"In addition to the springs, water flowed from an old well near Kosmo immediately after the first disturbance. The well is said to be 350 feet deep. Casing projects above the ground for about 1 foot. On March 16 water was not flowing from the well, but considerable wet mud around it showed that it had flowed a short time before.

"The springs have formed largely in loosely consolidated material along the old shore line of Great Salt Lake and hence the material is probably well saturated with water. It is believed that settling and slumping of this material as the result of the earthquake forced the water to the surface along the fractures.

"An observation by Professor Pack indicates that the water in some places must at first have been forced from the ground under considerable pressure. He reports that he found pieces of sod some distance away from old seeps from which they clearly had come.

"Airway officials at Locomotive Springs Landing Field report that Locomotive Springs dried up at first and then flowed red water for 8 hours. They report that the spring probably increased its

an alarming angle, and seemed ready to topple over at any moment, though the last that I heard, August 4, they were still standing.

"In the native village there were several cracks in the ground, about an inch wide and a foot or two deep, and there were several places that looked like geysers—that is where underground water had spouted up out of the ground. It would appear that the dock collapsed more or less in place, and by sections, the outboard section first, and so on, to the section just before the middle of the dock—



FIGURE 12.—Wrecked water tank. Puerto Armuelles yard. Panama earthquake.



FIGURE 13.—Railroad track shifted out of alignment at Puerto Armuelles. Panama earthquake.

where the dock bends. From later inspection, it was seen that the outboard section of the remaining dock had slid about 5 feet to the southward—the dock floor remaining more or less level, but the piers being canted about 5 feet out of plumb. The inshore section was canted about the same amount to the northward, while the center of the remaining portion remained about in place.

"There were two big mooring buoys just off the northern side of the dock and these were found to have shifted about 1,000 feet seaward—that is, a little south of east—maintaining their relative positions as to distance and alignment. One of our launches had been moored to one of these buoys and at the time of the quake

In view of the apparently wide spread of the aftershocks and the lack of precise information concerning the main shocks of the series an epicenter at $46^{\circ}37' \text{ N. } 111^{\circ}58' \text{ W.}$, is adopted as representing, as near as we know it, the central point of all activity. This is practically identical with the point of intersection of the two buried faults north and east of Helena as indicated by H. W. Scott. The wide spread of recorded aftershocks indicates, however, that any shock of the series may have easily originated several kilometers from this point and probably along the fault crossing the southern end of Prickly Pear Valley.

The Bozeman record.—Epicentral distances from Bozeman may be estimated by measuring the duration of the first preliminary tremor, S-P, and assuming that the seismic rays for the preliminary waves traverse only the granitic layer. Standard seismological practice assumes the velocity of compressional waves in granite to be 5.5 kilometers per second. The transverse wave velocity is about 3.2 kilometers per second. An error of 1 second in the S-P interval, therefore, corresponds to an error of 7.6 kilometers in focal distance. For various reasons this may be considered a probable error. The S-P intervals for the shocks of October 12, 18, and 31 averaged close to 17.0 seconds, indicating a distance of 130 kilometers which checks well

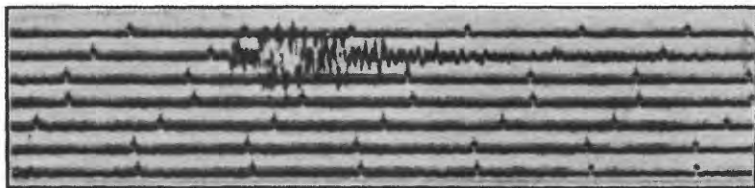


FIGURE 10.—Seismograph record of the Helena earthquake of November 28, obtained at the Montana State College, Bozeman.

with the adopted epicenter northeast of Helena. The interval for the November 29 shock is 2 seconds less, indicating an epicentral distance 15 kilometers shorter. This cannot be reconciled with the strong-motion data at Helena and should apparently be charged to questionable instrumental performance. The accelerograph data in this instance must be given the preference because of more precise time control. One millimeter corresponds to 4.0 seconds on the teleseismic record at Bozeman, but only 0.1 second on the Helena accelerograph.

The azimuth of epicenter is indicated quite well by the first impulsive movements recorded at Bozeman on October 12, 18, 31, and November 29. The computed azimuths are 30° , 35° , 33° , and 30° , west of north, respectively. The adopted epicenter bears 35° west of north. The 30° values are based on relatively small displacements of the light spot. The smallest light spot displacement was 1.2 millimeters on November 29 on the E-W component; the largest 30.8 millimeters on October 31 on the N-S component. It is noteworthy that the first horizontal movement at Bozeman on October 31 was nearly four times greater than on October 18 despite the fact that the most destructive shock was that of the 18th. The first movements on all of the records just discussed were rarefactions. It will be recalled that three out of the four first motions measured at Helena were also rarefactions.



