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# Summary of Seismic Activity and its Relation to Geology and Mining in the Sunnyside Mining District, Carbon and Emery Counties, Utah, during 1967-1970

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By

C. Richard Dunrud, Frank W. Osterwald, and Jerome Hernandez

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## Abstract

In the Sunnyside mining district, Utah, coal is mined under thick and variable overburden which is locally weakened by faults and other structural discontinuities. Stress changes and local stress concentrations produced by mining under these conditions often cause sudden and violent ruptures in the coal and surrounding rock mass. The strain energy released by this type of failure, which can produce shock waves and may discharge coal and rock with explosive force, is often a serious threat to life and property. These releases of strain energy are called bumps or bounces by miners if they occur in the coal, and rock bursts if they occur in the surrounding rock mass. Many of these releases are so violent that they generate seismic waves that can be felt, or at least detected by seismic instruments, miles from the site of the rupture, whereas others are smaller and can be detected only by those sensitive seismic instruments within a few thousand feet of the site of the rupture.

In 1969 and 1970, about 27,000 and about 15,000 earth tremors, respectively, were recorded by the five-station seismic monitoring network that is located at the surface and encompasses most of the mine workings in the district. Of these totals, 512 and 524 earth tremors, respectively, were of sufficient magnitude (greater than 1.5 on the Richter scale) so that the hypocenters could be accurately located. In 1968 about 20,000 tremors were recorded, with 281 large enough to plot, but in 1967 over 50,000 were recorded, of which 540 were plotted.

In this report we discuss the way in which seismic activity, geology, and mining are related or seem to be related for the period 1967 through 1970, with emphasis on the period 1969-70. We also suggest certain mining procedures which, based on studies during the period, might increase the safety and efficiency of mining operations in the Sunnyside district. A complete tabulation of the larger magnitude earth tremors which occurred during 1969-70 and descriptions of how they relate to mining are given in the appendix. Similar tabulations and descriptions for 1967 and 1968 are available in earlier reports (Barnes and others, 1969; Dunrud and others, 1970).

## Introduction

Coal mined in the Sunnyside district provides a large portion of the coking coal used in the steel mills in the western United States. When blended with other western coals, the coal produced from the Sunnyside bed makes a good metallurgical coke, which is used in the steel mills in Provo, Utah, and in Fontana, Calif. Mining beneath overburden that varies in thickness from a few hundred feet to more than 2,500 feet in short lateral distances produces stress changes and concentrations that cause coal-mine bumps, rock bursts, roof falls, and squeezes, which are hazardous to miners and mining equipment.

As mine workings become more extensive and more coal is extracted, overburden and tectonic stresses are redistributed and locally concentrated in the solid coal and rock mass near the mine workings. These stress changes and concentrations cause the coal and rock to readjust to a new state of stress. Some of these readjustments are slow and passive, but others are sudden and violent. The sudden and violent releases of strain energy are called rock bursts if they occur in the rock mass, and bumps or bounces if they occur in the coal. If the rock burst or bump occurs near active mining areas, the flying coal and rock expelled by its explosive failure can injure or kill miners and damage or cover up mining equipment, whereas if a burst occurs in the solid rock mass away from the mine workings the seismic waves may trigger more bumps or bursts in highly stressed zones near active mine workings or may cause damage to structures at the earth's surface.

Since 1958 we have compiled detailed engineering geologic maps of the district to determine what geologic factors control the location and severity of rock bursts and bumps (Osterwald, 1961; Osterwald and others, 1969; Dunrud and Barnes, 1972). Underground geologic and engineering studies also were conducted in order to relate the surface geology to specific underground deformation problems. To supplement these studies we built a seismic network in 1963 that encompasses most of the mine workings, in order to locate the sources of the earth tremors generated by the mine-induced stress changes.

This report summarizes the relationships that were found to exist between seismic activity, geology, and mining during 1967-70, with emphasis on the period 1969-70. We also discuss mining practices that might increase the safety and efficiency of coal production. The paper updates previous reports on seismic activity in the district (Dunrud and others, 1970; Barnes and others, 1969; Osterwald and Dunrud, 1966; Dunrud and Osterwald, 1965). A complete tabulation of the larger magnitude tremors that occurred during 1969-70 and a description of how they relate to mining are given in the appendix.

## Acknowledgments

Mine officials of U.S. Steel Corp. and Kaiser Steel Corp. have been very cooperative and have aided our studies in many ways. They have contributed maps of new mine workings, have given us many helpful suggestions and information, and have cheerfully allowed us access to their properties. We thank them for their help and cooperation.

## Seismic monitoring network

The seismic monitoring network at Sunnyside, which also is described in earlier reports (Barnes and others, 1969; Osterwald and Dunrud, 1966; Maberry, 1966; Dunrud and Osterwald, 1965), consists of three basic seismometer stations about 12 miles apart arranged in a triangular fashion around most of the mine workings in the district (Bear Canyon, Sheep Canyon, and Flat stations on figs. 3-10). The Horse Canyon and Pasture Canyon stations provide supplementary control, and the Pasture Canyon station also serves as the central recording station. Each station consists of a vertical-component Willmore seismometer and a battery-powered preamplifier that are housed in a reinforced concrete shelter that is anchored to bedrock. Two horizontal seismometers are also operated in a north-south and east-west position at the Pasture Canyon station.

Voltage signals induced by seismic-wave velocity are preamplified about 35,000 times at the seismometer stations and transmitted by wire to the central recording station, where the signals are recorded on magnetic tape and on helical Sprengnether drum recorders that rotate at 1 mm per second and translate at 2.5 mm per revolution. The system operates continuously except for 10-15 minutes per day, when the records and tapes are changed. The magnification of the system--the ratio between the amplitude measured on the seismograms and the ground-displacement amplitude--is approximately 250,000 at 10 cycles per second. Unfiltered frequency response of the magnetic tape system, which was constructed from surplus military components by John B. Bennetti, Jr., is flat from 0 to 200 cycles per second. The frequency response of the magnetic tape recording and playback system, including the seismometer, is flat from 1 1/2 to 80 cycles per second. The tremors are indexed and counted from the paper records; the tremors received by all stations are then played back at an expanded time scale on a light-beam oscillograph.

The location of a tremor hypocenter--the three-dimensional position of the point where the tremor originated--is determined by Jerome Hernandez at the recording station with the aid of a travel-time protractor (Osterwald and others, 1971, p. 6, 8). The travel-time curves can be readily interpolated so that a tremor hypocenter can be located within ±500 feet. However, if one basic network station is inoperative, the accuracy of location is probably reduced by a factor of 2. If a basic network station and a supplemental station are both inoperative, the accuracy normally is below an acceptable level. If the tremor hypocenter is located using drum records rather than oscillograms, the accuracy of the location is probably reduced by a factor of 2 to 4, even at peak efficiency.

Rugged field conditions at times reduce the network below optimum efficiency. The network was out of service from March 13 to April 20, 1969, when all signal lines to the recording station were broken by the heaviest snowfall, according to local residents, in 50 years. The Horse Canyon line was broken from February 27 through April 26, 1969. The system was below par during the period from April 15 through August 31, 1970, because of power problems and because the signal lines were being extensively repaired. The data also are unreliable from September 1 to the first part of December 1970 because of network difficulties. Also, a remote battery-charging capability was being added to the system during this period.

## Seismic activity

The daily level of seismic activity varied more than 300-fold during 1969 and apparently as much as 75-fold during 1970. The variation in 1969 thus is much greater than the 10-fold variation recorded in 1968 and considerably greater than the 90-fold variation in 1967. The total number of earth tremors recorded in the Sunnyside mining district was about 27,000 in 1969 (12,500 by the Bear Canyon seismometer station (fig. 1), 14,500 by the Horse Canyon station (fig. 2), and about 15,000 in 1970 (4,500 by the Bear Canyon seismometer station and 12,500 by the Horse Canyon station--these are low because of equipment problems during the last half of 1970). The total number of earth tremors recorded was about 20,000 in 1968 (Dunrud and others, 1970) and approximately 50,000 in 1967 (Barnes and others, 1969). Of the totals recorded in 1969 and 1970, 512 and 524 earth tremors, respectively, were of sufficient magnitude (over 1.5 on the Richter scale) so that the hypocenters could be accurately located (tables 1, 2, 3, 4). The hypocenters of 281 and 540 larger magnitude tremors were located in 1968 and 1967, respectively.

The daily tremor rate recorded by the Bear Canyon seismometer station varied from 1 to 318 in 1969, and from 1 to 75 in 1970, with an average of about 35 in 1969, and 12 in 1970 (fig. 1). The daily tremor rate recorded by the Horse Canyon seismometer station varied from 3 to 140 in 1969, and from 3 to 148 in 1970, with an average of about 40 in 1969 and 35 in 1970 (fig. 2).

All tremors that were located in 1969 and 1970 occurred relatively close to active mine workings (figs. 3 through 10). The lateral distance of the most remote tremor hypocenter was 7,000 feet in 1969 and only 3,000 feet in 1970. Most of the outlying tremor hypocenters were located near known or suspected faults.

Tremors that originated within the map areas of the various mine workings, which included the vast majority of the tremors, varied in depth from a few hundred feet above the mine workings to as much as 8,000 feet below the mine workings in 1969 and as much as 7,000 feet below the mine workings in 1970 (figs. 3, 4). Most tremor hypocenters are 3,000-5,000 feet deeper in the Geneva mine area than they are in the Sunnyside and Columbia mine areas. The focal depths change abruptly at a normal fault or fault zone which divides the Columbia and Geneva mines (Dunrud and others, 1970; Barnes and others, 1969).

Patterns of seismic activity

Two temporal patterns are evident from histograms of the daily tremor rate in the Sunnyside district during 1969 and 1970 (figs. 1, 2). The first is a cyclic variation, with peaks and troughs at weekly intervals. The peaks generally occur during midweek at the peak of mining activity, and the troughs on weekends, when the mines are idle. This pattern, which is more distinct on the Bear Canyon histogram (fig. 1) than on the Horse Canyon histogram (fig. 2), has been noted since monitoring began (Dunrud and Osterwald, 1965; Osterwald and Dunrud, 1966; Barnes and others, 1969; Dunrud and others, 1970). The weekly pattern generally shows a 2- to 5-fold fluctuation between peak and trough. The second pattern is less regular, having intervals of 3-6 months between peaks. This second pattern has also been observed in previous years, but the intervals between peaks or troughs have varied from a few weeks to as much as 6 months, and the fluctuations of daily tremors between peak and trough have been more variable than those of the weekly pattern. The fluctuation between peaks and troughs in the long-term pattern is commonly more than 5-fold and as high as 300-fold (figs. 1, 2). The relation between seismic activity, mining, and geology is discussed in a later section of this report.

Differences as well as similarities in the short-term and long-term patterns can be seen when the seismic activity in the northern part of the district (fig. 1) is compared with that in the southern part of the district (fig. 2). The peaks and troughs representing the short-term activity pattern in the northern and southern parts of the district generally coincide throughout 1969 and 1970. The peaks and troughs comprising the long-term pattern, however, coincide reasonably well for only the first three-quarters of 1969 and are different for the remainder of 1969 and most of 1970.

The seismic activity in the northern part of the district steadily declined during the last quarter of 1969 from its highest point of 318 tremors per day on October 1 to only 12 on December 30, and then increased again during the first quarter of 1970, whereas the activity in the southern part of the district constantly averaged about 70 tremors per day through April 1970. Inoperative periods of seismometers in the northern and southern parts of the district preclude an accurate comparison during the last half of 1970.

## Larger magnitude earth tremors

The daily rate of occurrence of tremors greater than 1.5 on the Richter scale varied from 0 to 7 (figs. 1, 2). Monthly and quarterly totals varied by as much as 10-fold and 1.5-fold, respectively, in 1969 (table 1) and by as much as 6-fold and 3-fold, respectively, in 1970 (table 2). This is not a true pattern during the last half of 1970, however.

The pattern of occurrence of the larger magnitude tremors (those above 1.5) generally coincided with the pattern of the total seismic activity during most of 1969 and 1970 (figs. 1, 2). However, during the latter part of September and the first part of October 1969, the total seismic tremor rate was at a 7-year high, but the larger magnitude tremor rate was low to moderate.

# Geology

## General stratigraphic setting

The coal is mined from the Sunnyside coal bed in the Blackhawk Formation of the Upper Cretaceous Mesaverde Group (Clark, 1928, p. 15-17). The Mesaverde Group varies from 1,250 to 1,400 feet in thickness in the Sunnyside district and comprises, in ascending order, the Blackhawk Formation, the Castlegate Sandstone, and the Price River Formation (Fisher and others, 1960, p. 11-14, 43-46; Brodsky, 1960, p. 14-15). The Mesaverde Group is underlain by the Mancos Shale, which averages about 4,000 feet in thickness (Fisher and others, 1960, p. 8), and is disconformably overlain by a 3,500- to 3,800-foot-thick sequence of variegated claystones, mudstones, limestones, sandstones, and shales of Late Cretaceous through Eocene age that formerly was called the Wasatch Formation (Clark, 1928, p. 21). Later, the lower 500-600 feet of the formation--a sequence of claystones and lenticular sandstones, with beds of fresh-water limestone at the top--was termed North Horn and Flagstaff Formations undifferentiated (Fisher and others, 1960, p. 21). The remainder, which is a very resistant sequence of tan intertonguing and locally discontinuous sandstones and interbedded varicolored limy mudstones, was correlated with the Colton Formation (Fisher and others, 1960, p. 21-22). Light-gray shales and asphaltic sandstones, which are equivalent in age and composition to the Green River Formation, intertongue with rocks of the Colton Formation in its upper few hundred to 1,500 feet.

The Sunnyside coal bed is underlain in turn by a massive to thickly layered sandstone 80-130 feet thick, a shale and mudstone sequence 100-140 feet thick, and a massive sandstone or sandstone sequence with thin shale interbeds with an aggregate thickness of 200-250 feet. It is overlain by a 135- to 150-foot-thick sequence of shales and mudstones with slabby sandstones and locally sandstone channels at or near the base. This sequence is overlain by the Castlegate Sandstone,

Table 1.--Monthly and quarterly summary of the larger magnitude earth tremors (between 1.5 and 3.0 on the Richter scale) that occurred in the various mining areas of the Sunnyside district during 1969

| Period 1969 | | Number of tremors plotted in the various mining areas | | | | | Total number of tremors | |
|---|---|---|---|---|---|---|---|---|
| | | Kaiser Steel Corp. Sunnyside mine area | | | U.S. Steel Corp. mine areas | | | |
| Qtr | Month | #1 | #2 | #3 | Columbia | Geneva | Month | Qtr |
| 1 | Jan. | 11 | 22 | 0 | 0 | 19 | 52 | |
| | Feb. | 13 | 17 | 0 | 1 | 10 | 41 | |
| | Mar. | 2 | -- | 0 | 0 | 3 | 5 | |
| | | 26 | 39 | 0 | 1 | 32 | | 98 |
| 2 | Apr. | 4 | 7 | 0 | 0 | 0 | 11 | |
| | May | 18 | 28 | 5 | 3 | 11 | 65 | |
| | June | 14 | 15 | 5 | 6 | 11 | 51 | |
| | | 36 | 50 | 10 | 9 | 22 | | 127 |
| 3 | July | 19 | 18 | 3 | 5 | 15 | 60 | |
| | Aug. | 25 | 3 | 1 | 1 | 13 | 43 | |
| | Sept. | 18 | 0 | 0 | 2 | 10 | 30 | |
| | | 62 | 21 | 4 | 8 | 38 | | 133 |
| 4 | Oct. | 13 | 6 | 2 | 3 | 11 | 35 | |
| | Nov. | 26 | 19 | 9 | 6 | 10 | 70 | |
| | Dec. | 10 | 10 | 2 | 4 | 23 | 49 | |
| | | 49 | 35 | 13 | 13 | 44 | | 154 |
| | | | | | Grand total--------- | | | 512 |

Table 2.--Monthly and quarterly summary of the larger magnitude earth tremors (between 1.5 and 3.0 on the Richter scale) that occurred in the various mining areas of the Sunnyside district during 1970

| Period 1970 | | Number of tremors plotted in the various mining areas | | | | | Total number of tremors | |
|---|---|---|---|---|---|---|---|---|
| | | Kaiser Steel Corp. Sunnyside mine area | | | U.S. Steel Corp. mine areas | | | |
| Qtr | Month | #1 | #2 | #3 | Columbia | Geneva | Month | Qtr |
| | Jan. | 39 | 23 | 1 | 2 | 28 | 93 | |
| 1 | Feb. | 29 | 23 | 1 | 3 | 14 | 70 | |
| | Mar. | 39 | 16 | - | 1 | 14 | 70 | |
| | | 107 | 62 | 2 | 6 | 56 | | 233 |
| | Apr. | 11 | 16 | 2 | - | 17 | 46 | |
| 2 | May | 1 | 15 | 2 | 5 | 27 | 50 | |
| | June | 2 | 2 | - | - | 4 | 8 | |
| | | 14 | 33 | 4 | 5 | 48 | | 104 |
| | July | --- | -- | - | - | -- | -- | |
| 3 | Aug. | 16 | 5 | - | 1 | 27 | 49 | |
| | Sept. | 10 | 1 | - | 4 | 14 | 29 | |
| | | 26 | 6 | - | 5 | 41 | | 78 |
| | Oct. | 9 | -- | - | 2 | 7 | 18 | |
| 4 | Nov. | 23 | -- | 4 | 4 | 21 | 52 | |
| | Dec. | 20 | 2 | 4 | 3 | 10 | 39 | |
| | | 52 | 2 | 8 | 9 | 38 | | 109 |
| | | | | | Grand total-------- | | | 524 |

NOTE: The seismic recording network was inoperative or functionally below par from April 15 to first part of December.

180-250 feet thick, and the Price River Formation, which is 450-550 feet thick. The lower half of the Price River Formation is predominantly mudstones and shales with local thin sandstone beds, whereas the upper half is predominantly sandstones with thin mudstone interbeds. The rocks beneath the coal bed, therefore, are strong, whereas the rocks above it are weak. This affects the type and amount of deformation in the floor and roof of the mine workings as stresses increase due to mining activities.

## Structure

The structure of the Mesaverde and younger rocks that crop out near the mine areas has been studied in detail at the surface and underground (Osterwald, 1961; Osterwald and others, 1969; Dunrud and Barnes, 1972). Bedrock units dip generally eastward 6°-10° in the southern half of the district and northeastward 6°-15° in the northern part of the district. Elevations of mine workings range from about 5,500 to 7,500 feet above sea level, but most workings range between 6,000 and 7,000 feet above sea level.

## Joints

Joints are common in the resistant rock units. Individual joints are planar to curved, and range in vertical and lateral dimensions, as well as in spacing, from a few inches to over 100 feet. Their attitude varies, but two well-defined sets of steeply dipping joints that parallel the dip and strike directions of the rock units are common, although other joints with a more random orientation can be observed on almost any outcrop as well.

## Faults

Bedrock units are displaced by faults that trend north-northwest, east, and northwest (figs. 3-10). The north-northwest and northwest faults dip steeply to vertically, whereas the east-trending faults dip at moderate angles. The north-northwest faults form the so-called Sunnyside fault zone, which is narrow in the northern part of the district but abruptly widens in the Sunnyside No. 2 mine area, where the rock units also change strike, into a complex branching and converging en echelon zone that is nearly a mile wide in the Columbia mine area. The east-trending faults form horst and graben structures which extend south of a major east-trending fault that divides the Columbia and Geneva mines, and within the limits of the Geneva mine are two well-defined grabens separated by a horst. The south graben is cut by east-trending faults. Both the horst and the northernmost graben are cut by a northwest-trending fault or fault zone, which exhibits a large left-lateral strike-slip component of movement and branches into horsetail faults parallel to the trend of the Sunnyside fault zone across the Columbia-Geneva mine boundary fault.

North of the Columbia-Geneva mine boundary fault, a wedge-shaped horst and a narrow east-trending graben are formed by two east-trending normal faults and an intervening shear zone. West of the Columbia mine the shear zone parallels the trend of the strike-slip fault, but to the east it branches and becomes parallel to the east-trending faults. A deeply buried, arcuate, normal fault, suspected from drill-hole and seismic-refraction data, which parallels the trend of the Sunnyside fault zone, may displace Paleozoic rocks about 2,600 feet beneath much of the Geneva mine workings, but passes to the west of the Columbia and Sunnyside mines (Tibbetts and others, 1966, p. D136).

## Topography

The topography is very rugged above and to the east, north, and south of the mine workings but is very subdued to the west of the mines, where the weakly resistant Mancos Shale is exposed (figs. 3-10). Erosion has sculptured two very steep escarpments from the predominantly resistant rocks of the Mesaverde Group and the Colton-Green River Formations. These escarpments, which generally parallel the strike of bedrock units, are composites of nearly vertical sandstone cliffs that are separated by moderate shale or mudstone slopes. The escarpment formed in the Mesaverde rocks is known as the Book Cliffs, and is located near the western or southwestern boundary of the mines. The other escarpment, formed in Colton-Green River rocks, is called the Roan Cliffs; it also forms the west flank of Patmos Mountain.

The two escarpments are separated by 2-3 miles of subdued terrain, which is underlain by weakly resistant claystones of the North Horn Formation or the lower part of the Colton Formation. Streams have incised deep canyons and reentrants in directions roughly parallel to the strike and dip of bedrock units, thus contributing to the ruggedness. Streams have advanced headward (eastward) in the dip direction to the Roan Cliffs, forming canyon-and-ridge topography between the two escarpments. The mines are located beneath these canyons and ridges, where overburden varies in thickness from a few hundred feet to as much as 2,500 feet within short lateral distances (Osterwald, 1961; Osterwald and others, 1969; Dunrud and Barnes, 1972). Should mining continue eastward under Patmos Mountain, the overburden thickness would rapidly increase to as much as 4,700 feet but would then be more uniform, and the stresses produced by overburden load would perhaps be more predictable.

## Methods of producing coal

Two different methods of producing coal are used in the Sunnyside district--the room-and-pillar method and the longwall method. Both methods are used in the Sunnyside mines; only the room-and-pillar method is employed in the Columbia and Geneva mines. After the initial development of a coal panel, the coal is removed in one step in the longwall method, but two steps, the driving of rooms and extraction of pillars, are involved in the room-and-pillar method.

Room-and-pillar mining

Where coal is produced by the room-and-pillar method, 16- to 20-foot-wide rooms and crosscuts are driven parallel to the dip and strike, respectively, of the coal bed between two haulageway-aircourse entry systems. After one to three rooms have been driven, a row of pillars nearest to the development boundary is extracted as another set of rooms and crosscuts is driven in the solid coal. The spacing of rooms and crosscuts should be such that the pillars are large enough to support the roof until the pillars can be extracted, but small enough to yield passively to abutment pressures and also small enough in one dimension (usually in the direction parallel to the dip direction) to be efficiently mined by continuous mining equipment. Within the district, room spacing varies from 40 to 80 feet and averages about 60 feet; crosscut spacing varies from 60 to 200 feet and averages about 100 feet.