FIGURE 11.—South Main Street, looking east. Helena.



FIGURE 12.—North wing of high school. Helena.



FIGURE 13. Bryant school. Helena.



FIGURE 14. County poor farm. Two miles north of Helena.



FIGURE 15.—Shrine Temple. Helena.



FIGURE 16.—State Armory. Helena.



FIGURE 17.—Residence, Twelfth and Ewing Streets. Helena.



FIGURE 18.—National Biscuit Co. Helena.



FIGURE 19.—Crack which spouted water and sand. Six miles northeast of Helena.

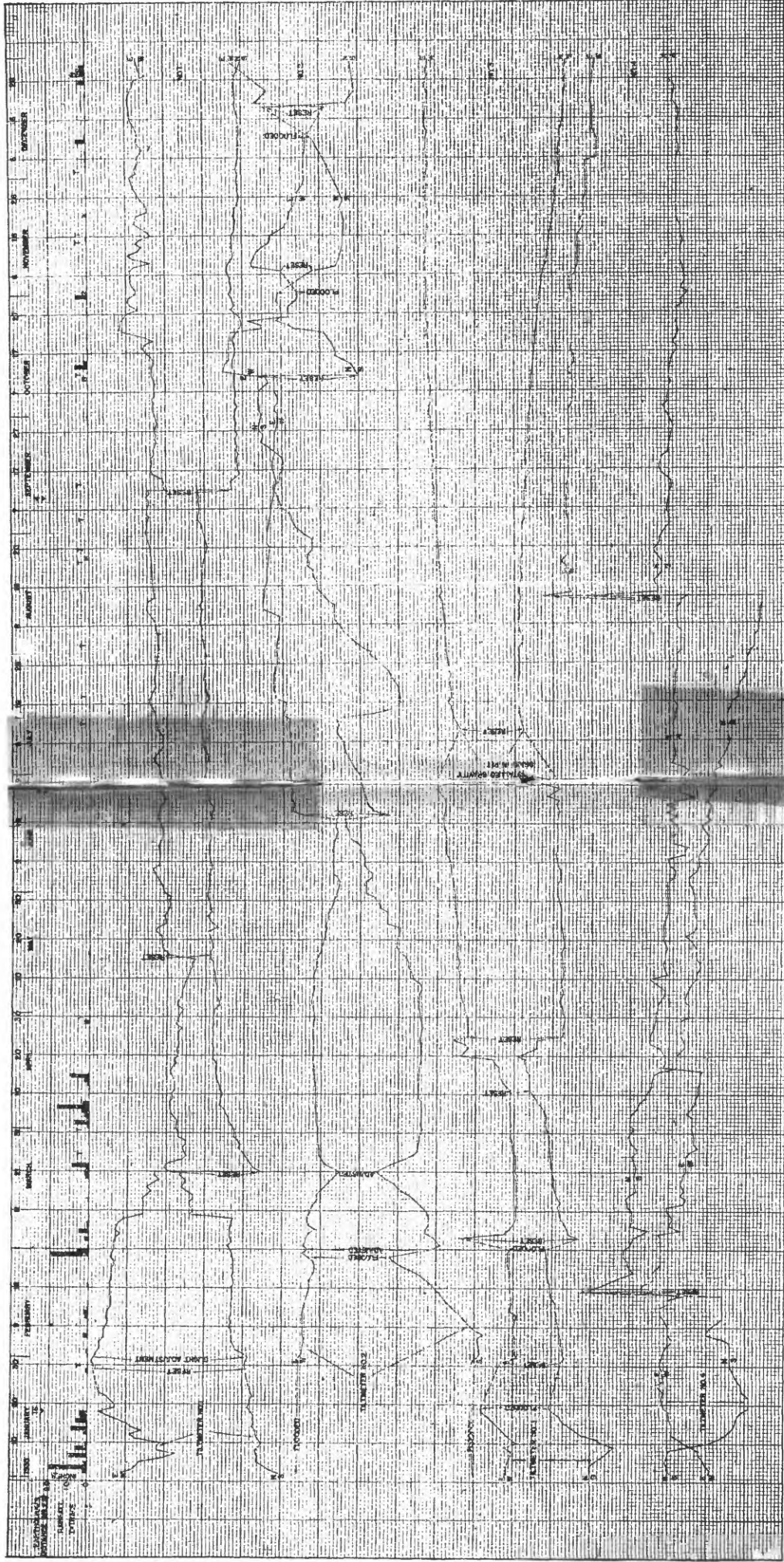


Figure 34.—Tilt curves for 1935

Figure 34.—Tilt curves for 1935—Continued