The roof normally caves after two or three rows of pillars have been extracted. This disperses the stresses that commonly concentrate on pillars near mined-out areas (the pillar lines) and transfers the overburden stresses to solid coal ahead of mining and to the chain pillars on the haulageway-aircourse system. The process of transfer and dispersal of overburden compressive stresses to abutment areas may be similar to the way in which natural arches and bridges support their superincumbent loads--through the formation of an arch of compressive stresses.

The process of stress transfer can be observed in the active mine area between the pillar line and the solid coal boundary. If caving, involving a few tens of feet of roof rock, occurs after a few rows of pillars have been extracted, then the pillar ribs, roofs, floors, and the solid coal boundary are deformed to only a small extent, indicating that the stresses are low and therefore have been transferred to abutment areas. However, if caving does not occur after a number of rows of pillars have been removed, stresses concentrate and increase as mining continues until pillars crush down by 20 percent or more of their original height, roofs and floors may bulge, and violent bumps may occur in pillars or in the adjacent solid coal.

Longwall mining

The longwall method of producing coal is simpler in concept and normally produces simpler stress patterns during mining and after mining is completed than the room-and-pillar method, but it is less flexible to changing geologic conditions. The occurrence of sandstone channels or faults may prohibit further access to the coal bed by longwall equipment and halt the operation, whereas development and extraction could continue with the room-and-pillar method by simply mining some rock and by changing direction of mining. Under the longwall method, a haulageway-aircourse entry system is driven to the boundary of the coal panel to be developed and connected to the next higher entry system by using conventional room-and-pillar mining equipment (see 2N, 3N, and 4N; 12L and 13L on figs. 7, 8, 9, and 10 for examples of longwall panels). A continuous face of coal, which is the height of the coal bed and the width of the longwall panel, is mined in increments of about a foot by a rotating cutter wheel moving along a guide carriage. The direction of the longwall face (free air surface of solid coal perpendicular to the direction of mining) is at right angles to that of the face when driving rooms under the room-and-pillar method. The coal falls on a moving conveyor system adjacent to the cutter wheel and is transported to the haulageway.

Self-advancing hydraulic jacks, with large surface areas at the base and top and capable of supporting a significant portion of the overburden load, are emplaced in offset fashion in at least two rows a few feet back of (toward caved zone) the cutter wheel-conveyor system. One row of jacks is retreated at a time to keep pace with the retreating face as more and more cuts are made. The immediate roof normally caves behind the second row of jacks; caving into higher strata occurs every 50 feet or so, depending on the strength of these higher strata. As in room-and-pillar mining, overburden stresses are transferred ahead of the mining face and are transferred to chain pillars on the haulageway-aircourse systems when the caving occurs; but, under the longwall method, caving is enhanced because there are no obstructions to partially support the roof; all the coal within the panel is removed.

One drawback with the longwall method is that it is difficult to mine the chain pillars along the haulageway-aircourse entries, whereas, under the room-and-pillar method, they can be extracted or at least partially extracted along with the coal in the adjacent room-and-pillar operation. If the chain pillars are not removed, abutment stresses increase in the pillars until they fail. Sometimes failure is passive by fracturing and crushing. At times, however, large amounts of strain energy are stored in the hearts of some pillars until they finally fail spontaneously and very explosively or, in other words, bump; air blasts, flying coal, and seismic waves created by the bump can endanger the lives of miners or damage mining equipment.

One possible solution to this problem, a solution suggested by John Peparakis, former manager of the Kaiser Steel Corp. Sunnyside mines, may be to drive a wider single entry instead of two or three and partition it in the middle with a strong, but yieldable, airtight barrier, and use the updip corridor for haulage and incoming air and use the other for return air circulation. Then, as abutment stresses increase behind the retreating longwall face, the partition would yield to an equilibrium condition but would not explode. However, problems of mine safety and ventilation could make this procedure untenable.

## Geologic and topographic controls on mining

### General

Whenever mine openings are excavated, the state of stress existing in the surrounding rock mass is disrupted to some degree. Vertical and lateral stresses resulting from overburden load, and any tectonic stresses present, cannot be transmitted across mine openings, but rather are redistributed around them. Also, because of this redistribution, the stress components, particularly the lateral stress components, tend to become more nearly parallel and perpendicular to the axes of the mine openings. As more and more openings are driven and as the openings are widened, as in areas where coal is being extracted, a larger and larger part of the stress field in the surrounding rock mass is affected.

Strain is the mechanism by which the stresses are redistributed. It may take the form of rock creep, of shear and tension fracturing, of slippage along preexisting discontinuities, or of some combination of these. If the fracturing or slippage is sudden, a violent rock burst or coal bump may endanger miners or damage mine equipment or mine structures in any nearby mine workings. The strength of the rock mass above and below the coal bed that is being mined and the overburden load and overburden configuration, therefore, govern the mining methods and mine layout that will be the safest and most productive.

The strength of the rock mass near mine workings affects the success of a mining operation in two conflicting ways. The rocks in the roof and floor of mine workings must be strong enough, with the aid of artificial support such as rock bolts and timbers, to support the mine openings until the coal can be mined. On the other hand, the rocks above the coal bed must also be weak enough to yield and to cave after the coal has been extracted before too large an opening is produced, or the stresses will concentrate in the rocks or on coal pillars near the mined-out area and cause rock bursts or bumps.

The amount of energy released in a given rock burst or bump can be estimated by measuring the frequency and amplitude of the seismic wave it generates, and seems to depend on the strength of the rock mass. Nearly all the tremors that have sufficient energy to be received by three or more network stations in the Sunnyside district occur a few hundred to a few thousand feet away from, or below, the nearest mine workings. By contrast, even the most violent bumps in coal or rock adjacent to mine workings commonly are recorded as very small amplitude events on the seismograms, probably because the rocks are much stronger in their undisturbed state at some distance away from mine workings than they are near the mine workings.

The confining pressures away from the workings are high, and any existing fractures probably are tightly closed. Large amounts of strain energy can therefore be stored before the rupture limit is reached. Coal and rocks near the mine opening, on the other hand, commonly display open fractures and are under much lower confining pressures because of the adjacent cavities. Consequently, rupture occurs at much lower strain energy thresholds near mine openings than in the solid rock mass. Much of the energy released by a bump occurring near mine openings may also be absorbed within the openings, whereas nearly all the energy generated from a bump within the rock mass under high confining pressures is radiated in the form of seismic waves.

Overburden thickness and distribution

The rugged topography above the mine workings greatly affects mining safety and productivity. In areas of uniformly thick overburden, somewhat uniform stress conditions prevail. However, in this area where local relief is great and overburden is thick under ridges and thin under valleys, local stress concentrations are caused by the gravitational part of the stress field. These stress concentrations appear to be greater than those produced under uniformly thick overburden. This is probably because lateral support in the overburden is reduced by the canyons from what it would have been under uniform loading, and load-carrying capacity of compression arches that normally form over the mine workings is therefore reduced. A greater stress can therefore occur in the mine workings under ridges than under uniform overburden of equal thickness.

Mine deformation problems generally are greater under ridges, particularly where overburden is more than 1,500 feet. Pillar-and-roof deformation seems to increase abruptly at the 1,500-foot overburden cover line (Joseph A. Harvey, oral commun., 1966). Maps showing overburden thickness and configuration, active and inactive mine workings, and structural data in the mine workings of the Sunnyside district are published at a scale of 1:6,000 (Osterwald, 1961; Osterwald and others, 1969; Dunrud and Barnes, 1972).

Structural controls on mining practices

The strength of the rocks above and below the coal bed is governed by their lithology and by the depositional and deformational structural features they contain. Bedding, crossbedding, contorted bedding, differential compaction features, and certain relic organic features (Maberry, 1971, p. 37-41) comprise the depositional and structural features that influence rock strength. The style, attitude, and areal distribution of faults and joints present in the rocks also are important controlling factors on rock strength. Mineral composition, type of cementation, and texture of the individual rock units, however, probably are the most important controls on rock strength.

The distribution, attitude, and types of faults also play a major role in mine layout in the various mining areas of the district. North of the Sunnyside No. 2 mine main haulage slope, faults are less common, and those that do occur near mining areas commonly parallel the strike of the coal bed. In this setting the main haulageway-aircourse slopes and raises can be positioned so that optimum blocks of coal are mined from them. Also, because of this structural integrity, coal can be developed and extracted directly off the slopes and raises. Double entries are driven nearly perpendicular to the main slopes and raises in both directions at 300- to 600-foot intervals. Rooms and crosscuts or longwall faces are cut between these temporary haulageway-aircourse entries, and the coal is extracted on the retreat to within 300 to 400 feet of the main slope or raise (figs. 3-10), so that a barrier is left to protect the main haulageway-aircourse systems from local stress concentrations created by extraction.

This method of extracting directly off the main slope or raise is very efficient, as virtually no blocks of coal are left, except for a few portions of chain pillars between the haulageway-aircourse entries that became too highly stressed to mine. Not only is a large percentage of the total coal mined, but the resulting stress pattern is simplified because the number of barrier pillars, and consequently pressure points, is kept to a minimum.

South of the main haulage slope of the Sunnyside No. 2 mine the structural conditions change rather abruptly, and the efficiency of mining directly off the main slope is greatly reduced. As the Sunnyside fault zone widens, the strike of bedrock units changes to a more southerly direction in the southern part of the No. 2 mine and in the northern part of the Columbia mine. This creates a divergence of 20°-45° between the strike of bedrock units and the trends of individual faults within the zone (figs. 3-10). Therefore, the entries on haulage grade intersect the faults at about this angle. This combination of profuse faulting and mine workings divergent from faults has created very severe stress problems and hazardous mining conditions and contributed to the closing of the Columbia mine in May 1967 and to the suspension of mining in the southern part of the No. 2 mine in October 1970. Coal bumps, rock bursts above and below the mine workings along nearby faults, and sudden roof falls were common.

The main haulageway-aircourse levels of the Columbia and Geneva mines comprise four or five entries and are driven on grade at right angles to the main slope haulageway at 1,000- to 2,500-foot intervals.

Oblique-angle crosscuts connect the individual entries at 100- to 200-foot intervals. Solid coal barrier pillars 200-300 feet wide are left on either side of the levels to protect them from overburden stress concentrations during coal extraction. Barriers 200-600 feet in width are left on either side of the main slopes. To develop and extract the blocks of coal between these levels, three-entry raises are driven updip from one level to the next higher level at intervals of 500-2,000 feet, depending on the spacing, trend, and amount of displacement of faulting. The raises are usually positioned so that the coal between two faults can be extracted in two directions perpendicular to the raises. Double-entry haulageway-aircourse entry systems, which are similar in geometry and spacing to those driven directly off the main slopes or raises in the Sunnyside mines, are then driven on haulage grade at right angles to these raises at 300- to 400-foot intervals (figs. 3-10). Beginning at the boundary of the block to be developed, rooms and crosscuts averaging about 20 feet in width are driven in the coal between these double-entry systems, and the remaining coal pillars are extracted on the retreat.

In the southern part of the Sunnyside No. 2 mine and in the northern part of the Columbia mine, where the Sunnyside fault zone transects much of the mine workings, the geologic and topographic setting is generally similar (Osterwald and others, 1969). In this setting, mining was hazardous under either mine layout. However, the layout employed in the Columbia mine--that of mining off barrier-protected levels--afforded an extra measure of protection on the main haulage track. Not only were overburden stresses excessive due to the numerous faults in the rock mass above and below the mine workings, but it was virtually impossible to leave adequate protective barrier pillars adjacent to each fault and still mine an economically feasible block of coal because of the angular discordance between haulageways and faults.

Perhaps even worse mining conditions were encountered in the highly faulted southwest part of the Columbia mine and in the northern part of the Geneva mine, where a system of moderately dipping, east-trending, normal faults form horst and graben structures where the Sunnyside fault zone passes to the east of the mine workings. In this part of the Columbia mine, abrupt changes in direction and amount of displacement of the faults in short lateral distances caused abrupt changes in the strike and dip of the coal bed (Dunrud and Barnes, 1972). Miners driving haulageways on grade were forced to change directions abruptly as they crossed many of the faults. Coal production was commonly limited to that mined when the entries were driven. Very few pillars could be extracted before various types of mine deformation hazards forced miners to retreat. Also, a slow but inexorable closing of the mine openings, called a "squeeze," developed as the miners retreated northward along the main level to the main haulage slope.

Southward in the Geneva mine, the influence of faults on mining conditions is less severe. Displacement across most of the faults is more uniform and predictable than in the northernmost part of the Geneva mine, except near the strike-slip fault in the northeast part of the Geneva mine (figs. 3-10), where local imbrications and abrupt variations in displacement reduced the strength of the rock mass and caused abrupt changes in attitude of the coal bed. In the southern part of the mine a competent sandstone unit, which thickens southward and occurs a few feet above the main coal bed, ultimately caused some large and dangerous bumps in coal pillars. A thin coal bed and weak shales and siltstones a few feet thick occur between the competent sandstone and the main coal bed. Roof falls, involving the weak material, were common and forced miners to retreat before the pillars could be completely extracted. This, in turn, prevented the competent sandstone and higher rocks from caving and, as mining progressed and the uncaved span increased, abutment stresses increased on adjacent mining areas until large bumps occurred. These bumps were particularly severe and damaging when they involved larger blocks of coal that had not yet been cut up into normal pillar size.

Geologic and topographic conditions are therefore key factors to consider in planning the safest and most efficient mining methods. Production costs and schedules, however, may dictate some compromises in mine layout and mining methods for the mining operation to be practical. For example, mine access portals are usually located in the coal bed near canyon bottoms, where they are most accessible to a railroad (figs. 3-10). The trends of the main haulageway-aircourse systems are controlled by the strike and dip of the coal bed. Slopes and raises are driven roughly parallel to the dip of the coal bed (figs. 3-10). Haulageway-aircourse levels are driven on grade both ways from the slope or raises in a direction subparallel to the strike of the coal bed. Therefore, the orientation of the mine workings normally varies as the strike of the coal bed varies.

## Relation between seismic activity, mining, and geology

New insight on how mining methods influence the pattern of seismic activity near mine workings was attained during 1970. For the past 7 years the short-term, cyclic-activity pattern clearly seemed to be related to periods when the various mines were producing coal. The daily tremor rate generally increased during the work week and decreased during idle periods (figs. 1, 2; Dunrud and others, 1970; Barnes and others, 1969; Osterwald and Dunrud, 1966; Dunrud and Osterwald, 1965). The long-term, less regular pattern, however, was thought to be the result of a complex combination of mine-induced stresses and natural stresses, although the tremor rate often declined markedly whenever the mines were idle for extended periods (see also fig. 1).

Recent studies of daily mining reports for 1969 and 1970 for the Sunnyside mines reveal that both mining methods and the geologic conditions control the level of seismic activity near actively mined areas. In other words, the tremor occurrence pattern seems to correlate not only with the amount of coal produced but also with how and where the coal is produced. Furthermore, these studies reveal that the longwall method of mining--which enables three to more than five times more coal per miner to be produced in a given time interval than the room-and-pillar method--caused less seismic activity during 1969 than the room-and-pillar method, even at much higher production rates.

The periods of active mining in the various mining sections in the Sunnyside mines were plotted on the daily tremor-frequency histograms for the Bear Canyon seismometer station (fig. 1). The tremors are plotted as two separate histograms, one showing the total number of tremors per day and the other showing the number of larger magnitude tremors per day. Although many periods of active mining in the various sections overlap, mining in some sections appears to raise the level of seismic activity significantly, while mining in other sections does not. For example, the periods when the overall daily tremor rate was relatively high during the first half of 1969 coincide very closely with periods of room-and-pillar mining in 13th and 14th Right sections of the Sunnyside No. 1 mine (13R CM and 14R CM on fig. 1), whereas periods of high coal production from the 12th Left longwall section (12L LW on fig. 1) did not significantly affect the level of activity. Also, the level of activity markedly declined when mining ended in 13th and 14th Right in November and December 1969.

Mining in the 2d and 3d North (2N CM and 3N CM on fig. 1) during the first half of 1969 was limited to the driving of two haulageway-aircourse entries and probably did not induce significant stress readjustments, at least it did not increase the level of total seismic activity. Room-and-pillar mining in the 1st North section (1N CM on fig. 1; 1N on figs. 3, 4) also did not increase the total seismic activity but did apparently cause some larger magnitude tremors in the rock mass of the raise area (figs. 3, 4).

The activity peak in the last quarter of 1969 seems to have at least four room-and-pillar contributors; 13th and 14th Right and 12th Left (12L CM on fig. 1, 12L on fig. 6) and 7th Right in the No. 2 mine (7R on fig. 6). A locally weak floor in the 12th Left longwall section forced management to remove the longwall equipment and to install room-and-pillar mining equipment during October 1969. The total seismic activity increased from October 25 through November 2, while room-and-pillar mining was conducted. By January 1970 the longwall equipment could again be installed. Coal production then increased markedly and the seismic activity again declined. Bumps were reportedly very intense in the 7th Right section within the

Sunnyside fault zone of the Sunnyside No. 2 mine between September 23 and October 6, 1969. This coincides with a period when a record number of tremors were recorded at the Bear Canyon seismometer station (fig. 1).

Seismic activity was only moderate during the first quarter of 1970 but appears as a peak because of the very low activity level that was recorded for the remainder of 1970 (of course, during much of the period April-December the recorded activity may have been low because of recording problems). This peak corresponds to longwall mining either in the 12th Left section or in the 3d North section when mining was on a two-shift-per-day basis. The activity decreased when mining ceased in the 3d North or when mining increased to three shifts per day in the 12th Left. In contrast to the very high level of seismic activity and the hazardous mining conditions that existed when the 7th Right of the Sunnyside No. 2 mine was being mined, room-and-pillar mining in the adjacent 9th and 11th Right sections, which are also within the Sunnyside fault zone, was reported to be relatively safe and efficient and apparently did not raise the level of seismic activity.

Coal production records are not available for the Geneva mine, so detailed correlations between active mining sections and their effects on the local seismic activity were not made. However, seismic activity generally increases near or within active mining areas where mine deformation problems are particularly severe, at places where, because of either geologic conditions or mining activity, stress concentrations are intense. Within the faulted graben in the northern part of the Geneva mine it was particularly difficult to maintain the proper sequence of pillar development and pillar extraction because the overburden, weakened by the faults, caused excessive stresses to accumulate before the coal pillars could be reduced to a yieldable dimension. Bumps and hazardous roof falls commonly were the end result. Within the faulted graben in the southern part of the Geneva mine, the barrier pillars, on either side of 1st level South (1S on figs. 3-10), were mined as a final stage of mining on that level during 1968 through much of 1970. Some of the most damaging bumps in the district occurred because these heavily stressed barrier pillars, which formed abutment zones and supported much of the overburden, were cut up and removed.

The occurrence pattern of the larger magnitude tremors (larger than 1.5 on the Richter scale) during most of 1969 and 1970 generally correlates with mining activities as the total seismic activity does with the mining activities (figs. 1 and 2, see uppermost histogram). However, the larger magnitude tremors were at a moderate level during the last week of September and the first week in October 1969, when the total seismic activity was at or near a 7-year high. These larger tremors, however, were clustered in the Sunnyside No. 2 mine, where room-and-pillar mining conditions were very severe because of the presence of numerous faults.

In 1969 and 1970, as well as during the previous 7 years of recording, the larger magnitude tremors originated near active mining areas where mine deformation problems were severe, for either geologic or mining reasons, or for a combination of these reasons (see the summary of seismic activity by quarter in the appendix, also figs. 3-10, for more details). In addition to those tremor hypocenters that occurred near the 1st North room-and-pillar area in the Sunnyside No. 1 raise area during the first half of 1969 (figs. 3, 4), most of the larger magnitude tremors during the remainder of 1969 occurred in: (1) the right side of the Sunnyside No. 1 mine, (2) the right side and main slope area of the Sunnyside No. 2 mine, and (3) the northern part of the Geneva mine (figs. 3, 4, 5, 6).

During the first half of 1970 (figs. 7, 8), most of the larger magnitude earth tremors which originated in the Sunnyside No. 2 and Geneva mine areas occurred in the same general areas as in 1969, except that many also occurred in the southern part of the Geneva mine near active mining areas of 1st and 2d levels South during the first quarter of 1970 (1S and 2S on fig. 7). In the Sunnyside No. 1 mine, however, the tremors decreased in the right side but increased markedly in the raise area near the 2d and 3d North longwall sections (2N and 3N on figs. 7, 8). The decrease on the right side correlates with completion of room-and-pillar mining in 13th and 14th Right in November and December 1969. The increase in the raise area correlates with violent and explosive failure of chain pillars in 2d and 3d North haulageways which were overstressed because they formed the abutment zones that carried much of the overburden load across the mined-out areas (John Peparakis, oral commun., 1972). Violent bursts occurred in the chain pillars during this time, but apparently there were no hazardous bumps near the longwall faces. A double row of large chain pillars was left behind the retreating longwall face in most of 2d North and in the first 700 feet of 3d North, and they were capable of storing large amounts of strain energy.

During the last half of 1970, a period when the recording system was functioning below peak efficiency, large-magnitude earth tremors ($M > 1.5$) were again common in the raise area of the Sunnyside No. 1 mine, because of chain pillar failure, but were fewer than in the 1st quarter of 1970; they also increased near the Sunnyside fault north of old mine workings and west of the 12th Left and 13th Left (12L and 13L on figs. 9, 10) longwall sections. In the Sunnyside No. 2 mine, the tremors declined markedly in the 3d quarter of 1970 and stopped almost completely during the last quarter of 1970 as mining moved east of an intensely faulted zone and then was suspended completely on the right side on October 10 (fig. 1). Tremors continued to emanate from within the north graben beneath the Geneva mine through the last half of 1970, even though mining was completed there in late 1969.

Most of the larger magnitude tremors that originate in the Geneva mine area occur many thousands of feet below the elevation of the mine workings, although some tremors originate near and even above the mine workings. In contrast, the larger magnitude tremors commonly originate near the elevation of the mine workings in the Sunnyside mines. The deep-seated releases of strain energy in the Geneva mine area and to some extent in the southern part of the Columbia mine area may occur because mining stresses influence more of the rock mass if it is cut by moderately to gently dipping faults than if it is cut by steeply dipping to vertical faults.

## Design suggestions

### General

Based on the geologic, mining, and seismic studies conducted by the U.S. Geological Survey in the Sunnyside mining district to date, some suggestions regarding (1) design of mine workings, (2) the utility of the longwall method of mining, and (3) possible ways to reduce mine deformation problems are summarized below, so that the safety and efficiency of future coal-mine development and production might be increased. The findings on design or layout of mine workings and on methods of mining most suitable for a particular geologic and topographic setting probably apply to areas where only a single coal bed is mined in a geologic setting similar to that of the Sunnyside district. The conclusions on bump prediction, however, are perhaps restricted to the Sunnyside district. Geology and topography are key factors in projecting engineering-geologic information from one mining area to another.

### Mine design

The geometry and spacing of mine workings in a new area should be designed on the basis of (1) overburden load and configuration; (2) strength of the rock mass above, and less importantly below, the coal bed to be mined; (3) occurrence and distribution of faults and joints; (4) possible tectonic stresses; and (5) convenience of access of mine haulage portals to a high-capacity haulage facility. A detailed geologic map on an up-to-date topographic base at a scale of at least 1:12,000, which also portrays information on overburden and on the tensile, shear, and compressive strengths of the major rock units and the coal, will help provide information on which to base comprehensive mining plans. In situ stress measurements should help determine whether or not tectonic stresses are present and should be incorporated in the mine design. A drilling program based on, and supplementing, the surface geologic data should then follow, to determine the thickness, lateral extent, and position of the coal in the total area to be mined.

Mine portals, main haulageway-aircourse systems, and coal extraction panels can then be laid out so that areas where the strata are weakened by faults, are locally warped by tectonic forces, or where the coal is cut out by faults or stratigraphic changes (wants) can be accommodated in the mining plans without undue loss of mining safety or efficiency. An accurate overburden-thickness map can be constructed from the topographic base map and structural contours of the top of the coal bed. Mining plans can then incorporate optimum dimensions of pillars, in room-and-pillar areas or along haulageway-aircourse systems, that will yield without storing large amounts of strain energy but will sustain mine openings until the coal can be extracted.

Comparison of the longwall and room-and-pillar methods

Geologic and seismic studies in the Sunnyside No. 1 mine indicate that in this area, where the coal is underlain by strong sandstone and overlain by relatively weak roof rocks, the longwall method of mining--a method whereby 3 to more than 5 times more coal can be mined per man than by the room-and-pillar method--causes less seismic activity, produces much higher tonnages of coal, and allows recovery of a greater percentage of the total coal reserves of an area than if mined by the room-and-pillar method. This is particularly true in areas where the rocks in the immediate roof are weak or where overburden thickness exceeds 1,500-2,000 feet. Probably this is because the coal is extracted completely in one operation and caving is therefore enhanced, whereas, with the room-and-pillar method, pillars are developed and extracted in basically two different steps.

In addition, with the room-and-pillar method, if the roof rocks are weak and roof falls become a hazard before pillar extraction is complete, miners may be forced to retreat before all the pillars are extracted. Caving of the higher strata thus is retarded by the partial supports left, and abutment pressures increase on the pillar line and on the solid coal being developed to a level where violent bumps and sudden roof falls may occur in the area being developed. The longwall support system of en echelon, self-advancing jacks, on the other hand, is specifically designed for mining under weak roofs. The rear row of jacks also serves as an effective breaker line that further induces caving behind them.

The longwall method may be the solution to the problems encountered within highly faulted areas like the Sunnyside fault zone. Coal extraction panels reportedly can be laid out obliquely to the strike and dip of the coal bed without significantly reducing the safety and efficiency of the method (John Peparakis, oral commun., 1972). Longwall sections could be developed between individual faults, with the faces perpendicular to the faults of the Sunnyside fault zone. Barrier pillars could be left adjacent to each fault, protecting the longwall section from high stresses. The basic problem with the room-and-pillar method--the problem of divergent haulageways, rooms, and crosscuts to faults--could thus be eliminated. Of course, this may be economically feasible only where the faults were spaced at least 400 or 500 feet apart.

Longwall equipment, however, is very expensive and once installed is less adaptable to structural and stratigraphic changes than the room-and-pillar method. Detailed geologic information is therefore particularly important in areas where the longwall method is under consideration. Coal beds thicker than about 8 feet normally cannot be extracted in one cut, but techniques such as making two cuts on a high coal face before retreating the cutter wheel-conveyor assembly or cutting very thick beds with high-pressure water jets reportedly are being utilized in parts of Europe and Canada (John Peparakis, oral commun., 1972). Also, because chain pillars in the haulageway-aircourse systems adjacent to the longwall panels are not mined as the longwall face retreats, abutment stresses commonly increase until the pillars fail either passively or violently. This problem was experienced in the Sunnyside No. 1 raise area during much of 1970. However, this problem might be solved by driving a single entry wide enough so that it can be partitioned off into two entries with a strong but yieldable and airtight support. The updip entry thus formed can be used for mine haulage and incoming air, the other for return air circulation and mine water.

Longwall mining in a coal bed above or below another coal bed that was incompletely mined out by the room-and-pillar method in prior years can pose severe stress problems. A longwall was installed in the northern part of the Sunnyside No. 3 mine during 1963 beneath old room-and-pillar mine workings which were only partially mined. Much of the overburden stress was concentrated on the remaining pillars. The longwall face often bumped violently as it passed under these pillars. Bumps on a longwall face are particularly hazardous and damaging because the men and equipment are concentrated in a narrow zone between the face and the caved area. One bump in late 1963 was so violent and damaging that the area was abandoned.

The longwall method of mining can be ineffective in areas where the coal bed is underlain by weak rocks. When this condition exists, the bases of the self-advancing jacks tend to penetrate the weak floor and render the support system inefficient. In certain cases, however, the bearing surfaces of the bases can be increased to again be effective and more efficient than a room-and-pillar operation under the same conditions.

Possible ways to reduce mine deformation problems

Possible prediction of bumps and other types of hazardous mine deformation, such as roof falls and squeezes, is one of the most important aspects of the geologic and seismic studies. In general, the local seismic activity that is related to mining is a measure of the relative safety and efficiency of mining activities in a given geologic setting. Bumps are more frequent in mines when the earth tremors increase in abundance and magnitude than when the seismic activity is low. In fact, during the first few years of the study in the Sunnyside district it appeared that we could predict general areas of a mine where a bump would most likely occur within the time span of a few days on the basis of time-space patterns of seismic activity, and we did so a number of times. Mine management was alerted when the earth tremors suddenly increased in number and magnitude and began to concentrate in particular mining areas. Within a few hours to a few days after the sudden increase in seismic activity, violent bumps were reported in the areas where the increased seismic activity originated.

This correlation between sudden increases in seismic activity and violent bumps seemed valid during the first few years of the study, particularly in the northern part of the district. During the mid-1960's, however, it appeared as though either the correlation was not as definitive or that mine management could significantly reduce the bump hazard or stop the violent bumps completely by taking corrective measures in their mining procedures after notification of an increase in seismic activity. Various mining men reported (oral commun., 1967-70) that bump hazards could be reduced in some active mining areas that were vulnerable to violent bumps because of faulting, weak roof, or high overburden during periods of increased seismic activity by taking corrective measures that would enhance the transfer of overburden stresses from the pillar line or longwall face to solid coal.

In room-and-pillar mining sections the stresses were reduced by the occurrence of substantial caving over mined-out areas--if a greater percentage of the pillars were extracted and if the width of the area being developed ahead of the extraction area were minimized. In room-and-pillar sections where the roof is too weak to remain stable until the pillars can be extracted, a change to the longwall method may increase safety and productivity and also reduce bumps and related bursts. In longwall or room-and-pillar sections where the roof is too strong to cave at the gob line, caving can often be enhanced by orienting the face parallel to the trend of a prominent set of joints which commonly occurs parallel to the dip of the coal bed. If the joints are exceptionally numerous and prominent, the pillar lines or longwall faces should perhaps be oriented at slight angles to this joint trend to reduce sudden roof releases along these joints.

Sudden and violent releases along joints in a sandstone roof above longwall faces--called "mountain shots"--were reported from the Ruhr region in Germany (Ende, 1929). These releases seemed to be more common when the longwall faces were oriented parallel to the direction of joints; however, the geologic setting and stress field are quite different in the Ruhr region where more coal beds are present and they have a steeper and more variable attitude than in the Sunnyside district.

Seismic activity probably is a better measure of the safety and efficiency of room-and-pillar mining than it is of longwall mining, because much seismic activity can be generated from explosive failure of chain pillars on haulageways at considerable distances from the longwall face, as occurred in much of 1970. Bumps on the longwall face were rare, however, in 1970, although the explosive failure of chain pillars at times advanced to chain pillars that were too close to the longwall face for comfort.

Bump prediction on the basis of increases in seismic activity was somewhat tenuous during 1967 through 1970. On October 24, 1967, where the barrier pillars in the southern part of 1st level South of the Geneva mine were being mined, an extremely violent bump occurred only 30 minutes after a sudden increase in tremor rate and magnitude began (Dunrud and Barnes, 1972). The bump occurred before enough tremors were recorded to reveal a recognizable pattern, and the pattern was only recognized as significant many hours after the bump had already occurred. On February 20, 1970, however, another violent bump occurred, while barrier pillars on 1st level South were being mined in a different structural setting, about 18 hours after an increase in the seismic activity--a pattern that fits the patterns noted in early years of recording, particularly in the northern part of the district. At other times during 1969 and 1970 the tremor rate and magnitude increased in both the Sunnyside and Geneva mine areas and no violent bump followed, although smaller bumps--still potentially dangerous to an individual--were perhaps more frequent than during periods when the activity was low.

Prediction of roof falls on the basis of seismic activity patterns is more tenuous than bump prediction, although, as was pointed out previously, in some room-and-pillar sections roof falls and bumps are interrelated. In these sections, where mining is proceeding under weak roof strata, shear failure can occur above the pillar ribs, creating a fracture which reduces the continuity of the roof so that falls occur. Miners then are forced to retreat. Caving in higher strata is thus retarded, because the pillars left behind support the overburden. Abutment stresses build up in the development area and on the pillar line until shear failures occur above the pillar ribs in the development area and roof falls begin there as well. Bumps then may occur in pillars of the development area and in the strata above the development area, which in turn increases the seismic activity of the area. The seismic energy produced from these bumps also can trigger further roof falls in the area of active mining.

Roof falls which occur rather sporadically along the major haulageway-aircourse systems probably are not related to patterns of seismic activity except that they might be finally triggered by seismic waves. These falls occur along entries, slopes, or raises, usually where more than three individual entries are driven, and also at intersections of entries and crosscuts where the roof area is largest and where the roof is weakened by numerous joints and (or) by the presence of primary structural features such as crossbeds, contorted beds, and relic animal tracks, burrows, and casts of remains. This type of roof fall can be decreased by reducing the width of individual openings, particularly at the intersections, and by reducing the number of individual entries on the major haulageway-aircourse systems. Of course, ventilation and fire safety also must be considered.

Squeezes--the predominantly passive failure of coal pillars in active mining areas or along haulageway-aircourse systems that tend to close the mine openings--are controlled primarily by the overburden stress plus any tectonic stresses active in the area and by the size, geometry, and spacing of the coal pillars. A squeeze occurs when the overburden and active or residual tectonic stresses exceed the ultimate strength of the pillars. Faults can change the distribution of these stresses and thus control the location of squeezes. Many areas which may be particularly susceptible to squeezes can be determined by underground studies coupled with studies of mine maps and maps showing overburden thickness and configuration and faults.

Mine workings that are developed under deep cover and are located between faults are susceptible to squeezing, because the overburden stresses may not bridge across the faults, but rather ride with full force upon the mine workings. A potential squeeze condition of this sort can be reduced or eliminated by (1) leaving large, solid coal barriers adjacent to the faults to act as a strong abutment zone for the overburden stresses; (2) developing entries and rooms with greater than normal spacing, so that the remaining pillars are large enough to support much of the load until the pillars are extracted; and (3) keeping the number of developed rooms ahead of the extraction area to a minimum.

## Conclusions

Surface and underground geologic and mining studies and surface seismic studies in the Sunnyside mining district have shown that bumps, fracture failure, and creep or plastic flow associated with stress changes in the rock mass caused by mining can be controlled to a certain degree and made less hazardous if the mine layout and mining method are tailored to the local geologic and overburden conditions in the district.

Mine openings cause changes in the natural stress field in the surrounding rocks. As the mine openings are widened or extended, more and more of the rock mass is affected. Strain--in the form of creep or plastic flow, fracturing, or sudden and often violent rupturing of the coal or rock--is the mechanism that effects these stress changes. The type of strain is dependent on the strength of the rock mass or individual rock units, the magnitude and rate of change of the stresses, and the confining pressure at which the stress changes are taking place. Geologic, seismic, and laboratory studies indicate that the strain releases are more likely to be sudden and violent if the magnitude and rate of change of stress are high and occur under high confining pressures (Osterwald and Dunrud, 1966).

Mining can therefore be made safer, and consequently more efficient, if the mine workings are designed so that stresses are dispersed rather than concentrated near mine workings, and if the pillars, in the case of room-and-pillar sections, are made small enough to yield without storing large amounts of strain energy but large enough to prevent a squeeze. Since the strength of the individual rock units, as well as the strength of the rock mass, plays such a vital role in the type and severity of strain that may occur around active mining sections, a detailed lithologic and structural map and a separate or composite overburden thickness map are invaluable in the designing of mine workings and in determining which mining method will be the safest and most productive.

Based on mining and seismic studies to date, the longwall method of mining, a method relatively new in this country but used for many years in other countries, shows much promise in certain faulted areas, in areas of thick overburden, in areas of weak roofs, or in some combination of these conditions. Coal-production records show that the longwall sections in the Sunnyside No. 1 mine produced 3 to more than 5 times more net tons of coal per man per unit time than the room-and-pillar sections produced in equivalent geologic settings, and at the same time created considerably less seismic activity per unit time, except during periods of chain-pillar failure. The longwall method also may be particularly effective within faulted areas where the room-and-pillar method produced many stress problems because the rooms were necessarily laid out at oblique angles to the faults which trend at angles to the strike of the coal bed. Longwall faces may be positioned perpendicular to and between two individual faults of a faulted area, leaving a protective coal barrier adjacent to each fault. This, of course, requires a very detailed knowledge of the geometry and spacing of the faults in the area. It perhaps requires surface drilling and underground exploration at the mine level in addition to detailed surface geologic mapping before committing expensive longwall equipment to an area. The coal probably can be produced safely and more economically from longwall than from room-and-pillar mining if the distance between two faults is more than 500-600 feet; if the distance is less than 400-500 feet, the operation might be marginal, at best, from an economic standpoint.

On the basis of the pattern of seismic activity in some mining areas, it has been possible to forecast bumps that occurred in the same areas within a time span of a few days on a number of occasions. During the last few years, however, there were periods when the tremor rate and magnitude increased near an active mining area and then decreased again, and no violent bump was reported. Most of the earth tremors of magnitude greater than 1.5 originate hundreds to thousands of feet from active mining areas, at locations where the confining pressures are large enough to store the large amounts of energy necessary to generate such tremors. Bumps can be triggered in overstressed pillars and gob lines near active mining sections by the seismic energy radiated from the hypocenters of these larger magnitude events. If, however, precautionary steps are taken in active mining areas by cleaning up stumps, which promote caving, and by minimizing the development area ahead of the pillar line, violent bumps may be reduced or eliminated. Management, on occasion, probably has prevented serious bumps by following these precautionary measures after being alerted to an increase in seismic activity.

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## Appendix

### Summary of the patterns of seismic activity and their relation to geology and to mining by calendar quarter

### A. Summary for 1969 (figs. 3, 4, 5, and 6)

First-quarter seismic activity (fig. 3):

Sunnyside No. 1 mine area.--Most tremor hypocenters were concentrated in two parts of the mine near active mining areas--the 1st North room-and-pillar section (1N) and the 2d North (2N) longwall section off the raise and near the 13th Right (13R) active mining section. All tremor focal depths were near the elevation of the mine workings, which ranges between 6,000 and 7,500 feet above sea level.

Sunnyside No. 2 mine area.--Tremor hypocenters were clustered near or along branch faults of the Sunnyside fault zone, around the barrier pillars adjacent to the main haulage slope, or around the 7 Right and 9 Right (7R and 9R) room-and-pillar active sections. Most tremor foci were near the elevation of the mine workings, which ranges from 6,200 to 7,000 feet above sea level.

Sunnyside No. 3 mine area.--No larger magnitude tremors occurred in this area.

Columbia mine area.--The mine has been closed since May 1967. One tremor originated about 2,000 feet below the west end of the 7 East (7E) main slope. The mine workings range in elevation from 5,800 to 7,000 feet above sea level.

Geneva mine area.--Tremor hypocenters were concentrated 2,000-6,000 feet beneath 1st level North (1N) and the northern part of 1st level South (1S), and within the graben in the northern part of the mine. A few tremors originated near the northwest-trending strike-slip fault and near the easternmost limit of the Sunnyside fault system. The mine workings range in elevation from 5,400 to 7,000 feet above sea level.

Second-quarter seismic activity (fig. 4):

Sunnyside No. 1 mine area.--Tremor hypocenters were again concentrated in two general sectors near the active room-and-pillar and longwall sections in the raise area and near the 13th and 14th Right (13R and 14R) active sections, but were also distributed as much as 7,000 feet east-northeastward from the 13th and 14th Right sections along a belt 1,500-2,000 feet wide. All tremor foci that originated near the map location of the mine workings were located near the elevation of the mine workings. Six of the 16 tremors east of the mine area originated 2,000-4,000 feet above sea level, the remaining 10 between 4,000 and 6,000 feet above sea level.

Sunnyside No. 2 mine area.--The distribution of tremor hypocenters was similar to that of the 1st quarter, except that the grouping was more diffuse--ranging farther eastward and westward from the active room-and-pillar mine workings.

Sunnyside No. 3 mine area.--Tremor hypocenters were located near or along barriers adjacent to haulage slopes or in mined-out areas. All were near the elevation of the mine workings. No larger magnitude tremor originated near the active mine workings.

Columbia mine area.--Six of the seven tremors originated near or along faults in the southern part of the mine, probably in response to stresses induced by mining in the Geneva mine. The tremor hypocenters plot from points near the elevation of the mine workings to as much as 6,000 feet below them. The remaining tremor originated 4,500 feet west of the nearest mine workings near an east-trending normal fault.

Geneva mine area.--All 18 tremors originated in the northern part of the mine near faults or to the east of the northern part of the mine. Tremor foci ranged from near the elevation of the mine workings to as much as 6,000 feet below them.

Third-quarter seismic activity (fig. 5):

Sunnyside No. 1 mine area.--The seismic activity increased in the right side of the slope area and decreased in the raise area in comparison with that of the 2d quarter. Seismic activity continued along an elongate area trending east-northeast of the 13th and 14th Right active mining sections. Focal depths were distributed the same as those in the 2d quarter.

Sunnyside No. 2 mine area.--Tremors originated near the slope barrier pillars, near the 13th Right entry, and along branch faults of the Sunnyside fault system near the elevation of the mine workings.

Sunnyside No. 3 mine area.--Five tremor hypocenters were plotted 1,000-5,000 feet beneath old mine workings in the right side off the main haulage slope. Mining was suspended on August 25, 1969.

Columbia mine area.--Three tremor hypocenters were plotted along east-west-trending faults near the 8 East, 9 East, and 3 East (8E, 9E, 3E) areas but were located 500-5,000 feet below the elevation of the mine workings.

Geneva mine area.--Most tremor hypocenters were clustered beneath the northern part of the mine area within the east-west-trending graben near a strike-slip fault which horsetails and transects the graben. Foci were located 500-6,000 feet below the elevation of the mine workings.

Fourth-quarter seismic activity (fig. 6):

Sunnyside No. 1 mine area.--Most tremor hypocenters were clustered within the right side of the mine, near and east of the 13th and 14th Right active mining sections. A few were scattered around the left side of the mine, and a few were relatively close to the Sunnyside fault. Most tremor foci originated near the elevation of the mine workings.

Sunnyside No. 2 mine area.--Most tremor hypocenters were clustered tightly west of the active mine workings and near or along faults comprising the Sunnyside fault zone, with focal depths ranging from 500 to 5,000 feet beneath the mine workings. Two were located near an east-trending fault near the north boundary of the mine, about 3,000 feet beneath the elevation of the mine workings.

Sunnyside No. 3 mine area.--Four tremor hypocenters were located in the left section of the mine near the boundaries of mined-out areas and solid coal; four originated in the extreme right side of the mine near solid coal pillars and mined-out areas or in old mine workings. Seven foci were near the elevation of the mine workings; one was about 2,000 feet below the mine workings.

Columbia mine area.--Ten tremors originated in the southern part of the mine area, along or near faults and from 2,000 to 6,000 feet below the elevation of the mine workings.

Geneva mine area.--Tremor hypocenters were concentrated in the faulted graben in the northern part of the mine area, north and west of the 2d North (2N) active mining section, as in the last quarter, but also occurred to the south near the northwest-trending strike-slip fault. Most foci were located 2,000-6,000 feet below the elevation of the mine workings, with the exception of one that originated near the map position and elevation of the Horse Canyon tipple.

## B. Summary for 1970 (figs. 7, 8, 9, and 10)

A summary of the patterns of seismic activity and their relation to geology and mining follows. There are two changes in plotting procedure from 1968 (Dunrud and others, 1970) and 1969--the focal-depth range and Richter-magnitude-scale range. Focal-depth ranges are shown on the 1970 maps to within a 1,000-foot vertical interval (as indicated by small pie segment within the epicenter circles on figs. 7, 8, 9, and 10) rather than the 2,000-foot vertical interval that was shown in 1969 (figs. 3, 4, 5, and 6).

First-quarter seismic activity (fig. 7):

Sunnyside No. 1 mine area.--Most of the tremors originated in the raise area in response to violent and explosive failure of overstressed chain pillars along the 2d North and 3d North (2N and 3N) haulageways of the longwall area. The chain pillars were of conventional room-and-pillar size (50 feet X 80 feet or 50 feet X 100 feet) and hence were capable of storing large amounts of strain energy before failing. Also, there were two rows of these pillars along most of 2d North and along the first 700 feet of 3d North, where a three-entry haulageway-aircourse system was tried. Tremors also were centered in the left side of the mine near the Sunnyside fault zone and in the right side between 9th and 15th Right. Nearly all tremor foci were near the elevation of the mine workings.

Sunnyside No. 2 mine area.--Nearly all tremor hypocenters were clustered near faults of the Sunnyside fault zone west of the mine development near the 10th Right (10R) room-and-pillar section. Two hundred and four tremors registering between 1 and 1.5 on the Richter scale originated in the same general area but were not plotted because of the tight grouping. Two tremors originated in a barrier pillar near the active mining area on 16th Left (16L). Tremor hypocenters plotted near the elevation of the mine workings, but some plotted as much as 3,000 feet below them.

Sunnyside No. 3 mine area.--One tremor originated in the right side of the mine about 3,000 feet below old mine workings.

Columbia mine area.--Six tremor hypocenters were plotted in the southern part of this inactive mine area along east-trending faults and 3,000-5,000 feet below the elevation of the mine workings.

Geneva mine area.--Tremors originated throughout most of the mine area. Two tremors of Richter magnitude of 2.5 and one of 2.6, the largest magnitude tremors to occur in the district during this quarter, occurred in the northern, central, and southern parts of the mine area. Most of the tremors that originated in the northern part of the area were clustered in an area where a left-lateral strike-slip fault fans out or horsetails within the north graben. Tremors were scattered in the central and southern parts of the mine area, but in general they were near areas of active mining. Many tremors were near faults in the southern part of the mine area. Tremor focal depths generally were 4,000-6,000 feet below the elevation of the mine workings; however, one occurred near but perhaps above the elevation of the mine workings in both the northern and central parts of the area.

Second-quarter seismic activity (fig. 8):

The seismic network operated below par during much of this quarter. The playback truck was in Denver from April 27 to May 30 to update the playback system. Then, on June 8, the Flat, Horse Canyon, and Sheep Canyon seismometer stations were taken out of service to upgrade the electronics and install a remote battery-charging capability. Consequently, most of the tremors plotted during May and from June 1 to June 8 were worked up from the paper records rather than from expanded-time-scale playbacks made from magnetic tape. This probably reduced the plotting accuracy by a factor of 2. From June 8 through June 30, too many stations were out of service to permit locating any tremor hypocenters.

Sunnyside No. 1 mine area.--Tremor hypocenters occurred in the raise area and near the bottom of the No. 1 slope area. All tremor foci originated near the elevation of the mine workings.

Sunnyside No. 2 mine area.--Tremors originated in the same general area and depth as in the previous quarter, but were more dispersed.

Sunnyside No. 3 mine area.--Three tremors originated in mined-out areas near the elevation of the mine workings: two in the southern part and one in the northern part of the mine area.

Columbia mine area.--Five tremor hypocenters plotted in the southern part of the mine area near or within a profusely faulted region. The tremors probably were in response to mining activities in the northern part of the Geneva mine, and originated 4,000-6,000 feet below the elevation of the mine workings.

Geneva mine area.--Most of the larger magnitude tremors originated north of the main slope near active mining areas or near faults and fault intersections. Nearly all tremor foci were 4,000-7,000 feet below the elevation of the mine workings.

Third-quarter seismic activity (fig. 9):

During parts of the months of July, August, September, October, and November and the first part of December, too many seismometer stations were out of service to permit plotting tremor hypocenters. The months of August and September were marginal, because electronic problems continued to keep most of the stations below peak efficiency, thus reducing the plotting accuracy and decreasing the number of seismic events recorded during the quarter (figs. 1, 2).

Sunnyside No. 1 mine area.--Most of tremor hypocenters originated near the raise area as a result of explosive failure of chain pillars on the 2d, 3d, and 4th North haulageways. Tremor hypocenters also occurred near the Sunnyside fault west of 12th Left (12L) longwall section. Most tremor foci plotted within 500 feet of the elevation of the mine workings.

Sunnyside No. 2 mine area.--The seismic activity declined markedly, as compared with that of the two previous quarters, perhaps because no active mining was conducted east of the intensely faulted portion of the Sunnyside fault zone. The tremor hypocenters also shifted eastward as compared with those of the last quarter. Most tremor foci were near the elevation of the mine workings, but two were as much as 6,000 feet below that elevation.

Sunnyside No. 3 mine area.--No tremors with sufficient energy to plot originated in this area.

Columbia mine area.--The pattern for this idle mine was much the same as in the last quarter. Four tremor hypocenters occurred in the extreme southern part of the mine near faults and fault intersections and from 1,000 to 4,000 feet below the elevation of the mine workings.

Geneva mine area.--All but three tremor hypocenters were concentrated in the northern part of the mine area near or within the faulted graben--north of the active mining area on 1st level North (1N) at depths ranging from near the elevation of the mine workings to 7,000 feet below them.

Fourth-quarter seismic activity (fig. 10):

Sunnyside No. 1 mine area.--The distribution of tremor hypocenters here is essentially the same as in the last quarter, but is somewhat more scattered northwest of the limits of the mine workings. Tremor foci commonly were near the elevation of mine workings except for those occurring northwest of the mine workings, where three occurred 6,000-7,000 feet below the elevation of the Sunnyside coal bed.

Sunnyside No. 2 mine area.--The seismic activity again markedly declined. Mining was suspended in 9 Right and 11 Right as of October 10. The mining area also was farther away from the intensely faulted part of the Sunnyside fault zone. Only two tremors originated in the area, one on each side of the Sunnyside fault zone; both occurred near the elevation or projected elevation of the mine workings.

Sunnyside No. 3 mine area.--The seismic activity increased in this area. Seven tremor hypocenters were located in the southern part of the mine area near the elevation of the mine workings and west of room-and-pillar mining that was initiated again on October 17 after having been suspended on August 25, 1969.

Columbia mine area.--Seven tremor hypocenters were located in the southern part of the mine, 4,000-7,000 feet below the elevation of the mine workings and near east-trending faults and fault intersections. The tremors probably were in response to stress changes induced by mining in the northern part of the Geneva mine.

Geneva mine area.--All tremor hypocenters were concentrated in the northern half of the mine, around the active mining off 1st level North (1N) or near or along faults and fault intersections, and from near the mine workings to as much as 7,000 feet below them.

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MST) | | | | | |
| 1 | Jan 1 | 3:55 p.m. | 2.2 | 42,000 N., 57,300 E. | 3 | ---------- | ---------- |
| 2 | 2 | 4:42 p.m. | 2.2 | ---------- | ---------- | 20,500 S., 2,900 E. | 2 |
| 3 | 3 | 4:52 a.m. | 2.0 | 40,400 N., 57,600 E. | 4 | ---------- | ---------- |
| 4 | 4 | 8:03 a.m. | 1.9 | ---------- | ---------- | 20,300 S., 2,400 E. | 1 |
| 5 | 6 | 11:48 a.m. | 2.4 | 39,600 N., 56,800 E. | 5 | ---------- | ---------- |
| 6 | 7 | 10:10 a.m. | 2.2 | 39,400 N., 57,300 E. | 5 | ---------- | ---------- |
| 7 | 7 | 10:59 a.m. | 1.9 | ---------- | ---------- | 20,600 S., 2,300 E. | 0 |
| 8 | 7 | 1:41 p.m. | 2.3 | 41,700 N., 59,500 E. | 3 | ---------- | ---------- |
| 9 | 7 | 2:20 p.m. | 2.0 | 40,300 N., 57,000 E. | 3 | ---------- | ---------- |
| 10 | 7 | 8:45 p.m. | 2.0 | 58,200 N., 50,900 E. | 5 | ---------- | ---------- |
| 11 | 7 | 11:00 p.m. | 2.5 | ---------- | ---------- | 20,600 S., 2,300 E. | 2 |
| 12 | 8 | 8:09 a.m. | 2.0 | 39,400 N., 57,300 E. | 5 | ---------- | ---------- |
| 13 | 9 | 4:04 a.m. | 2.2 | ---------- | ---------- | 20,200 S., 1,800 E. | 1 |
| 14 | 9 | 5:44 a.m. | 2.3 | 39,800 N., 56,200 E. | 2 | ---------- | ---------- |
| 15 | 9 | 9:52 a.m. | 2.3 | 41,200 N., 57,500 E. | 2 | ---------- | ---------- |
| 16 | 9 | 12:17 p.m. | 2.3 | 40,400 N., 57,400 E. | 3 | ---------- | ---------- |
| 17 | 10 | 10:57 p.m. | 2.2 | 58,200 N., 53,400 E. | 5 | ---------- | ---------- |
| 18 | 14 | 5:29 p.m. | 2.4 | 40,300 N., 58,200 E. | 6 | ---------- | ---------- |
| 19 | 15 | 10:43 a.m. | 2.2 | 41,100 N., 58,600 E. | 2 | ---------- | ---------- |
| 20 | 15 | 4:44 p.m. | 2.2 | 41,100 N., 56,000 E. | 1 | ---------- | ---------- |
| 21 | 17 | 1:17 a.m. | 2.0 | 41,500 N., 56,400 E. | 2 | ---------- | ---------- |
| 22 | 17 | 4:14 a.m. | 2.0 | 58,200 N., 52,100 E. | 6 | ---------- | ---------- |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MST) | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 23 | Jan 18 | 6:54 a.m. | 2.2 | ------------------- | ----------- | 19,800 S., 2,500 E. | 1 |
| 24 | 18 | 4:44 p.m. | 2.2 | ------------------- | ----------- | 18,800 S., 12,800 E. | 2 |
| 25 | 20 | 1:13 a.m. | 2.1 | ------------------- | ----------- | 17,100 S., 11,600 E. | 1 |
| 26 | 20 | 10:07 a.m. | 2.1 | 39,800 N., 60,000 E. | 6 | ------------------- | ----------- |
| 27 | 20 | 11:29 a.m. | 2.2 | 42,000 N., 52,800 E. | 2 | ------------------- | ----------- |
| 28 | 21 | 7:04 a.m. | 2.6 | 57,900 N., 48,500 E. | 6 | ------------------- | ----------- |
| 29 | 22 | 1:35 p.m. | 2.2 | 40,800 N., 56,100 E. | 4 | ------------------- | ----------- |
| 30 | 23 | 1:36 p.m. | 2.4 | 40,100 N., 57,600 E. | 5 | ------------------- | ----------- |
| 31 | 23 | 4:25 p.m. | 1.9 | 58,500 N., 52,000 E. | 5 | ------------------- | ----------- |
| 32 | 23 | 6:40 p.m. | 1.9 | 41,000 N., 57,100 E. | 4 | ------------------- | ----------- |
| 33 | 24 | 12:01 p.m. | 2.2 | ------------------- | ----------- | 16,600 S., 6,100 E. | 2 |
| 34 | 24 | 12:38 p.m. | 2.1 | 39,200 N., 57,700 E. | 4 | ------------------- | ----------- |
| 35 | 24 | 1:20 p.m. | 2.1 | ------------------- | ----------- | 19,800 S., 8,700 E. | 3 |
| 36 | 24 | 2:03 p.m. | 2.6 | 39,800 N., 58,200 E. | 5 | ------------------- | ----------- |
| 37 | 25 | 5:09 p.m. | 2.1 | 58,300 N., 51,600 E. | 5 | ------------------- | ----------- |
| 38 | 27 | 4:26 p.m. | 1.6 | 61,800 N., 40,400 E. | 5 | ------------------- | ----------- |
| 39 | 27 | 6:15 p.m. | 1.9 | 58,000 N., 51,300 E. | 6 | ------------------- | ----------- |
| 40 | 27 | 8:15 p.m. | 1.9 | 59,200 N., 39,800 E. | 6 | ------------------- | ----------- |
| 41 | 27 | 10:49 p.m. | 2.2 | ------------------- | ----------- | 14,000 S., 2,200 E. | 2 |
| 42 | 27 | 11:27 p.m. | 1.9 | ------------------- | ----------- | 14,400 S., 3,400 E. | 1 |
| 43 | 28 | 3:34 a.m. | 2.2 | ------------------- | ----------- | 19,400 S., 900 E. | 0 |
| 44 | 28 | 3:35 a.m. | 1.9 | ------------------- | ----------- | 19,800 S., 1,400 E. | 1 |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| Tremor No. | Date | Time (MST) | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| 45 | Jan 28 | 12:34 p.m. | 2.4 | 39,200 N., 58,200 E. | 5 | ------------ | ------------ |
| 46 | 29 | 12:35 a.m. | 1.9 | ------------ | ------------ | 17,700 S., 1,100 E. | 2 |
| 47 | 29 | 3:05 a.m. | 2.2 | 58,000 N., 49,700 E. | 5 | ------------ | ------------ |
| 48 | 31 | 4:20 a.m. | 2.0 | 57,600 N., 51,500 E. | 6 | ------------ | ------------ |
| 49 | 31 | 7:10 p.m. | 2.6 | ------------ | ------------ | 16,800 S., 0000 | 1 |
| 50 | 31 | 7:38 p.m. | 2.1 | ------------ | ------------ | 16,900 S., 500 E. | 1 |
| 51 | 31 | 7:54 p.m. | 2.3 | ------------ | ------------ | 16,800 S., 000 | 1 |
| 52 | 31 | 10:14 p.m. | 2.1 | ------------ | ------------ | 17,600 S., 900 E. | 1 |
| 52a | 31 | 11:26 p.m. | 1.9 | ------------ | ------------ | 17,400 S., 400 E. | 1 |
| 53 | Feb 1 | 1:17 a.m. | 2.2 | 39,400 N., 56,900 E. | 5 | ------------ | ------------ |
| 54 | 1 | 3:42 a.m. | 2.3 | 58,000 N., 51,200 E. | 5 | ------------ | ------------ |
| 55 | 1 | 5:56 a.m. | 2.1 | 59,200 N., 41,100 E. | 5 | ------------ | ------------ |
| 56 | 2 | 8:34 a.m. | 2.0 | ------------ | ------------ | 13,400 S., 200 W. | 1 |
| 57 | 2 | 1:56 p.m. | 2.5 | ------------ | ------------ | 4,700 S., 1,100 E. | 3 |
| 58 | 3 | 11:38 a.m. | 2.3 | ------------ | ------------ | 15,100 S., 500 W. | 2 |
| 59 | 3 | 8:29 p.m. | 2.3 | 41,000 N., 54,700 E. | 4 | ------------ | ------------ |
| 60 | 4 | 12:14 p.m. | 2.0 | 41,900 N., 52,800 E. | 3 | ------------ | ------------ |
| 61 | 4 | 12:31 p.m. | 1.9 | 39,500 N., 56,900 E. | 5 | ------------ | ------------ |
| 62 | 4 | 3:10 p.m. | 2.0 | 39,300 N., 56,800 E. | 4 | ------------ | ------------ |
| 63 | 4 | 5:05 p.m. | 1.8 | 60,900 N., 41,600 E. | 4 | ------------ | ------------ |
| 64 | 4 | 6:56 p.m. | 1.9 | 58,500 N., 41,800 E. | 6 | ------------ | ------------ |
| 65 | 5 | 3:55 a.m. | 2.6 | ------------ | ------------ | 19,000 S., 1,400 E. | 1 |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| Tremor No. | Date | Time (MST) | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| 66 | Feb 5 | 6:53 a.m. | 1.9 | ------------------ | ----------- | 19,000 S., 900 E. | 1 |
| 67 | 5 | 12:55 p.m. | 2.3 | 57,600 N., 40,900 E. | 6 | ------------------ | ----------- |
| 68 | 5 | 8:08 p.m. | 2.0 | 57,900 N., 41,600 E. | 6 | ------------------ | ----------- |
| 69 | 5 | 9:23 p.m. | 2.3 | 40,700 N., 55,100 E. | 4 | ------------------ | ----------- |
| 70 | 6 | 5:44 a.m. | 2.1 | 40,600 N., 55,600 E. | 3 | ------------------ | ----------- |
| 71 | 6 | 12:34 p.m. | 2.1 | ------------------ | ----------- | 18,300 S., 1,200 E. | 1 |
| 72 | 6 | 6:02 p.m. | 2.1 | ------------------ | ----------- | 16,400 S., 200 W. | 1 |
| 73 | 6 | 6:42 p.m. | 2.2 | 40,000 N., 55,000 E. | 5 | ------------------ | ----------- |
| 74 | 8 | 10:35 a.m. | 2.2 | 39,600 N., 57,900 E. | 4 | ------------------ | ----------- |
| 75 | 8 | 11:18 p.m. | 2.4 | ------------------ | ----------- | 18,900 S., 1,500 E. | 1 |
| 76 | 9 | 8:42 p.m. | 2.3 | 59,900 N., 27,100 E. | 6 | ------------------ | ----------- |
| 77 | 10 | 12:29 a.m. | 2.4 | 40,700 N., 55,800 E. | 3 | ------------------ | ----------- |
| 78 | 10 | 5:18 p.m. | 2.1 | 39,400 N., 56,300 E. | 4 | ------------------ | ----------- |
| 79 | 10 | 7:02 p.m. | 2.3 | 39,100 N., 57,600 E. | 5 | ------------------ | ----------- |
| 80 | 11 | 8:36 a.m. | 2.0 | 39,900 N., 55,500 E. | 4 | ------------------ | ----------- |
| 81 | 11 | 8:46 a.m. | 2.0 | 39,600 N., 57,900 E. | 3 | ------------------ | ----------- |
| 82 | 11 | 12:11 p.m. | 2.2 | 59,300 N., 41,000 E. | 5 | ------------------ | ----------- |
| 83 | 11 | 2:53 p.m. | 2.2 | 58,800 N., 40,400 E. | 6 | ------------------ | ----------- |
| 84 | 12 | 1:48 p.m. | 2.1 | 40,600 N., 53,500 E. | 4 | ------------------ | ----------- |
| 85 | 12 | 2:09 p.m. | 2.2 | ------------------ | ----------- | 17,300 S., 8,600 E. | 3 |
| 86 | 13 | 7:00 p.m. | 1.8 | 60,400 N., 40,200 E. | 4 | ------------------ | ----------- |
| 87 | 14 | 8:41 a.m. | 2.2 | 39,100 N., 58,800 E. | 6 | ------------------ | ----------- |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in thé Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MST) | | | | | |
| 88 | Feb 14 | 4:42 p.m. | 2.0 | 59,700 N., 40,000 E. | 7 | ------------------ | ------------ |
| 89 | 22 | 7:03 p.m. | 2.5 | 41,200 N., 56,800 E. | 7 | ------------------ | ------------ |
| 90 | 23 | 2:35 a.m. | 2.2 | 57,000 N., 47,600 E. | 6 | ------------------ | ------------ |
| 91 | 23 | 3:41 a.m. | 2.1 | ------------------ | ------------ | 19,300 S., 000 | 1 |
| 92 | 28 | 6:45 p.m. | 2.1 | ------------------ | ------------ | 15,500 S., 800 E. | 3 |
| 93 | 28 | 7:48 p.m. | 2.0 | 57,000 N., 41,300 E. | 7 | ------------------ | ------------ |
| 94 | Mar 3 | 5:35 p.m. | 2.4 | 57,200 N., 41,900 E. | 6 | ------------------ | ------------ |
| 95 | 12 | 5:30 p.m. | 2.3 | 56,200 N., 42,700 E. | 7 | ------------------ | ------------ |
| 96 | 13 | 12:04 a.m. | 2.5 | ------------------ | ------------ | 14,100 S., 1,900 W. | 1 |
| 97 | 13 | 1:16 a.m. | 2.5 | ------------------ | ------------ | 14,300 S., 1,000 W. | 1 |
| 98 | 13 | 12:02 p.m. | 2.5 | ------------------ | ------------ | 15,000 S., 500 E. | 1 |
| From March 13-21 signal lines broken due to storm | | | | | | | |
| 99 | Apr 21 | 11:34 a.m. | 2.1 | 41,500 N., 57,700 E. | 7 | ------------------ | ------------ |
| 100 | 21 | 5:42 p.m. | 2.2 | 60,200 N., 39,900 E. | 6 | ------------------ | ------------ |
| 101 | 22 | 11:46 p.m. | 2.2 | 58,400 N., 40,100 E. | 7 | ------------------ | ------------ |
| 102 | 23 | 12:05 a.m. | 1.9 | 59,400 N., 40,100 E. | 6 | ------------------ | ------------ |
| 103 | 24 | 3:31 a.m. | 2.1 | 56,500 N., 42,200 E. | 7 | ------------------ | ------------ |
| 104 | 24 | 8:02 a.m. | 2.0 | 37,800 N., 54,400 E. | 7 | ------------------ | ------------ |
| | | (MDT) | | | | | |
| 105 | 26 | 10:05 p.m. | 2.1 | 41,500 N., 60,900 E. | 1 | ------------------ | ------------ |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MDT) | | | | | |
| 106 | Apr 26 | 10:33 p.m. | 1.9 | 40,500 N., 56,000 E. | 6 | -------------------- | ----------- |
| 107 | 29 | 4:24 a.m. | 2.2 | 39,700 N., 57,100 E. | 6 | -------------------- | ----------- |
| 108 | 29 | 10:32 a.m. | 2.3 | 40,300 N., 59,600 E. | 5 | -------------------- | ----------- |
| 109 | 29 | 9:18 p.m. | 2.1 | 40,300 N., 58,800 E. | 2 | -------------------- | ----------- |
| 110 | May 1 | 1:42 a.m. | 2.4 | 40,600 N., 60,300 E. | 5 | -------------------- | ----------- |
| 111 | 3 | 6:39 p.m. | 2.4 | 40,300 N., 52,900 E. | 1 | -------------------- | ----------- |
| 112 | 3 | 11:28 p.m. | 2.2 | 57,800 N., 42,600 E. | 1 | -------------------- | ----------- |
| 113 | 4 | 1:46 p.m. | 2.1 | 58,400 N., 42,200 E. | 7 | -------------------- | ----------- |
| 114 | 4 | 7:25 p.m. | 2.2 | 60,100 N., 55,100 E. | 6 | -------------------- | ----------- |
| 115 | 4 | 8:33 p.m. | 2.3 | 40,800 N., 57,100 E. | 3 | -------------------- | ----------- |
| 116 | 5 | 12:08 a.m. | 2.3 | 40,700 N., 55,500 E. | 7 | -------------------- | ----------- |
| 117 | 6 | 10:30 a.m. | 2.4 | -------------------- | ----------- | 12,800 S., 1,300 E. | 1 |
| 118 | 6 | 10:38 a.m. | 2.1 | 40,500 N., 59,500 E. | 4 | -------------------- | ----------- |
| 119 | 6 | 6:04 p.m. | 2.4 | 61,000 N., 57,000 E. | 5 | -------------------- | ----------- |
| 120 | 6 | 6:57 p.m. | 2.2 | 50,300 N., 55,100 E. | 7 | -------------------- | ----------- |
| 121 | 6 | 7:00 p.m. | 2.2 | 60,600 N., 55,800 E. | 4 | -------------------- | ----------- |
| 122 | 6 | 9:56 p.m. | 2.3 | 40,700 N., 57,800 E. | 4 | -------------------- | ----------- |
| 123 | 6 | 10:19 p.m. | 2.0 | 39,400 N., 59,100 E. | 5 | -------------------- | ----------- |
| 124 | 7 | 6:46 p.m. | 2.2 | 40,200 N., 58,100 E. | 6 | -------------------- | ----------- |
| 125 | 9 | 1:22 a.m. | 2.1 | 40,800 N., 57,000 E. | 7 | -------------------- | ----------- |
| 126 | 10 | 7:01 a.m. | 2.2 | -------------------- | ----------- | 16,900 S., 1,100 W. | 1 |
| 127 | 10 | 1:54 p.m. | 2.5 | 60,400 N., 57,300 E. | 7 | -------------------- | ----------- |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| Tremor No. | Date | Time | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| | | (MDT) | | | | | |
| 128 | May 11 | 1:10 a.m. | 2.4 | 40,300 N., 60,500 E. | 5 | ---------- | ---------- |
| 129 | 13 | 8:53 a.m. | 2.4 | ---------- | ---------- | 18,100 S., 300 W. | 1 |
| 130 | 13 | 9:02 a.m. | 2.5 | 60,200 N., 56,800 E. | 6 | ---------- | ---------- |
| 131 | 13 | 9:39 a.m. | 2.1 | 42,800 N., 59,800 E. | 7 | ---------- | ---------- |
| 132 | 13 | 11:17 a.m. | 2.3 | ---------- | ---------- | 11,600 S., 2,800 W. | 1 |
| 133 | 13 | 5:17 p.m. | 2.1 | 61,400 N., 57,700 E. | 6 | ---------- | ---------- |
| 134 | 13 | 7:28 p.m. | 2.3 | 60,700 N., 57,400 E. | 6 | ---------- | ---------- |
| 135 | 15 | 2:32 a.m. | 2.2 | 61,400 N., 57,700 E. | 6 | ---------- | ---------- |
| 136 | 15 | 10:48 a.m. | 2.3 | 48,800 N., 55,300 E. | 7 | ---------- | ---------- |
| 137 | 15 | 12:35 p.m. | 2.0 | 46,700 N., 54,000 E. | 2 | ---------- | ---------- |
| 138 | 15 | 9:51 a.m. | 2.4 | 39,600 N., 57,800 E. | 5 | ---------- | ---------- |
| 139 | 16 | 1:21 p.m. | 2.2 | 58,300 N., 42,900 E. | 7 | ---------- | ---------- |
| 140 | 17 | 9:21 a.m. | 2.3 | 39,400 N., 56,300 E. | 7 | ---------- | ---------- |
| 141 | 17 | 4:27 p.m. | 2.3 | 40,400 N., 56,500 E. | 7 | ---------- | ---------- |
| 142 | 18 | 9:22 a.m. | 2.5 | ---------- | ---------- | 17,200 S., 6,100 E. | 2 |
| 143 | 18 | 12:45 p.m. | 2.3 | 40,500 N., 56,100 E. | 5 | ---------- | ---------- |
| 144 | 19 | 4:45 a.m. | 2.2 | 42,100 N., 50,600 E. | 5 | ---------- | ---------- |
| 145 | 19 | 6:28 a.m. | 2.3 | 39,200 N., 56,000 E. | 7 | ---------- | ---------- |
| 146 | 19 | 8:08 a.m. | 2.2 | 39,400 N., 57,600 E. | 5 | ---------- | ---------- |
| 147 | 21 | 6:55 a.m. | 2.2 | ---------- | ---------- | 15,500 S., 300 W. | 3 |
| 148 | 21 | 10:32 a.m. | 2.3 | 42,200 N., 55,900 E. | 7 | ---------- | ---------- |
| 149 | 21 | 11:03 a.m. | 2.1 | 42,200 N., 55,900 E. | 3 | ---------- | ---------- |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MDT) | | | | | |
| 150 | May 21 | 1:49 p.m. | 2.1 | 41,800 N., 57,200 E. | 3 | ------------------ | ------------ |
| 151 | 21 | 2:29 p.m. | 2.2 | 41,100 N., 55,800 E. | 4 | ------------------ | ------------ |
| 152 | 22 | 9:25 a.m. | 2.2 | 41,500 N., 55,100 E. | 5 | ------------------ | ------------ |
| 153 | 22 | 12:33 p.m. | 2.3 | 58,000 N., 51,600 E. | 5 | ------------------ | ------------ |
| 154 | 22 | 1:29 p.m. | 2.1 | ------------------ | ------------ | 16,700 S., 400 E. | 1 |
| 155 | 22 | 8:02 p.m. | 2.2 | 39,500 N., 49,600 E. | 7 | ------------------ | ------------ |
| 156 | 22 | 8:24 p.m. | 2.2 | 39,000 N., 52,300 E. | 7 | ------------------ | ------------ |
| 157 | 22 | 10:34 p.m. | 2.5 | 57,700 N., 50,800 E. | 7 | ------------------ | ------------ |
| 158 | 23 | 1:40 a.m. | 2.1 | 57,800 N., 51,800 E. | 6 | ------------------ | ------------ |
| 159 | 23 | 2:06 a.m. | 2.1 | 57,800 N., 52,500 E. | 6 | ------------------ | ------------ |
| 160 | 23 | 4:35 a.m. | 2.3 | ------------------ | ------------ | 12,400 S., 7,900 E. | 7 |
| 161 | 23 | 9:44 a.m. | 2.1 | 48,700 N., 53,800 E. | 6 | ------------------ | ------------ |
| 162 | 24 | 2:18 a.m. | 2.2 | 42,400 N., 53,800 E. | 3 | ------------------ | ------------ |
| 163 | 25 | 5:46 a.m. | 2.1 | 40,300 N., 55,200 E. | 5 | ------------------ | ------------ |
| 164 | 25 | 7:51 a.m. | 2.2 | ------------------ | ------------ | 14,000 S., 2,400 W. | 7 |
| 165 | 25 | 1:28 p.m. | 2.2 | 49,400 N., 58,700 E. | 7 | ------------------ | ------------ |
| 166 | 25 | 7:01 p.m. | 2.1 | 59,400 N., 54,500 E. | 7 | ------------------ | ------------ |
| 167 | 25 | 9:15 p.m. | 2.1 | ------------------ | ------------ | 17,400 S., 600 W. | 2 |
| 168 | 26 | 10:12 a.m. | 2.4 | 39,500 N., 58,200 E. | 7 | ------------------ | ------------ |
| 169 | 28 | 6:54 a.m. | 2.2 | 52,200 N., 54,400 E. | 7 | ------------------ | ------------ |
| 170 | 29 | 1:15 p.m. | 2.0 | 57,000 N., 51,500 E. | 5 | ------------------ | ------------ |
| 171 | 29 | 5:35 p.m. | 2.2 | ------------------ | ------------ | 14,700 S., 2,000 E. | 3 |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MDT) | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 172 | May 30 | 12:32 a.m. | 1.9 | ------------------ | ----------- | 14,500 S., 2,700 W. | 6 |
| 173 | 30 | 2:21 a.m. | 2.1 | ------------------ | ----------- | 2,300 S., 3,100 W. | 7 |
| 174 | 30 | 8:56 a.m. | 2.3 | 58,600 N., 54,600 E. | 7 | ------------------ | ----------- |
| 175 | Jun 1 | 2:12 p.m. | 2.2 | ------------------ | ----------- | 13,200 S., 9,000 E. | 7 |
| 176 | 2 | 5:39 p.m. | 2.1 | ------------------ | ----------- | 11,400 S., 600 W. | 5 |
| 177 | 4 | 12:11 a.m. | 2.1 | 43,600 N., 48,100 E. | 2 | ------------------ | ----------- |
| 178 | 4 | 5:47 a.m. | 1.9 | 42,900 N., 44,700 E. | 1 | ------------------ | ----------- |
| 179 | 4 | 6:08 a.m. | 2.1 | 38,700 N., 51,400 E. | 7 | ------------------ | ----------- |
| 180 | 4 | 12:13 p.m. | 2.3 | 38,800 N., 53,100 E. | 7 | ------------------ | ----------- |
| 181 | 4 | 7:46 p.m. | 2.4 | 48,200 N., 54,800 E. | 7 | ------------------ | ----------- |
| 182 | 6 | 3:54 p.m. | 2.1 | ------------------ | ----------- | 12,000 S., 600 W. | 7 |
| 183 | 7 | 12:35 a.m. | 2.1 | 60,200 N., 57,700 E. | 4 | ------------------ | ----------- |
| 184 | 10 | 9:30 a.m. | 2.1 | 40,100 N., 55,600 E. | 7 | ------------------ | ----------- |
| 185 | 11 | 10:12 a.m. | 2.3 | 60,400 N., 55,700 E. | 4 | ------------------ | ----------- |
| 186 | 11 | 12:52 p.m. | 2.1 | 41,800 N., 54,100 E. | 5 | ------------------ | ----------- |
| 187 | 12 | 7:55 a.m. | 2.4 | 40,500 N., 54,200 E. | 3 | ------------------ | ----------- |
| 188 | 12 | 11:44 a.m. | 2.1 | 61,200 N., 58,800 E. | 5 | ------------------ | ----------- |
| 189 | 12 | 12:18 p.m. | 1.9 | 56,800 N., 50,200 E. | 5 | ------------------ | ----------- |
| 190 | 12 | 2:10 p.m. | 2.2 | 66,500 N., 51,700 E. | 6 | ------------------ | ----------- |
| 191 | 12 | 2:41 p.m. | 2.5 | 58,400 N., 51,200 E. | 7 | ------------------ | ----------- |
| 192 | 12 | 5:21 p.m. | 2.2 | 40,300 N., 57,200 E. | 6 | ------------------ | ----------- |
| 193 | 16 | 10:26 p.m. | 2.2 | 40,300 N., 57,200 E. | 6 | ------------------ | ----------- |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MDT) | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 194 | Jun 17 | 10:02 p.m. | 2.1 | 40,500 N., 61,700 E. | 6 | ---------- | ---------- |
| 195 | 19 | 6:04 a.m. | 2.3 | ---------- | ---------- | 7,200 S., 200 E. | 3 |
| 196 | 19 | 1:56 p.m. | 2.2 | 59,400 N., 53,000 E. | 5 | ---------- | ---------- |
| 197 | 19 | 8:52 p.m. | 2.1 | ---------- | ---------- | 11,600 S., 100 E. | 7 |
| 198 | 21 | 2:16 p.m. | 2.0 | 40,500 N., 57,700 E. | 6 | ---------- | ---------- |
| 199 | 21 | 2:48 p.m. | 2.2 | 58,100 N., 50,800 E. | 6 | ---------- | ---------- |
| 200 | 23 | 10:38 a.m. | 2.4 | 40,500 N., 56,000 E. | 7 | ---------- | ---------- |
| 201 | 23 | 2:16 p.m. | 2.2 | 40,300 N., 57,200 E. | 7 | ---------- | ---------- |
| 202 | 23 | 3:34 p.m. | 2.1 | 58,000 N., 51,600 E. | 7 | ---------- | ---------- |
| 203 | 24 | 9:41 p.m. | 2.0 | ---------- | ---------- | 13,600 S., 2,000 W. | 7 |
| 204 | 24 | 12:37 p.m. | 1.8 | ---------- | ---------- | 13,800 S., 1,200 W. | 3 |
| 205 | 25 | 1:16 a.m. | 2.1 | 48,800 N., 54,400 E. | 7 | ---------- | ---------- |
| 206 | 25 | 1:38 a.m. | 1.8 | 57,500 N., 50,800 E. | 7 | ---------- | ---------- |
| 207 | 25 | 3:46 p.m. | 2.0 | 51,200 N., 52,500 E. | 2 | ---------- | ---------- |
| 208 | 25 | 6:24 p.m. | 2.1 | 49,900 N., 54,000 E. | 6 | ---------- | ---------- |
| 209 | 25 | 8:12 p.m. | 1.8 | ---------- | ---------- | 9,500 S., 4,700 W. | 1 |
| 210 | 25 | 8:19 p.m. | 2.1 | ---------- | ---------- | 16,100 S., 3,000 W. | 3 |
| 211 | 25 | 10:05 p.m. | 1.8 | ---------- | ---------- | 13,300 S., 1,500 W. | 3 |
| 212 | 26 | 1:06 a.m. | 2.0 | 60,700 N., 58,700 E. | 5 | ---------- | ---------- |
| 213 | 26 | 1:12 a.m. | 1.8 | 57,500 N., 50,800 E. | 7 | ---------- | ---------- |
| 214 | 26 | 4:55 a.m. | 2.1 | 48,100 N., 53,900 E. | 7 | ---------- | ---------- |
| 215 | 27 | 7:02 p.m. | 2.0 | ---------- | ---------- | 12,700 S., 2,200 W. | 7 |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MDT) | | | | | |
| 216 | Jun 27 | 9:17 p.m. | 1.9 | 60,400 N., 57,500 E. | 4 | ------------------ | ----------- |
| 217 | 28 | 12:50 a.m. | 2.1 | ------------------ | ----------- | 14,300 S. 700 W. | 1 |
| 218 | 28 | 4:19 a.m. | 2.1 | ------------------ | ----------- | 13,300 S., 1,400 W. | 3 |
| 219 | 28 | 9:55 p.m. | 2.1 | ------------------ | ----------- | 13,300 S., 2,100 W. | 5 |
| 220 | 28 | 10:10 p.m. | 2.1 | ------------------ | ----------- | 13,700 S., 1,900 W. | 5 |
| 221 | 29 | 5:22 a.m. | 2.1 | 40,400 N., 57,700 E. | 7 | ------------------ | ----------- |
| 222 | 29 | 9:08 a.m. | 2.3 | ------------------ | ----------- | 13,900 S., 1,200 W. | 3 |
| 223 | 30 | 4:59 p.m. | 2.0 | 58,400 N., 52,200 E. | 6 | ------------------ | ----------- |
| 224 | 30 | 10:06 p.m. | 1.9 | 50,100 N., 58,000 E. | 7 | ------------------ | ----------- |
| 225 | Jul 1 | 1:22 a.m. | 2.4 | 38,200 N., 54,400 E. | 7 | ------------------ | ----------- |
| 226 | 1 | 1:58 a.m. | 2.1 | 60,700 N., 56,800 E. | 7 | ------------------ | ----------- |
| 227 | 1 | 8:36 p.m. | 2.3 | ------------------ | ----------- | 12,600 S., 400 W. | 7 |
| 228 | 2 | 12:53 a.m. | 2.2 | 58,300 N., 52,300 E. | 7 | ------------------ | ----------- |
| 229 | 2 | 9:27 a.m. | 2.3 | 59,300 N., 53,400 E. | 5 | ------------------ | ----------- |
| 230 | 2 | 2:43 p.m. | 2.1 | 59,200 N., 52,100 E. | 7 | ------------------ | ----------- |
| 231 | 3 | 1:21 p.m. | 2.1 | 48,800 N., 55,400 E. | 7 | ------------------ | ----------- |
| 232 | 3 | 1:23 p.m. | 2.4 | 57,300 N., 51,000 E. | 7 | ------------------ | ----------- |
| 233 | 3 | 1:45 p.m. | 2.3 | 61,200 N., 66,100 E. | 7 | ------------------ | ----------- |
| 234 | 3 | 4:00 p.m. | 2.4 | 61,200 N., 58,100 E. | 6 | ------------------ | ----------- |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| Tremor No. | Date | | Time | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|---|
| | | | (MDT) | | | | | |
| 235 | Jul | 3 | 6:52 p.m. | 2.4 | 41,100 N., 57,100 E. | 7 | ---------------- | ----------- |
| 236 | | 4 | 10:11 p.m. | 2.0 | 48,600 N., 53,700 E. | 7 | ---------------- | ----------- |
| 237 | | 5 | 9:44 a.m. | 2.2 | ---------------- | ----------- | 5,100 S., 1,500 E. | 4 |
| 238 | | 5 | 12:50 p.m. | 2.2 | 39,300 N., 60,300 E. | 5 | ---------------- | ----------- |
| 239 | | 5 | 9:57 p.m. | 2.1 | 42,500 N., 57,200 E. | 5 | ---------------- | ----------- |
| 240 | | 6 | 1:49 a.m. | 2.1 | 40,200 N., 57,300 E. | 5 | ---------------- | ----------- |
| 241 | | 7 | 1:14 p.m. | 2.2 | ---------------- | ----------- | 15,000 S., 500 E. | 3 |
| 242 | | 7 | 7:40 p.m. | 2.1 | 59,500 N., 52,200 E. | 5 | ---------------- | ----------- |
| 243 | | 8 | 7:28 p.m. | 2.0 | 58,200 N., 52,700 E. | 7 | ---------------- | ----------- |
| 244 | | 10 | 10:36 a.m. | 2.1 | 39,200 N., 59,400 E. | 7 | ---------------- | ----------- |
| 245 | | 10 | 11:45 a.m. | 2.2 | 39,900 N., 59,600 E. | 7 | ---------------- | ----------- |
| 246 | | 10 | 12:33 p.m. | 2.2 | 38,000 N., 56,600 E. | 6 | ---------------- | ----------- |
| 247 | | 11 | 2:44 a.m. | 2.3 | 41,100 N., 56,000 E. | 7 | ---------------- | ----------- |
| 248 | | 11 | 10:15 a.m. | 2.1 | 58,200 N., 51,600 E. | 6 | ---------------- | ----------- |
| 249 | | 11 | 10:47 a.m. | 2.2 | 40,700 N., 56,500 E. | 6 | ---------------- | ----------- |
| 250 | | 11 | 5:00 p.m. | 2.4 | 41,400 N., 59,000 E. | 5 | ---------------- | ----------- |
| 251 | | 11 | 7:14 p.m. | 2.0 | 41,500 N., 58,400 E. | 5 | ---------------- | ----------- |
| 252 | | 12 | 6:42 a.m. | 2.3 | 59,000 N., 53,500 E. | 4 | ---------------- | ----------- |
| 253 | | 12 | 11:20 a.m. | 2.1 | 40,100 N., 56,400 E. | 7 | ---------------- | ----------- |
| 254 | | 13 | 8:43 p.m. | 2.2 | 40,900 N., 55,300 E. | 5 | ---------------- | ----------- |
| 255 | | 14 | 6:05 a.m. | 2.0 | 48,600 N., 57,100 E. | 7 | ---------------- | ----------- |
| 256 | | 17 | 9:51 p.m. | 2.2 | ---------------- | ----------- | 12,800 S., 2,200 W. | 7 |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| Tremor No. | Date | Time (MDT) | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| 257 | Jul 17 | 9:59 p.m. | 2.1 | ------------------ | ----------- | 13,500 S., 1,900 W. | 7 |
| 258 | 18 | 1:13 a.m. | 2.3 | ------------------ | ----------- | 11,900 S., 2,600 W. | 3 |
| 259 | 18 | 7:20 p.m. | 2.2 | 58,300 N., 52,300 E. | 7 | ------------------ | ----------- |
| 260 | 22 | 5:32 a.m. | 2.5 | 40,100 N., 59,100 E. | 7 | ------------------ | ----------- |
| 261 | 22 | 9:57 p.m. | 2.5 | 40,300 N., 55,700 E. | 6 | ------------------ | ----------- |
| 262 | 22 | 11:36 p.m. | 2.2 | ------------------ | ----------- | 12,900 S., 200 E. | 2 |
| 263 | 23 | 3:40 a.m. | 2.3 | ------------------ | ----------- | 14,400 S., 1,900 E. | 2 |
| 264 | 23 | 10:02 a.m. | 2.3 | ------------------ | ----------- | 14,100 S., 1,500 W. | 3 |
| 265 | 23 | 10:35 a.m. | 2.2 | 59,800 N., 48,700 E. | 6 | ------------------ | ----------- |
| 266 | 23 | 10:47 a.m. | 2.2 | ------------------ | ----------- | 14,600 S., 1,300 W. | 3 |
| 267 | 23 | 11:26 a.m. | 2.0 | 56,900 N., 51,800 E. | 7 | ------------------ | ----------- |
| 268 | 23 | 6:14 p.m. | 2.3 | 56,700 N., 51,100 E. | 6 | ------------------ | ----------- |
| 269 | 24 | 5:49 a.m. | 2.3 | ------------------ | ----------- | 14,100 S., 1,200 E. | 5 |
| 270 | 24 | 9:54 a.m. | 2.3 | ------------------ | ----------- | 13,100 S., 400 E. | 3 |
| 271 | 24 | 8:41 p.m. | 2.3 | ------------------ | ----------- | 14,400 S., 900 W. | 2 |
| 272 | 25 | 6:15 a.m. | 2.2 | ------------------ | ----------- | 13,800 S., 600 E. | 3 |
| 273 | 26 | 6:44 a.m. | 2.3 | ------------------ | ----------- | 12,700 S., 1,200 E. | 1 |
| 274 | 26 | 10:48 p.m. | 2.1 | ------------------ | ----------- | 14,700 S., 3,000 E. | 3 |
| 275 | 27 | 6:09 p.m. | 2.3 | 60,200 N., 57,200 E. | 4 | ------------------ | ----------- |
| 276 | 28 | 8:58 a.m. | 2.0 | 56,700 N., 49,200 E. | 7 | ------------------ | ----------- |
| 277 | 29 | 1:28 a.m. | 2.1 | 61,200 N., 57,300 E. | 7 | ------------------ | ----------- |
| 278 | 29 | 5:26 a.m. | 2.4 | 41,100 N., 57,100 E. | 7 | ------------------ | ----------- |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MDT) | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 279 | Jul 29 | 6:33 a.m. | 2.1 | ---------- | ---------- | 13,600 S., 800 W. | 2 |
| 280 | 29 | 10:12 a.m. | 2.0 | ---------- | ---------- | 14,600 S., 1,300 W. | 7 |
| 281 | 29 | 6:36 p.m. | 2.2 | ---------- | ---------- | 11,900 S., 2,600 W. | 7 |
| 282 | 30 | 10:13 a.m. | 2.2 | ---------- | ---------- | 14,800 S., 1,600 E. | 2 |
| 283 | 30 | 11:09 p.m. | 2.2 | ---------- | ---------- | 12,600 S., 2,800 W. | 7 |
| 284 | 31 | 8:01 p.m. | 2.4 | 39,900 N., 55,500 E. | 6 | ---------- | ---------- |
| 285 | Aug 5 | 1:40 p.m. | 2.5 | 60,200 N., 52,100 E. | 6 | ---------- | ---------- |
| 286 | 8 | 5:46 a.m. | 2.2 | ---------- | ---------- | 13,100 S., 1,200 W. | 1 |
| 287 | 8 | 9:21 a.m. | 2.2 | 60,100 N., 53,600 E. | 7 | ---------- | ---------- |
| 288 | 8 | 12:47 p.m. | 2.2 | 49,100 N., 54,300 E. | 1 | ---------- | ---------- |
| 289 | 8 | 2:11 p.m. | 2.6 | 57,200 N., 49,800 E. | 6 | ---------- | ---------- |
| 290 | 9 | 12:05 p.m. | 2.5 | 56,000 N., 49,200 E. | 7 | ---------- | ---------- |
| 291 | 9 | 6:49 p.m. | 2.4 | 58,500 N., 53,100 E. | 6 | ---------- | ---------- |
| 292 | 10 | 6:37 a.m. | 2.2 | 60,600 N., 55,900 E. | 7 | ---------- | ---------- |
| 293 | 10 | 11:26 a.m. | 2.3 | 58,900 N., 50,700 E. | 6 | ---------- | ---------- |
| 294 | 10 | 8:13 p.m. | 2.4 | ---------- | ---------- | 15,900 S., 6,200 E. | 7 |
| 295 | 10 | 10:26 a.m. | 2.2 | 62,600 N., 55,600 E. | 7 | ---------- | ---------- |
| 296 | 12 | 11:16 a.m. | 2.4 | 60,400 N., 59,300 E. | 7 | ---------- | ---------- |
| 297 | 14 | 5:22 a.m. | 2.2 | ---------- | ---------- | 15,400 S., 2,400 W. | 3 |
| 298 | 14 | 7:56 p.m. | 2.6 | 59,100 N., 48,000 E. | 5 | ---------- | ---------- |
| 299 | 14 | 9:56 p.m. | 2.2 | ---------- | ---------- | 15,600 S., 1,300 E. | 1 |
| 300 | 15 | 12:56 a.m. | 1.8 | ---------- | ---------- | 17,600 S., 1,100 E. | 0 |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| Tremor No. | Date | Time (MDT) | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| 301 | Aug 14 | 9:56 p.m. | 2.2 | ------------------ | ----------- | 15,600 S., 1,300 E. | 1 |
| 302 | 15 | 12:56 a.m. | 1.8 | ------------------ | ----------- | 17,600 S., 1,100 E. | 0 |
| 303 | 15 | 6:52 a.m. | 1.8 | ------------------ | ----------- | 12,400 S., 500 W. | 7 |
| 304 | 15 | 9:40 a.m. | 1.8 | ------------------ | ----------- | 13,400 S., 0 | 5 |
| 305 | 15 | 11:13 a.m. | 1.8 | ------------------ | ----------- | 13,000 S., 1,000 E. | 1 |
| 306 | 15 | 2:39 p.m. | 2.1 | ------------------ | ----------- | 14,400 S., 900 W. | 7 |
| 307 | 15 | 9:45 p.m. | 2.3 | 41,200 N., 57,900 E. | 7 | ------------------ | ----------- |
| 308 | 16 | 12:59 a.m. | 2.3 | 60,300 N., 44,800 E. | 5 | ------------------ | ----------- |
| 309 | 16 | 6:44 p.m. | 2.4 | 59,400 N., 50,100 E. | 7 | ------------------ | ----------- |
| 310 | 16 | 11:51 p.m. | 1.8 | ------------------ | ----------- | 13,500 S., 1,100 E. | 7 |
| 311 | 17 | 3:43 a.m. | 1.9 | ------------------ | ----------- | 19,600 S., 6,800 E. | 1 |
| 312 | 17 | 11:44 a.m. | 1.9 | 63,800 N., 56,900 E. | 4 | ------------------ | ----------- |
| 313 | 17 | 4:48 p.m. | 2.1 | 59,700 N., 54,900 E. | 4 | ------------------ | ----------- |
| 314 | 19 | 12:23 p.m. | 2.0 | 40,700 N., 58,100 E. | 5 | ------------------ | ----------- |
| 315 | 21 | 1:04 a.m. | 2.2 | 42,200 N., 56,800 E. | 1 | ------------------ | ----------- |
| 316 | 21 | 1:04 p.m. | 2.3 | 55,900 N., 51,100 E. | 7 | ------------------ | ----------- |
| 317 | 21 | 1:10 p.m. | 2.3 | 60,800 N., 58,300 E. | 5 | ------------------ | ----------- |
| 318 | 22 | 4:19 p.m. | 2.3 | 58,900 N., 55,000 E. | 7 | ------------------ | ----------- |
| 319 | 23 | 2:18 a.m. | 2.3 | 58,800 N., 49,500 E. | 7 | ------------------ | ----------- |
| 320 | 23 | 5:02 a.m. | 2.1 | 60,200 N., 40,200 E. | 6 | ------------------ | ----------- |
| 321 | 23 | 2:01 p.m. | 2.4 | 60,200 N., 54,700 E. | 6 | ------------------ | ----------- |
| 322 | 23 | 11:44 p.m. | 2.4 | 59,500 N., 54,400 E. | 2 | ------------------ | ----------- |
| 323 | 28 | 11:44 a.m. | 2.2 | ------------------ | ----------- | 6,500 S., 9,000 E. | 1 |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| Tremor No. | Date | Time (MDT) | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| 324 | Aug 28 | 9:23 p.m. | 2.0 | 56,200 N., 50,200 E. | 7 | ---------- | ---------- |
| 325 | 30 | 3:23 p.m. | 2.4 | 58,900 N., 54,100 E. | 6 | ---------- | ---------- |
| 326 | 30 | 11:18 a.m. | 2.1 | 58,400 N., 54,400 E. | 7 | ---------- | ---------- |
| 327 | 31 | 4:49 p.m. | 1.9 | 57,200 N., 49,800 E. | 7 | ---------- | ---------- |
| 328 | 31 | 10:24 p.m. | 2.1 | ---------- | ---------- | 16,100 S., 1,200 E. | 7 |
| 329 | Sep 4 | 8:56 p.m. | 2.0 | 56,800 N., 52,100 E. | 5 | ---------- | ---------- |
| 330 | 5 | 12:07 a.m. | 2.3 | 57,400 N., 51,200 E. | 6 | ---------- | ---------- |
| 331 | 5 | 4:43 a.m. | 2.3 | 58,700 N., 52,200 E. | 6 | ---------- | ---------- |
| 332 | 6 | 5:49 a.m. | 2.2 | 58,900 N., 52,700 E. | 6 | ---------- | ---------- |
| 333 | 7 | 11:32 p.m. | 2.5 | 59,000 N., 50,900 E. | 6 | ---------- | ---------- |
| 334 | 8 | 12:44 p.m. | 2.3 | 58,300 N., 49,800 E. | 6 | ---------- | ---------- |
| 335 | 11 | 9:03 p.m. | 1.8 | 59,800 N., 52,300 E. | 6 | ---------- | ---------- |
| 336 | 12 | 3:33 a.m. | 2.1 | 60,800 N., 51,300 E. | 6 | ---------- | ---------- |
| 337 | 12 | 6:45 a.m. | 2.0 | 59,400 N., 51,900 E. | 7 | ---------- | ---------- |
| 338 | 12 | 1:00 p.m. | 1.8 | 59,800 N., 56,000 E. | 7 | ---------- | ---------- |
| 339 | 17 | 8:51 a.m. | 2.3 | ---------- | ---------- | 15,100 S., 1,400 E. | 3 |
| 340 | 17 | 4:51 p.m. | 1.8 | ---------- | ---------- | 15,000 S., 100 W. | 1 |
| 341 | 18 | 7:54 a.m. | 2.5 | ---------- | ---------- | 16,300 S., 2,500 E. | 3 |
| 342 | 18 | 2:32 p.m. | 1.9 | ---------- | ---------- | 16,900 S., 2,600 E. | 7 |
| 343 | 18 | 3:17 p.m. | 2.5 | 55,400 N., 49,900 E. | 6 | ---------- | ---------- |
| 344 | 18 | 7:50 p.m. | 1.9 | ---------- | ---------- | 15,100 S., 1,300 E. | 3 |
| 345 | 19 | 5:01 a.m. | 1.5 | ---------- | ---------- | 17,800 S., 2,600 E. | 7 |
| 346 | 19 | 8:42 p.m. | 2.0 | ---------- | ---------- | 14,900 S., 11,300 E. | 7 |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magni-tude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MDT) | | | | | |
| 347 | Sep 20 | 5:54 a.m. | 2.1 | ------------------ | ---------- | 13,500 S., 900 E. | 2 |
| 348 | 20 | 2:47 p.m. | 2.0 | ------------------ | ---------- | 10,700 S., 900 W. | 3 |
| 349 | 21 | 5:26 a.m. | 2.2 | 59,900 N., 52,800 E. | 7 | ------------------ | ---------- |
| 350 | 21 | 2:12 p.m. | 2.2 | 61,000 N., 51,900 E. | 7 | ------------------ | ---------- |
| 351 | 27 | 10:48 a.m. | 1.8 | ------------------ | ---------- | 12,500 S., 100 W. | 7 |
| 352 | 27 | 2:50 p.m. | 2.4 | 58,000 N., 53,200 E. | 6 | ------------------ | ---------- |
| 353 | 28 | 10:51 p.m. | 2.5 | 58,200 N., 48,300 E. | 7 | ------------------ | ---------- |
| 354 | 28 | 12:41 p.m. | 1.8 | ------------------ | ---------- | 14,000 S., 3,700 E. | 3 |
| 355 | 28 | 4:31 p.m. | 2.0 | ------------------ | ---------- | 12,000 S., 200 E. | 3 |
| 356 | 29 | 4:01 a.m. | 2.2 | 58,600 N., 52,900 E. | 6 | ------------------ | ---------- |
| 357 | 30 | 12:23 a.m. | 2.3 | 58,900 N., 47,500 E. | 6 | ------------------ | ---------- |
| 358 | 30 | 2:00 p.m. | 2.0 | 60,200 N., 49,800 E. | 7 | ------------------ | ---------- |
| 359 | Oct 1 | 2:54 a.m. | 2.4 | 56,800 N., 49,800 E. | 6 | ------------------ | ---------- |
| 360 | 1 | 8:51 a.m. | 1.8 | 58,200 N., 51,100 E. | 6 | ------------------ | ---------- |
| 361 | 2 | 12:49 a.m. | 2.0 | ------------------ | ---------- | 14,800 S., 1,800 E. | 2 |
| 362 | 2 | 1:56 p.m. | 2.0 | 43,200 N., 53,100 E. | 3 | ------------------ | ---------- |
| 363 | 4 | 11:14 a.m. | 2.3 | 60,800 N., 44,700 E. | 6 | ------------------ | ---------- |
| 364 | 4 | 11:32 a.m. | 2.1 | 58,100 N., 50,800 E. | 5 | ------------------ | ---------- |
| 365 | 4 | 12:07 p.m. | 2.3 | ------------------ | ---------- | 17,000 S., 3,400 E. | 3 |
| 366 | 5 | 10:08 p.m. | 2.0 | 58,700 N., 51,700 E. | 4 | ------------------ | ---------- |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| Tremor No. | Date | Time | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| | | (MDT) | | | | | |
| 367 | Oct 8 | 6:30 p.m. | 2.4 | ------------------- | ----------- | 12,400 S., 7,300 E. | -1 |
| 368 | 9 | 6:40 p.m. | 2.3 | ------------------- | ----------- | 15,400 S., 1,800 E. | 1 |
| 369 | 9 | 8:01 p.m. | 2.1 | 39,000 N., 54,700 E. | 5 | ------------------ | ----------- |
| 370 | 10 | 6:48 a.m. | 2.2 | 58,700 N., 51,300 E. | 5 | ------------------ | ----------- |
| 371 | 10 | 11:21 a.m. | 2.5 | ------------------- | ----------- | 16,700 S., 2,900 E. | 1 |
| 372 | 11 | 11:28 p.m. | 2.4 | ------------------- | ----------- | 14,600 S., 1,200 E. | 2 |
| 373 | 15 | 10:32 p.m. | 2.0 | ------------------- | ----------- | 15,200 S., 1,000 E. | 2 |
| 374 | 16 | 11:06 a.m. | 2.2 | 39,600 N., 53,200 N. | 5 | ------------------ | ----------- |
| 375 | 16 | 3:27 p.m. | 1.8 | 57,800 N., 51,000 E. | 6 | ------------------ | ----------- |
| 376 | 16 | 7:02 p.m. | 1.9 | 57,600 N., 50,500 E. | 7 | ------------------ | ----------- |
| 377 | 16 | 10:06 p.m. | 1.9 | 59,100 N., 56,000 E. | 6 | ------------------ | ----------- |
| 378 | 16 | 11:01 p.m. | 1.9 | 54,100 N., 52,500 E. | 7 | ------------------ | ----------- |
| 379 | 23 | 9:05 p.m. | 2.1 | ------------------- | ----------- | 12,700 S., 1,100 W. | 1 |
| 380 | 23 | 11:08 p.m. | 2.1 | ------------------- | ----------- | 14,500 S., 1,800 W. | 1 |
| 381 | 27 | 2:58 p.m. | 1.8 | 41,700 N., 54,000 E. | 5 | ------------------ | ----------- |
| | | (MST) | | | | | |
| 382 | 27 | 6:27 p.m. | 1.9 | ------------------- | ----------- | 6,700 S., 2,200 W. | 3 |
| 383 | 28 | 2:13 p.m. | 1.9 | 57,600 N., 47,200 E. | 7 | ------------------ | ----------- |
| 384 | 29 | 3:20 a.m. | 2.1 | ------------------- | ----------- | 14,200 S., 400 E. | 1 |
| 385 | 29 | 10:45 a.m. | 1.8 | 45,100 N., 53,700 E. | 5 | ------------------ | ----------- |
| 386 | 29 | 2:32 p.m. | 1.9 | 57,900 N., 52,100 E. | 6 | ------------------ | ----------- |
| 387 | 29 | 3:15 p.m. | 1.7 | ------------------- | ----------- | 13,100 S., 800 W. | 0 |
| 388 | 30 | 12:01 a.m. | 1.8 | 56,300 N., 48,400 E. | 4 | ------------------ | ----------- |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MST) | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 389 | Oct 30 | 12:48 a.m. | 1.8 | 41,300 N., 54,600 E. | 1 | ---------- | ---------- |
| 390 | 30 | 12:10 p.m. | 2.1 | ---------- | ---------- | 14,200 S., 400 W. | 3 |
| 391 | 30 | 9:51 p.m. | 1.8 | ---------- | ---------- | 10,800 S., 900 W. | 1 |
| 392 | 31 | 5:32 a.m. | 1.8 | 63,200 N., 46,700 E. | 7 | ---------- | ---------- |
| 393 | 31 | 8:26 a.m. | 2.2 | 40,900 N., 53,800 E. | 7 | ---------- | ---------- |
| 394 | Nov 2 | 11:15 p.m. | 2.4 | 41,900 N., 54,900 E. | 6 | ---------- | ---------- |
| 395 | 3 | 4:36 p.m. | 1.8 | 62,200 N., 54,300 E. | 7 | ---------- | ---------- |
| 396 | 4 | 2:33 a.m. | 1.7 | 58,600 N., 49,900 E. | 7 | ---------- | ---------- |
| 397 | 4 | 9:27 a.m. | 2.4 | 39,800 N., 55,600 E. | 6 | ---------- | ---------- |
| 398 | 4 | 10:41 a.m. | 2.1 | 40,600 N., 55,100 E. | 3 | ---------- | ---------- |
| 399 | 4 | 6:15 p.m. | 2.1 | 56,400 N., 50,600 E. | 6 | ---------- | ---------- |
| 400 | 4 | 9:20 p.m. | 2.0 | 42,300 N., 57,000 E. | 1 | ---------- | ---------- |
| 401 | 4 | 10:19 p.m. | 2.1 | 57,600 N., 48,600 E. | 7 | ---------- | ---------- |
| 402 | 5 | 4:28 a.m. | 1.8 | ---------- | ---------- | 12,100 S., 500 W. | 1 |
| 403 | 5 | 7:58 a.m. | 2.0 | 54,400 N., 49,900 E. | 5 | ---------- | ---------- |
| 404 | 5 | 6:08 p.m. | 1.8 | 59,500 N., 50,400 E. | 7 | ---------- | ---------- |
| 405 | 6 | 5:05 p.m. | 1.9 | 53,400 N., 47,600 E. | 7 | ---------- | ---------- |
| 406 | 7 | 1:50 a.m. | 1.9 | 48,300 N., 57,100 E. | 7 | ---------- | ---------- |
| 407 | 7 | 11:51 a.m. | 2.0 | 40,200 N., 56,600 E. | 7 | ---------- | ---------- |
| 408 | 7 | 12:34 p.m. | 1.9 | 40,300 N., 55,300 E. | 7 | ---------- | ---------- |
| 409 | 8 | 3:11 a.m. | 2.1 | 62,100 N., 40,700 E. | 4 | ---------- | ---------- |
| 410 | 8 | 3:32 a.m. | 1.9 | 61,800 N., 43,500 E. | 7 | ---------- | ---------- |
| 411 | 8 | 7:42 p.m. | 1.8 | 57,300 N., 39,700 E. | 6 | ---------- | ---------- |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MST) | | | | | |
| 412 | Nov 8 | 10:20 p.m. | 1.7 | 56,000 N., 51,300 E. | 7 | ---------- | ---------- |
| 413 | 9 | 8:21 a.m. | 2.0 | 40,600 N., 55,900 E. | 1 | ---------- | ---------- |
| 414 | 9 | 4:47 p.m. | 1.9 | ---------- | ---------- | 18,100 S., 3,200 E. | 7 |
| 415 | 9 | 5:39 p.m. | 1.9 | ---------- | ---------- | 16,400 S., 3,700 E. | 1 |
| 416 | 10 | 8:58 a.m. | 2.0 | ---------- | ---------- | 18,200 S., 5,200 E. | 1 |
| 417 | 10 | 9:58 a.m. | 2.0 | ---------- | ---------- | 9,400 S., 1,200 W. | 1 |
| 418 | 11 | 2:39 a.m. | 1.8 | 57,700 N., 51,700 E. | 7 | ---------- | ---------- |
| 419 | 11 | 8:43 a.m. | 2.0 | 44,500 N., 54,500 E. | 7 | ---------- | ---------- |
| 420 | 11 | 11:55 a.m. | 2.1 | 49,600 N., 54,200 E. | 5 | ---------- | ---------- |
| 421 | 11 | 2:39 p.m. | 2.1 | 41,800 N., 55,600 E. | 7 | ---------- | ---------- |
| 422 | 12 | 9:43 a.m. | 2.2 | 57,200 N., 51,000 E. | 6 | ---------- | ---------- |
| 423 | 12 | 4:29 p.m. | 2.2 | 58,200 N., 52,800 E. | 4 | ---------- | ---------- |
| 424 | 12 | 10:01 p.m. | 2.1 | ---------- | ---------- | 10,400 S., 200 E. | 3 |
| 425 | 13 | 3:35 a.m. | 2.3 | 55,900 N., 51,100 E. | 7 | ---------- | ---------- |
| 426 | 13 | 3:36 a.m. | 2.3 | 58,100 N., 49,700 E. | 7 | ---------- | ---------- |
| 427 | 13 | 4:51 a.m. | 1.7 | 58,300 N., 49,800 E. | 7 | ---------- | ---------- |
| 428 | 14 | 7:38 a.m. | 1.9 | 56,000 N., 50,000 E. | 5 | ---------- | ---------- |
| 429 | 14 | 7:43 a.m. | 1.8 | 58,200 N., 49,000 E. | 5 | ---------- | ---------- |
| 430 | 14 | 9:39 a.m. | 1.8 | 40,600 N., 56,700 E. | 1 | ---------- | ---------- |
| 431 | 14 | 11:21 a.m. | 1.8 | 39,700 N., 55,000 E. | 7 | ---------- | ---------- |
| 432 | 14 | 11:43 p.m. | 2.1 | 58,200 N., 46,400 E. | 7 | ---------- | ---------- |
| 433 | 16 | 12:51 p.m. | 2.0 | 61,300 N., 41,200 E. | 7 | ---------- | ---------- |
| 434 | 16 | 4:22 p.m. | 2.0 | 54,200 N., 48,000 E. | 7 | ---------- | ---------- |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MST) | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 435 | Nov 17 | 1:16 a.m. | 2.5 | ------------------- | ---------- | 9,300 S., 3,200 E. | 1 |
| 436 | 17 | 5:17 p.m. | 2.1 | 49,100 N., 54,000 E. | 7 | ------------------- | ---------- |
| 437 | 18 | 9:42 a.m. | 1.8 | 41,200 N., 53,200 E. | 7 | ------------------- | ---------- |
| 438 | 19 | 8:29 a.m. | 2.1 | 41,200 N., 57,000 E. | 6 | ------------------- | ---------- |
| 439 | 20 | 7:11 p.m. | 2.2 | 40,600 N., 54,200 E. | 1 | ------------------- | ---------- |
| 440 | 20 | 9:34 p.m. | 2.0 | 41,200 N., 56,100 E. | 3 | ------------------- | ---------- |
| 441 | 20 | 10:05 p.m. | 2.0 | 41,000 N., 51,700 E. | 1 | ------------------- | ---------- |
| 442 | 20 | 10:48 p.m. | 2.1 | ------------------- | ---------- | 18,300 S., 500 E. | 0 |
| 443 | 21 | 3:04 p.m. | 1.8 | ------------------- | ---------- | 8,100 S., 2,600 E. | 1 |
| 445 | 23 | 6:58 a.m. | 2.1 | ------------------- | ---------- | 21,600 S., 2,000 W. | 7 |
| 446 | 23 | 10:48 a.m. | 1.8 | 58,800 N., 52,400 E. | 6 | ------------------- | ---------- |
| 447 | 23 | 4:13 p.m. | 2.2 | 39,100 N., 54,900 E. | 3 | ------------------- | ---------- |
| 448 | 23 | 6:19 p.m. | 2.1 | 44,300 N., 57,200 E. | 3 | ------------------- | ---------- |
| 449 | 23 | 6:21 p.m. | 2.0 | 49,700 N., 56,000 E. | 7 | ------------------- | ---------- |
| 450 | 23 | 9:11 p.m. | 1.8 | ------------------- | ---------- | 15,500 S., 600 E. | 7 |
| 451 | 24 | 1:10 p.m. | 2.1 | 40,800 N., 56,100 E. | 1 | ------------------- | ---------- |
| 452 | 24 | 5:39 p.m. | 1.8 | 56,800 N., 49,400 E. | 5 | ------------------- | ---------- |
| 453 | 25 | 11:46 a.m. | 1.8 | 41,200 N., 55,400 E. | 1 | ------------------- | ---------- |
| 454 | 26 | 2:31 a.m. | 1.9 | ------------------- | ---------- | 13,800 S., 2,400 E. | 1 |
| 455 | 26 | 5:00 a.m. | 1.7 | 54,500 N., 53,900 E. | 6 | ------------------- | ---------- |
| 456 | 26 | 5:45 a.m. | 1.8 | 54,600 N., 52,200 E. | 4 | ------------------- | ---------- |
| 457 | 26 | 5:10 p.m. | 2.0 | 57,000 N., 48,900 E. | 7 | ------------------- | ---------- |
| 458 | 26 | 5:45 p.m. | 2.3 | ------------------- | ---------- | 15,800 S., 1,300 E. | 0 |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MST) | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 459 | Nov 27 | 5:39 p.m. | 1.8 | 55,800 N., 48,400 E. | 6 | ------------------- | ------------ |
| 460 | 27 | 5:41 p.m. | 2.0 | 56,600 N., 47,200 E. | 6 | ------------------- | ------------ |
| 461 | 29 | 6:04 a.m. | 2.0 | ------------------- | ------------ | 12,800 S., 1,700 E. | 1 |
| 462 | 29 | 10:25 p.m. | 1.8 | ------------------- | ------------ | 13,500 S., 1,000 E. | 1 |
| 463 | 30 | 4:45 a.m. | 2.2 | 59,500 N., 48,000 E. | 5 | ------------------- | ------------ |
| 464 | Dec 3 | 4:25 p.m. | 2.0 | 56,900 N., 40,300 E. | 7 | ------------------- | ------------ |
| 465 | 3 | 4:36 p.m. | 2.0 | ------------------- | ------------ | 13,400 S., 200 E. | 3 |
| 466 | 4 | 8:23 a.m. | 2.1 | 58,400 N., 52,100 E. | 4 | ------------------- | ------------ |
| 467 | 5 | 4:26 p.m. | 1.9 | 49,300 N., 56,100 E. | 6 | ------------------- | ------------ |
| 468 | 6 | 2:00 a.m. | 2.0 | ------------------- | ------------ | 12,600 S., 900 W. | 1 |
| 469 | 8 | 7:15 p.m. | 2.0 | ------------------- | ------------ | 13,700 S., 1,000 E. | 1 |
| 470 | 9 | 7:29 a.m. | 1.8 | ------------------- | ------------ | 13,800 S., 2,700 W. | 3 |
| 471 | 9 | 9:59 a.m. | 1.9 | 41,500 N., 56,700 E. | 1 | ------------------- | ------------ |
| 472 | 9 | 1:17 p.m. | 1.9 | ------------------- | ------------ | 14,100 S., 600 W. | 0 |
| 473 | 9 | 3:21 p.m. | 2.2 | 40,600 N., 56,600 E. | 6 | ------------------- | ------------ |
| 474 | 10 | 3:39 a.m. | 2.1 | ------------------- | ------------ | 14,200 S., 700 W. | 3 |
| 475 | 10 | 10:02 a.m. | 1.9 | 42,000 N., 57,400 E. | 2 | ------------------- | ------------ |
| 476 | 10 | 1:27 p.m. | 2.0 | 41,000 N., 57,100 E. | 3 | ------------------- | ------------ |
| 477 | 11 | 3:36 a.m. | 1.8 | ------------------- | ------------ | 12,200 S., 1,400 E. | 3 |
| 478 | 11 | 1:09 p.m. | 1.9 | 40,100 N., 56,200 E. | 5 | ------------------- | ------------ |
| 479 | 11 | 10:29 p.m. | 2.2 | 40,300 N., 61,700 E. | 1 | ------------------- | ------------ |
| 480 | 12 | 12:25 a.m. | 2.0 | ------------------- | ------------ | 13,800 S., 100 E. | 3 |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MST) | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 481 | Dec 12 | 4:06 a.m. | 1.8 | ------------------ | ---------- | 11,400 S., 2,300 E. | 5 |
| 482 | 12 | 7:54 a.m. | 1.8 | 39,800 N., 54,800 E. | 7 | ------------------ | ---------- |
| 483 | 12 | 8:32 p.m. | 1.8 | 56,600 N., 50,600 E. | 7 | ------------------ | ---------- |
| 484 | 13 | 6:14 a.m. | 1.9 | ------------------ | ---------- | 13,600 S., 1,500 E. | 1 |
| 485 | 13 | 9:03 a.m. | 1.9 | ------------------ | ---------- | 21,200 S., 3,500 E. | 1 |
| 486 | 13 | 8:26 p.m. | 1.7 | 58,100 N., 51,700 E. | 5 | ------------------ | ---------- |
| 487 | 14 | 12:14 a.m. | 1.9 | 57,700 N., 49,900 E. | 7 | ------------------ | ---------- |
| 488 | 15 | 9:56 a.m. | 2.0 | ------------------ | ---------- | 17,600 S., 1,700 E. | 1 |
| 489 | 16 | 2:36 a.m. | 2.0 | ------------------ | ---------- | 16,800 S., 2,000 E. | 3 |
| 490 | 16 | 7:55 a.m. | 1.9 | 39,700 N., 56,600 E. | 3 | ------------------ | ---------- |
| 491 | 16 | 11:06 a.m. | 1.7 | 58,100 N., 53,600 E. | 7 | ------------------ | ---------- |
| 492 | 16 | 6:05 p.m. | 1.9 | ------------------ | ---------- | 13,400 S., 600 W. | 1 |
| 493 | 17 | 10:14 a.m. | 1.8 | 41,900 N., 56,700 E. | 1 | ------------------ | ---------- |
| 494 | 17 | 12:09 p.m. | 1.6 | 59,000 N., 52,700 E. | 7 | ------------------ | ---------- |
| 495 | 17 | 10:27 p.m. | 1.8 | ------------------ | ---------- | 17,100 S., 2,200 E. | 1 |
| 496 | 18 | 12:28 a.m. | 1.6 | 55,900 N., 50,600 E. | 7 | ------------------ | ---------- |
| 497 | 18 | 5:46 p.m. | 1.8 | ------------------ | ---------- | 11,000 S., 400 W. | 3 |
| 498 | 19 | 12:07 a.m. | 2.1 | ------------------ | ---------- | 12,800 S., 1,100 E. | 1 |
| 499 | 19 | 1:24 a.m. | 1.8 | 67,500 N., 52,800 E. | 7 | ------------------ | ---------- |
| 500 | 23 | 8:59 p.m. | 2.0 | ------------------ | ---------- | 11,900 S., 300 E. | 1 |
| 501 | 24 | 11:20 p.m. | 2.0 | ------------------ | ---------- | 12,400 S., 200 E. | 1 |
| 502 | 25 | 3:35 a.m. | 2.0 | ------------------ | ---------- | 13,600 S., 500 E. | 3 |
| 503 | 25 | 3:46 a.m. | 1.8 | ------------------ | ---------- | 9,800 S., 200 E. | 5 |

Table 3.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1969--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MST) | | | | | |
| 504 | Dec 26 | 11:37 a.m. | 2.0 | -------------------- | ------------ | 12,700 S., 1,100 W. | 7 |
| 505 | 26 | 3:39 p.m. | 1.9 | -------------------- | ------------ | 12,600 S., 400 W. | 7 |
| 506 | 26 | 10:32 p.m. | 1.9 | 59,800 N., 52,500 E. | 7 | -------------------- | ------------ |
| 507 | 27 | 2:42 a.m. | 2.0 | -------------------- | ------------ | 12,800 S., 400 E. | 3 |
| 508 | 27 | 4:13 a.m. | 1.9 | -------------------- | ------------ | 12,800 S., 100 E. | 3 |
| 509 | 27 | 4:44 p.m. | 1.8 | -------------------- | ------------ | 12,800 S., 200 W. | 3 |
| 510 | 27 | 5:51 p.m. | 2.1 | -------------------- | ------------ | 22,700 S., 2,500 E. | 1 |
| 511 | 28 | 5:02 a.m. | 2.5 | 47,500 N., 56,400 E. | 5 | -------------------- | ------------ |
| 512 | 28 | 12:09 p.m. | 2.1 | 39,000 N., 55,600 E. | 6 | -------------------- | ------------ |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MST) | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 1 | Jan 1 | 1:45 p.m. | 2.0 | 56,700 N., 51,600 E. | 3 | ---------- | ---------- |
| 2 | 2 | 8:48 a.m. | 2.2 | 57,700 N., 52,900 E. | 6 | ---------- | ---------- |
| 3 | 4 | 7:27 p.m. | 1.8 | 58,800 N., 48,400 E. | 7 | ---------- | ---------- |
| 4 | 4 | 7:28 p.m. | 2.0 | 59,200 N., 50,700 E. | 6 | ---------- | ---------- |
| 5 | 5 | 11:41 p.m. | 1.8 | ---------- | ---------- | 12,700 S., 500 W. | 3 |
| 6 | 6 | 9:17 p.m. | 1.9 | ---------- | ---------- | 12,900 S., 100 E. | 3 |
| 7 | 6 | 11:47 p.m. | 1.9 | ---------- | ---------- | 14,100 S., 200 E. | 3 |
| 8 | 7 | 12:31 a.m. | 1.8 | ---------- | ---------- | 14,400 S., 100 E. | 3 |
| 9 | 7 | 12:17 p.m. | 1.8 | 41,400 N., 56,800 E. | 1 | ---------- | ---------- |
| 10 | 7 | 8:19 p.m. | 1.8 | ---------- | ---------- | 13,200 S., 100 E. | 3 |
| 11 | 8 | 6:52 a.m. | 1.9 | ---------- | ---------- | 14,300 S., 700 E. | 1 |
| 12 | 8 | 11:09 a.m. | 1.9 | ---------- | ---------- | 13,700 S., 100 W. | 3 |
| 13 | 8 | 12:58 a.m. | 1.8 | 40,500 N., 55,100 E. | 5 | ---------- | ---------- |
| 14 | 8 | 2:56 p.m. | 1.9 | 40,300 N., 55,500 E. | 5 | ---------- | ---------- |
| 15 | 9 | 5:09 a.m. | 1.8 | 40,600 N., 56,700 E. | 6 | ---------- | ---------- |
| 16 | 9 | 11:24 p.m. | 2.5 | ---------- | ---------- | 13,900 S., 700 W. | 0 |
| 17 | 11 | 7:55 p.m. | 2.1 | ---------- | ---------- | 20,700 S., 3,900 E. | 1 |
| 18 | 12 | 7:11 a.m. | 1.9 | ---------- | ---------- | 19,100 S., 3,500 E. | 1 |
| 19 | 12 | 8:24 a.m. | 2.0 | 40,900 N., 56,600 E. | 3 | ---------- | ---------- |
| 20 | 12 | 2:04 p.m. | 1.8 | ---------- | ---------- | 14,200 S., 1,100 W. | 2 |
| 21 | 12 | 2:16 p.m. | 1.8 | 41,600 N., 57,200 E. | 1 | ---------- | ---------- |
| 22 | 13 | 1:12 a.m. | 1.8 | 41,100 N., 55,900 E. | 3 | ---------- | ---------- |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MST) | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 23 | Jan 13 | 1:12 a.m. | 1.8 | 41,100 N., 55,900 E. | 3 | ---------- | ---------- |
| 24 | 13 | 9:48 a.m. | 1.8 | 41,500 N., 55,800 E. | 2 | ---------- | ---------- |
| 25 | 13 | 6:20 p.m. | 1.8 | ---------- | ---------- | 13,500 S., 1,500 E. | 1 |
| 26 | 14 | 9:59 a.m. | 1.9 | 39,900 N., 57,100 E. | 1 | ---------- | ---------- |
| 27 | 14 | 1:24 p.m. | 1.7 | 57,800 N., 56,500 E. | 7 | ---------- | ---------- |
| 28 | 15 | 9:03 a.m. | 1.9 | ---------- | ---------- | 12,600 S., 100 E. | 3 |
| 29 | 15 | 9:45 a.m. | 1.6 | ---------- | ---------- | 14,300 S., 1,600 E. | 1 |
| 30 | 15 | 12:18 p.m. | 2.1 | 41,000 N., 55,100 E. | 3 | ---------- | ---------- |
| 31 | 15 | 8:19 p.m. | 1.9 | ---------- | ---------- | 8,800 S., 1,500 E. | 0 |
| 32 | 15 | 8:29 p.m. | 1.9 | 40,000 N., 55,400 E. | 5 | ---------- | ---------- |
| 33 | 16 | 10:34 a.m. | 1.9 | 59,200 N., 52,000 E. | 4 | ---------- | ---------- |
| 34 | 16 | 12:07 p.m. | 1.9 | 40,300 N., 54,400 E. | 3 | ---------- | ---------- |
| 35 | 16 | 12:10 p.m. | 1.8 | 41,400 N., 55,300 E. | 1 | ---------- | ---------- |
| 36 | 16 | 8:12 p.m. | 1.7 | 59,000 N., 45,300 E. | 7 | ---------- | ---------- |
| 37 | 17 | 12:43 a.m. | 2.0 | 40,700 N., 54,800 E. | 5 | ---------- | ---------- |
| 38 | 17 | 2:13 p.m. | 1.8 | 41,700 N., 56,300 E. | 3 | ---------- | ---------- |
| 39 | 18 | 12:56 a.m. | 1.9 | 58,200 N., 50,800 E. | 7 | ---------- | ---------- |
| 40 | 19 | 12:47 p.m. | 1.8 | 41,900 N., 55,000 E. | 3 | ---------- | ---------- |
| 41 | 19 | 1:56 p.m. | 1.8 | 41,400 N., 55,400 E. | 1 | ---------- | ---------- |
| 42 | 20 | 1:50 a.m. | 1.9 | 55,200 N., 41,600 E. | 6 | ---------- | ---------- |
| 43 | 20 | 11:44 a.m. | 1.9 | 56,700 N., 49,200 E. | 5 | ---------- | ---------- |
| 44 | 20 | 9:57 p.m. | 2.0 | 39,900 N., 56,200 E. | 5 | ---------- | ---------- |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MST) | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 45 | Jan 20 | 10:34 p.m. | 1.7 | 59,900 N., 44,000 E. | 7 | ------------ | ------------ |
| 46 | 20 | 11:44 p.m. | 1.7 | 58,500 N., 43,100 E. | 1 | ------------ | ------------ |
| 47 | 21 | 1:21 a.m. | 2.0 | ------------ | ------------ | 25,700 S., 4,500 E. | 1 |
| 48 | 21 | 5:37 a.m. | 2.6 | ------------ | ------------ | 25,200 S., 4,800 E. | 1 |
| 49 | 21 | 9:37 a.m. | 1.8 | 40,400 N., 56,500 E. | 3 | ------------ | ------------ |
| 50 | 21 | 11:20 a.m. | 1.9 | 57,600 N., 42,700 E. | 5 | ------------ | ------------ |
| 51 | 21 | 11:40 a.m. | 2.0 | 57,800 N., 42,500 E. | 4 | ------------ | ------------ |
| 52 | 21 | 11:28 p.m. | 2.0 | 58,300 N., 42,400 E. | 5 | ------------ | ------------ |
| 53 | 22 | 5:49 a.m. | 2.5 | 59,700 N., 41,600 E. | 5 | ------------ | ------------ |
| 54 | 22 | 7:10 a.m. | 2.3 | 58,100 N., 40,700 E. | 7 | ------------ | ------------ |
| 55 | 22 | 11:54 a.m. | 2.0 | 59,700 N., 42,900 E. | 5 | ------------ | ------------ |
| 56 | 22 | 12:07 p.m. | 1.8 | 40,900 N., 56,600 E. | 3 | ------------ | ------------ |
| 57 | 22 | 6:49 p.m. | 2.0 | 61,300 N., 43,600 E. | 6 | ------------ | ------------ |
| 58 | 22 | 9:58 p.m. | 1.9 | ------------ | ------------ | 14,200 S., 300 W. | 3 |
| 59 | 22 | 10:47 p.m. | 1.8 | ------------ | ------------ | 13,300 S., 400 W. | 3 |
| 60 | 23 | 12:15 p.m. | 2.0 | ------------ | ------------ | 13,700 S., 100 W. | 3 |
| 61 | 23 | 1:46 p.m. | 1.6 | 48,000 N., 55,000 E. | 2 | ------------ | ------------ |
| 62 | 23 | 6:00 p.m. | 1.9 | 59,200 N., 39,800 E. | 7 | ------------ | ------------ |
| 63 | 23 | 6:46 p.m. | 1.8 | 61,200 N., 45,200 E. | 7 | ------------ | ------------ |
| 64 | 24 | 2:00 a.m. | 1.8 | 61,800 N., 45,100 E. | 5 | ------------ | ------------ |
| 65 | 24 | 3:29 a.m. | 1.9 | ------------ | ------------ | 26,800 S., 4,900 E. | 1 |
| 66 | 24 | 7:00 a.m. | 2.2 | ------------ | ------------ | 15,800 S., 200 E. | 3 |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of Tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MST) | | | | | |
| 67 | Jan 24 | 8:26 a.m. | 1.8 | ---------- | ---------- | 13,500 S., 200 E. | 3 |
| 68 | 24 | 5:34 p.m. | 1.7 | 58,000 N., 41,900 E. | 5 | ---------- | ---------- |
| 69 | 24 | 8:03 p.m. | 2.1 | ---------- | ---------- | 13,200 S., 100 E. | 3 |
| 70 | 25 | 11:39 a.m. | 2.0 | 57,700 N., 42,100 E. | 6 | ---------- | ---------- |
| 71 | 26 | 8:24 a.m. | 1.8 | ---------- | ---------- | 12,700 S., 900 W. | 5 |
| 72 | 26 | 5:59 p.m. | 1.8 | 58,100 N., 44,200 E. | 7 | ---------- | ---------- |
| 73 | 26 | 6:00 p.m. | 1.9 | ---------- | ---------- | 9,100 S., 2,800 E. | 3 |
| 74 | 26 | 9:10 p.m. | 1.9 | ---------- | ---------- | 26,500 S., 5,200 E. | 0 |
| 75 | 26 | 9:43 p.m. | 1.9 | ---------- | ---------- | 26,300 S., 4,100 E. | 0 |
| 76 | 26 | 10:53 p.m. | 1.7 | 58,100 N., 43,900 E. | 5 | ---------- | ---------- |
| 77 | 28 | 12:05 a.m. | 1.7 | ---------- | ---------- | 13,600 S., 600 E. | 3 |
| 78 | 28 | 1:02 p.m. | 1.6 | 62,700 N., 46,500 E. | 7 | ---------- | ---------- |
| 79 | 28 | 1:08 p.m. | 1.8 | 40,500 N., 56,100 E. | 7 | ---------- | ---------- |
| 80 | 28 | 6:30 p.m. | 1.6 | 58,000 N., 43,000 E. | 5 | ---------- | ---------- |
| 81 | 29 | 12:58 p.m. | 1.9 | 40,100 N., 54,600 E. | 5 | ---------- | ---------- |
| 82 | 29 | 2:14 p.m. | 1.9 | ---------- | ---------- | 12,900 S., 500 E. | 3 |
| 83 | 29 | 7:59 p.m. | 1.7 | 57,800 N., 51,000 E. | 7 | ---------- | ---------- |
| 84 | 30 | 5:56 p.m. | 1.7 | 57,700 N., 43,700 E. | 7 | ---------- | ---------- |
| 85 | 30 | 7:14 p.m. | 1.7 | 57,800 N., 44,100 E. | 6 | ---------- | ---------- |
| 86 | 30 | 8:01 p.m. | 1.8 | 57,700 N., 40,800 E. | 7 | ---------- | ---------- |
| 87 | 30 | 8:13 p.m. | 1.5 | 58,000 N., 41,300 E. | 5 | ---------- | ---------- |
| 88 | 31 | 12:07 a.m. | 1.9 | 58,400 N., 42,600 E. | 6 | ---------- | ---------- |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MST) | Richter magnitude | Coordinates in feet | Depth of Tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 89 | Jan 31 | 12:48 p.m. | 1.7 | ------------ | ------------ | 12,900 S., 100 E. | 3 |
| 90 | 31 | 2:43 a.m. | 2.1 | 59,300 N., 41,300 E. | 6 | ------------ | ------------ |
| 91 | 31 | 2:56 a.m. | 2.2 | 57,600 N., 41,700 E. | 7 | ------------ | ------------ |
| 92 | 31 | 2:59 a.m. | 1.5 | 58,100 N., 40,900 E. | 6 | ------------ | ------------ |
| 93 | 31 | 3:04 a.m. | 1.7 | 58,500 N., 41,900 E. | 6 | ------------ | ------------ |
| 94 | Feb 2 | 3:10 p.m. | 1.8 | 40,400 N., 56,500 E. | 7 | ------------ | ------------ |
| 95 | 2 | 4:44 p.m. | 2.0 | 40,300 N., 57,500 E. | 7 | ------------ | ------------ |
| 96 | 3 | 5:31 p.m. | 2.0 | 40,100 N., 59,300 E. | 6 | ------------ | ------------ |
| 97 | 3 | 1:24 a.m. | 1.7 | 58,200 N., 51,800 E. | 7 | ------------ | ------------ |
| 98 | 3 | 1:25 a.m. | 1.7 | 59,000 N., 49,700 E. | 7 | ------------ | ------------ |
| 99 | 3 | 8:04 a.m. | 1.6 | 57,800 N., 52,000 E. | 5 | ------------ | ------------ |
| 100 | 5 | 7:56 a.m. | 2.0 | 39,400 N., 56,300 E. | 7 | ------------ | ------------ |
| 101 | 5 | 7:11 p.m. | 2.4 | 62,300 N., 45,600 E. | 6 | ------------ | ------------ |
| 102 | 5 | 9:20 p.m. | 2.3 | 41,100 N., 57,100 E. | 3 | ------------ | ------------ |
| 103 | 6 | 5:03 a.m. | 2.4 | ------------ | ------------ | 8,300 S., 2,400 E. | 3 |
| 104 | 6 | 9:09 a.m. | 2.3 | 57,300 N., 43,100 E. | 5 | ------------ | ------------ |
| 105 | 6 | 9:18 a.m. | 1.8 | 40,900 N., 55,600 E. | 5 | ------------ | ------------ |
| 106 | 6 | 12:57 p.m. | 1.8 | 41,900 N., 56,100 E. | 5 | ------------ | ------------ |
| 107 | 6 | 2:15 p.m. | 1.7 | 41,300 N., 57,300 E. | 5 | ------------ | ------------ |
| 108 | 6 | 5:15 p.m. | 2.2 | 58,200 N., 42,300 E. | 6 | ------------ | ------------ |
| 109 | 6 | 5:15 p.m. | 2.0 | 58,900 N., 42,700 E. | 6 | ------------ | ------------ |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| Tremor No. | Date | Time (MST). | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| 110 | Feb 7 | 3:02 p.m. | 1.6 | 57,700 N., 42,100 E. | 6 | ------------------ | ------------ |
| 111 | 7 | 3:29 p.m. | 1.7 | ------------------ | ------------ | 13,900 S., 700 E. | 3 |
| 112 | 8 | 10:04 p.m. | 2.0 | ------------------ | ------------ | 20,300 S., 1,500 E. | 1 |
| 113 | 9 | 4:26 p.m. | 1.9 | 40,700 N., 57,100 E. | 7 | ------------------ | ------------ |
| 114 | 10 | 6:16 a.m. | 1.9 | 40,600 N., 58,100 E. | 5 | ------------------ | ------------ |
| 115 | 10 | 12:47 p.m. | 2.3 | 57,400 N., 44,000 E. | 5 | ------------------ | ------------ |
| 116 | 10 | 2:12 p.m. | 2.0 | 40,200 N., 56,800 E. | 6 | ------------------ | ------------ |
| 117 | 10 | 2:26 p.m. | 1.7 | ------------------ | ------------ | 12,700 S., 900 W. | 3 |
| 118 | 11 | 4:58 a.m. | 2.0 | 57,000 N., 43,700 E. | 5 | ------------------ | ------------ |
| 119 | 11 | 8:37 a.m. | 2.0 | 40,200 N., 56,800 E. | 7 | ------------------ | ------------ |
| 120 | 11 | 9:10 a.m. | 2.0 | 40,000 N., 57,900 E. | 5 | ------------------ | ------------ |
| 121 | 11 | 11:18 p.m. | 2.0 | 46,000 N., 57,800 E. | 3 | ------------------ | ------------ |
| 122 | 12 | 7:18 a.m. | 2.3 | ------------------ | ------------ | 29,400 S., 5,600 E. | 0 |
| 123 | 12 | 10:40 a.m. | 2.0 | 40,000 N., 58,500 E. | 6 | ------------------ | ------------ |
| 124 | 12 | 6:53 p.m. | 2.3 | 57,000 N., 43,100 E. | 6 | ------------------ | ------------ |
| 125 | 12 | 7:11 p.m. | 2.3 | 40,300 N., 57,500 E. | 6 | ------------------ | ------------ |
| 126 | 12 | 9:00 p.m. | 1.9 | 40,400 N., 56,500 E. | 7 | ------------------ | ------------ |
| 127 | 13 | 12:00 midnight | 1.6 | 58,500 N., 43,600 E. | 7 | ------------------ | ------------ |
| 128 | 13 | 11:59 a.m. | 2.0 | 40,700 N., 57,100 E. | 7 | ------------------ | ------------ |
| 129 | 13 | 10:30 p.m. | 1.8 | 58,700 N., 44,200 E. | 5 | ------------------ | ------------ |
| 130 | 14 | 6:00 p.m. | 2.0 | 58,400 N., 42,900 E. | 7 | ------------------ | ------------ |
| 131 | 14 | 9:12 p.m. | 1.7 | ------------------ | ------------ | 11,600 S., 400 W. | 3 |
| 132 | 15 | 1:23 p.m. | 1.6 | ------------------ | ------------ | 14,600 S., 700 E. | 3 |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magni-tude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MST) | | | | | |
| 133 | Feb 15 | 2:05 p.m. | 1.8 | 58,500 N., 52,000 E. | 7 | --- | --- |
| 134 | 15 | 4:04 p.m. | 2.0 | 58,700 N., 41,000 E. | 7 | --- | --- |
| 135 | 16 | 6:48 p.m. | 1.8 | 41,300 N., 54,600 E. | 4 | --- | --- |
| 136 | 17 | 2:54 a.m. | 1.7 | --- | --- | 15,300 S., 1,300 E. | 1 |
| 137 | 17 | 8:02 p.m. | 1.9 | 58,200 N., 42,200 E. | 7 | --- | --- |
| 138 | 17 | 11:48 p.m. | 1.8 | 56,400 N., 44,900 E. | 7 | --- | --- |
| 139 | 18 | 7:16 a.m. | 1.9 | 57,700 N., 43,200 E. | 7 | --- | --- |
| 140 | 20 | 6:14 a.m. | 1.8 | --- | --- | 12,300 S., 900 W. | 3 |
| 141 | 20 | 6:58 a.m. | 2.1 | --- | --- | 12,200 S., 1,400 E. | 3 |
| 142 | 20 | 7:17 a.m. | 1.8 | --- | --- | 13,200 S., 100 E. | 2 |
| 143 | 20 | 11:14 p.m. | 2.5 | --- | --- | 18,600 S., 1,600 E. | 5 |
| 144 | 21 | 11:56 a.m. | 2.0 | 58,600 N., 44,000 E. | 7 | --- | --- |
| 145 | 21 | 4:52 p.m. | 1.5 | 57,700 N., 46,500 E. | 7 | --- | --- |
| 146 | 21 | 6:24 p.m. | 1.5 | 59,000 N., 47,000 E. | 7 | --- | --- |
| 147 | 25 | 9:02 a.m. | 2.1 | 40,900 N., 57,800 E. | 7 | --- | --- |
| 148 | 25 | 10:57 a.m. | 1.8 | --- | --- | 13,900 S., 700 E. | 3 |
| 149 | 26 | 9:36 a.m. | 2.0 | 40,000 N., 58,400 E. | 6 | --- | --- |
| 150 | 26 | 9:50 a.m. | 1.6 | 58,300 N., 42,200 E. | 7 | --- | --- |
| 151 | 26 | 10:59 p.m. | 2.2 | 40,400 N., 56,500 E. | 7 | --- | --- |
| 152 | 27 | 2:22 a.m. | 2.3 | 57,100 N., 43,400 E. | 6 | --- | --- |
| 153 | 27 | 3:57 p.m. | 1.9 | 57,100 N., 43,400 E. | 6 | --- | --- |
| 154 | 27 | 4:42 p.m. | 1.6 | --- | --- | 21,400 S., 2,000 E. | 1 |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MST) | Richter magni- tude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 155 | Feb 27 | 5:02 p.m. | 2.0 | 40,100 N., 57,300 E. | 7 | ---------- | ---------- |
| 156 | 27 | 9:20 p.m. | 1.9 | 57,400 N., 43,900 E. | 6 | ---------- | ---------- |
| 157 | 27 | 11:42 p.m. | 2.3 | 57,200 N., 44,200 E. | 5 | ---------- | ---------- |
| 158 | 28 | 12:27 a.m. | 2.4 | 57,700 N., 43,300 E. | 6 | ---------- | ---------- |
| 159 | 28 | 8:58 a.m. | 2.2 | ---------- | ---------- | 18,400 S., 1,300 E. | 1 |
| 160 | 28 | 1:43 p.m. | 1.7 | ---------- | ---------- | 12,900 S., 700 W. | 5 |
| 161 | 28 | 1:53 p.m. | 1.8 | ---------- | ---------- | 13,300 S., 800 W. | 3 |
| 162 | 28 | 8:59 p.m. | 1.9 | 57,800 N., 42,100 E. | 7 | ---------- | ---------- |
| 163 | Mar 1 | 8:40 a.m. | 2.3 | ---------- | ---------- | 13,100 S., 800 W. | 3 |
| 164 | 2 | 1:30 a.m. | 1.8 | 57,600 N., 44,700 E. | 7 | ---------- | ---------- |
| 165 | 2 | 10:50 a.m. | 1.8 | ---------- | ---------- | 13,000 S., 300 W. | 7 |
| 166 | 2 | 8:57 p.m. | 2.0 | 58,200 N., 42,300 E. | 7 | ---------- | ---------- |
| 167 | 3 | 12:12 a.m. | 1.6 | ---------- | ---------- | 13,200 S., 100 E. | 3 |
| 168 | 3 | 1:47 a.m. | 2.3 | 57,100 N., 42,700 E. | 6 | ---------- | ---------- |
| 169 | 3 | 11:31 a.m. | 2.0 | 40,100 N., 55,900 E. | 7 | ---------- | ---------- |
| 170 | 3 | 5:00 p.m. | 1.7 | 58,900 N., 42,500 E. | 6 | ---------- | ---------- |
| 171 | 4 | 1:36 a.m. | 1.9 | 58,000 N., 40,600 E. | 7 | ---------- | ---------- |
| 172 | 4 | 3:07 a.m. | 2.0 | 61,400 N., 46,200 E. | 6 | ---------- | ---------- |
| 173 | 4 | 10:03 a.m. | 2.1 | 57,200 N., 42,700 E. | 7 | ---------- | ---------- |
| 174 | 4 | 10:28 a.m. | 1.9 | 57,100 N., 43,400 E. | 6 | ---------- | ---------- |
| 175 | 4 | 12:58 p.m. | 2.1 | 40,300 N., 57,200 E. | 7 | ---------- | ---------- |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| Tremor No. | Date | Time (MST) | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| 176 | Mar 4 | 7:43 p.m. | 2.0 | 63,200 N., 44,500 E. | 6 | ------------------ | ---------- |
| 177 | 5 | 11:21 a.m. | 2.3 | 57,400 N., 44,000 E. | 6 | ------------------ | ---------- |
| 178 | 5 | 5:46 p.m. | 2.1 | 57,100 N., 43,400 E. | 7 | ------------------ | ---------- |
| 179 | 5 | 6:00 p.m. | 2.0 | 59,200 N., 43,200 E. | 6 | ------------------ | ---------- |
| 180 | 5 | 6:09 p.m. | 1.8 | 57,900 N., 44,500 E. | 7 | ------------------ | ---------- |
| 181 | 7 | 10:22 a.m. | 1.9 | ------------------ | ---------- | 13,100 S., 800 W. | 3 |
| 182 | 7 | 10:05 a.m. | 2.3 | 64,300 N., 45,800 E. | 6 | ------------------ | ---------- |
| 183 | 9 | 12:34 p.m. | 1.9 | ------------------ | ---------- | 23,200 S., 4,700 E. | 1 |
| 184 | 9 | 5:43 p.m. | 2.0 | 57,300 N., 52,400 E. | 6 | ------------------ | ---------- |
| 185 | 9 | 6:44 p.m. | 1.8 | ------------------ | ---------- | 21,400 S., 5,000 E. | 3 |
| 186 | 9 | 8:41 p.m. | 2.2 | 56,900 N., 43,600 E. | 6 | ------------------ | ---------- |
| 187 | 10 | 11:34 a.m. | 2.0 | ------------------ | ---------- | 17,200 S., 1,200 E. | 3 |
| 188 | 10 | 1:30 a.m. | 2.1 | 57,300 N., 43,100 E. | 6 | ------------------ | ---------- |
| 189 | 10 | 11:23 p.m. | 1.9 | 57,700 N., 42,100 E. | [illegible] | ------------------ | ---------- |
| 190 | 12 | 12:35 p.m. | 2.0 | 40,200 N., 56,500 E. | 7 | ------------------ | ---------- |
| 191 | 13 | 2:45 p.m. | 1.8 | 39,600 N., 56,000 E. | 7 | ------------------ | ---------- |
| 192 | 13 | 3:08 p.m. | 2.1 | ------------------ | ---------- | 13,900 S., 100 W. | 1 |
| 193 | 13 | 5:47 p.m. | 2.0 | ------------------ | ---------- | 13,000 S., 800 W. | 3 |
| 194 | 13 | 10:45 p.m. | 2.0 | 38,800 N., 56,400 E. | 7 | ------------------ | ---------- |
| 195 | 13 | 11:53 p.m. | 1.9 | ------------------ | ---------- | 12,200 S., 400 W. | 3 |
| 196 | 15 | 1:54 a.m. | 2.1 | ------------------ | ---------- | 15,600 S., 1,700 E. | 7 |
| 197 | 15 | 11:05 p.m. | 2.4 | 57,300 N., 41,600 E. | 7 | ------------------ | ---------- |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MST) | | | | | |
| 198 | Mar 16 | 1:39 a.m. | 2.2 | 41,800 N., 56,800 E. | 6 | ---------- | ---------- |
| 199 | 16 | 9:31 a.m. | 1.8 | ---------- | ---------- | 16,300 S., 1,500 E. | 1 |
| 200 | 16 | 1:13 p.m. | 1.9 | 40,300 N., 55,500 E. | 7 | ---------- | ---------- |
| 201 | 16 | 6:23 p.m. | 2.2 | 40,200 N., 56,500 E. | 7 | ---------- | ---------- |
| 202 | 16 | 11:56 p.m. | 2.0 | 57,800 N., 42,600 E. | 7 | ---------- | ---------- |
| 203 | 17 | 2:14 a.m. | 2.3 | 57,100 N., 43,400 E. | 7 | ---------- | ---------- |
| 204 | 17 | 7:23 a.m. | 2.0 | 57,300 N., 42,400 E. | 7 | ---------- | ---------- |
| 205 | 17 | 11:04 a.m. | 2.0 | 57,100 N., 43,400 E. | 6 | ---------- | ---------- |
| 206 | 17 | 12:13 p.m. | 1.9 | 57,300 N., 42,400 E. | 7 | ---------- | ---------- |
| 207 | 17 | 10:21 p.m. | 2.0 | 56,500 N., 43,400 E. | 6 | ---------- | ---------- |
| 208 | 17 | 11:38 p.m. | 2.0 | 40,300 N., 54,800 E. | 7 | ---------- | ---------- |
| 209 | 18 | 3:06 a.m. | 2.1 | 58,000 N., 45,200 E. | 6 | ---------- | ---------- |
| 210 | 18 | 3:16 a.m. | 2.0 | 57,200 N., 45,000 E. | 7 | ---------- | ---------- |
| 211 | 18 | 5:46 a.m. | 2.0 | 56,500 N., 43,400 E. | 7 | ---------- | ---------- |
| 212 | 18 | 3:51 p.m. | 1.7 | 57,200 N., 43,400 E. | 7 | ---------- | ---------- |
| 213 | 19 | 1:11 a.m. | 1.9 | 58,100 N., 46,100 E. | 7 | ---------- | ---------- |
| 214 | 20 | 7:43 p.m. | 2.0 | ---------- | ---------- | 13,600 S., 1,100 E | 1 |
| 215 | 20 | 2:51 a.m. | 1.9 | 56,900 N., 43,600 E. | 7 | ---------- | ---------- |
| 216 | 24 | 1:30 a.m. | 2.2 | 57,800 N., 42,100 E. | 7 | ---------- | ---------- |
| 217 | 24 | 3:03 a.m. | 1.8 | 57,300 N., 43,800 E. | 6 | ---------- | ---------- |
| 218 | 24 | 6:47 a.m. | 2.0 | 57,000 N., 43,100 E. | 7 | ---------- | ---------- |
| 219 | 24 | 2:16 p.m. | 2.3 | 40,600 N., 55,600 E. | 7 | ---------- | ---------- |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| Tremor No. | Date | Time (MST) | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| 220 | Mar 24 | 2:28 p.m. | 1.8 | 57,600 N., 43,700 E. | 7 | ---------- | ---------- |
| 221 | 24 | 4:30 p.m. | 1.7 | ---------- | ---------- | 17,800 S., 4,300 E. | 7 |
| 222 | 25 | 4:01 a.m. | 2.0 | 39,200 N., 56,300 E. | 7 | ---------- | ---------- |
| 223 | 25 | 4:52 a.m. | 1.7 | ---------- | ---------- | 23,500 S., 6,000 E. | 0 |
| 224 | 25 | 10:26 a.m. | 2.4 | 39,300 N., 55,800 E. | 7 | ---------- | ---------- |
| 225 | 25 | 1:45 p.m. | 2.3 | 40,100 N., 59,800 E. | 7 | ---------- | ---------- |
| 226 | 25 | 4:38 p.m. | 2.4 | 57,800 N., 42,600 E. | 7 | ---------- | ---------- |
| 227 | 25 | 4:39 p.m. | 2.3 | 57,600 N., 44,700 E. | 7 | ---------- | ---------- |
| 228 | 25 | 5:01 p.m. | 1.8 | 56,900 N., 43,100 E. | 7 | ---------- | ---------- |
| 229 | 26 | 1:03 p.m. | 1.6 | 39,400 N., 56,900 E. | 7 | ---------- | ---------- |
| 230 | 30 | 12:47 p.m. | 1.9 | 58,200 N., 42,100 E. | 7 | ---------- | ---------- |
| 231 | 31 | 3:33 a.m. | 2.3 | 42,500 N., 54,000 E. | 7 | ---------- | ---------- |
| 232 | 31 | 4:42 p.m. | 2.0 | 40,500 N., 53,100 E. | 7 | ---------- | ---------- |
| 233 | Apr 1 | 10:33 a.m. | 2.0 | ---------- | ---------- | 17,100 S., 4,300 E. | 1 |
| 234 | 1 | 2:20 p.m. | 2.3 | 59,500 N., 50,000 E. | 7 | ---------- | ---------- |
| 235 | 2 | 4:55 a.m. | 2.1 | 59,200 N., 50,200 E. | 7 | ---------- | ---------- |
| 236 | 2 | 10:22 p.m. | 1.9 | ---------- | ---------- | 26,100 S., 3,300 E. | 0 |
| 237 | 3 | 10:15 a.m. | 2.3 | 46,000 N., 55,700 E. | 7 | ---------- | ---------- |
| 238 | 3 | 10:05 p.m. | 1.9 | ---------- | ---------- | 15,700 S., 2,500 E. | 3 |
| 239 | 3 | 11:24 p.m. | 2.1 | 41,100 N., 54,800 E. | 5 | ---------- | ---------- |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| Tremor No. | Date | Time (MST) | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| 240 | Apr 4 | 2:33 a.m. | 2.0 | 54,800 N., 40,200 E. | 6 | ---------- | ---------- |
| 241 | 7 | 9:24 a.m. | 2.0 | 41,400 N., 57,800 E. | 7 | ---------- | ---------- |
| 242 | 7 | 9:34 a.m. | 1.6 | 52,400 N., 51,900 E. | 7 | ---------- | ---------- |
| 243 | 7 | 10:17 a.m. | 2.3 | 40,200 N., 56,900 E. | 7 | ---------- | ---------- |
| 244 | 7 | 12:16 p.m. | 1.7 | ---------- | ---------- | 13,600 S., 700 W. | 1 |
| 245 | 8 | 12:14 p.m. | 1.9 | 40,500 N., 55,200 E. | 7 | ---------- | ---------- |
| 246 | 8 | 1:59 p.m. | 1.8 | ---------- | ---------- | 16,800 S., 2,000 E. | 1 |
| 247 | 8 | 2:27 p.m. | 2.2 | 41,800 N., 55,300 E. | 7 | ---------- | ---------- |
| 248 | 8 | 9:10 p.m. | 2.1 | ---------- | ---------- | 15,200 S., 1,700 E. | 1 |
| 249 | 8 | 9:41 p.m. | 1.5 | 58,100 N., 51,100 E. | 7 | ---------- | ---------- |
| 250 | 8 | 10:22 p.m. | 1.9 | ---------- | ---------- | 16,200 S., 1,600 E. | 1 |
| 251 | 9 | 3:36 a.m. | 1.5 | 59,200 N., 41,300 E. | 7 | ---------- | ---------- |
| 252 | 9 | 3:53 p.m. | 2.3 | 40,200 N., 54,100 E. | 7 | ---------- | ---------- |
| 253 | 9 | 11:02 a.m. | 1.7 | 57,200 N., 44,400 E. | 6 | ---------- | ---------- |
| 254 | 9 | 11:59 a.m. | 2.0 | 57,000 N., 43,600 E. | 7 | ---------- | ---------- |
| 255 | 9 | 2:08 p.m. | 2.0 | ---------- | ---------- | 15,900 S., 1,700 E. | 1 |
| 256 | 9 | 2:20 p.m. | 1.9 | 41,000 N., 53,400 E. | 5 | ---------- | ---------- |
| 257 | 9 | 3:04 p.m. | 2.0 | 40,200 N., 54,100 E. | 7 | ---------- | ---------- |
| 258 | 9 | 3:08 p.m. | 2.1 | 40,600 N., 55,200 E. | 7 | ---------- | ---------- |
| 259 | 10 | 4:26 a.m. | 1.8 | ---------- | ---------- | 19,500 S., 2,000 E. | 1 |
| 260 | 11 | 3:25 p.m. | 2.4 | 39,900 N., 56,100 E. | | ---------- | ---------- |
| 261 | 11 | 7:51 p.m. | 2.0 | ---------- | ---------- | 17,600 S., 4,100 E. | 1 |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-) sea level in thousands of feet |
| | | (MST) | | | | | |
| 262 | Apr 13 | 5:01 a.m. | 1.6 | ---------- | ---------- | 15,700 S., 700 W. | 1 |
| 263 | 13 | 11:43 a.m. | 1.7 | ---------- | ---------- | 14,700 S., 1,400 E. | 1 |
| 264 | 13 | 1:19 p.m. | 1.7 | 43,200 N., 55,200 E. | 7 | ---------- | ---------- |
| 265 | 13 | 1:58 p.m. | 2.0 | 39,100 N., 54,700 E. | 7 | ---------- | ---------- |
| 266 | 13 | 10:26 p.m. | 1.8 | ---------- | ---------- | 16,200 S., 600 E. | 1 |
| 267 | 14 | 2:59 a.m. | 2.0 | ---------- | ---------- | 21,800 S., 2,700 E. | 0 |
| 268 | 15 | 6:46 a.m. | 1.9 | 56,600 N., 46,200 E. | 7 | ---------- | ---------- |
| 269 | 15 | 11:47 a.m. | 2.2 | 57,800 N., 42,700 E. | 7 | ---------- | ---------- |
| 270 | 20 | 6:38 p.m. | 2.1 | ---------- | ---------- | 19,200 S., 2,700 E. | 1 |
| 271 | 22 | 4:46 a.m. | 1.9 | 44,400 N., 53,800 E. | 6 | ---------- | ---------- |
| 272 | 22 | 11:26 a.m. | 2.0 | 39,800 N., 55,400 E. | 7 | ---------- | ---------- |
| 273 | 23 | 10:56 a.m. | 1.9 | 39,300 N., 57,300 E. | 7 | ---------- | ---------- |
| 274 | 23 | 1:13 p.m. | 2.2 | 39,400 N., 56,900 E. | 7 | ---------- | ---------- |
| 275 | 23 | 8:29 p.m. | 1.8 | ---------- | ---------- | 15,100 S., 2,100 E. | 1 |
| 276 | 23 | 11:20 p.m. | 1.8 | ---------- | ---------- | 22,400 S., 2,800 E. | 1 |
| 277 | 24 | 11:31 a.m. | 2.0 | 55,200 N., 49,300 E. | 7 | ---------- | ---------- |
| 278 | 25 | 12:18 p.m. | 2.0 | 58,000 N., 51,700 E. | 6 | ---------- | ---------- |
| | | (MDT) | | | | | |
| 279 | 30 | 9:05 a.m. | 1.9 | 38,300 N., 53,900 E. | 7 | ---------- | ---------- |
| 280 | May 5 | 10:32 p.m. | 2.0 | 44,800 N., 59,700 E. | 1 | ---------- | ---------- |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MDT) | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-) sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 281 | May 9 | 10:34 a.m. | 2.0 | ------------------- | ------------ | 20,300 S., 900 E. | 2 |
| 282 | 11 | 10:38 a.m. | 1.8 | 41,000 N., 54,300 E. | 5 | ------------------ | ------------- |
| 283 | 11 | 6:08 p.m. | 1.9 | ------------------- | ------------ | 13,300 S., 3,200 W. | 3 |
| 284 | 11 | 7:11 p.m. | 1.5 | 47,500 N., 53,100 E. | 1 | ------------------ | ------------- |
| 285 | 12 | 2:38 a.m. | 2.1 | 41,000 N., 58,000 E. | 7 | ------------------ | ------------- |
| 286 | 13 | 6:26 a.m. | 2.0 | ------------------- | ------------ | 21,000 S., 900 W. | 2 |
| 287 | 14 | 4:41 p.m. | 1.5 | ------------------- | ------------ | 13,500 S., 1,000 W. | 1 |
| 288 | 14 | 5:38 p.m. | 1.9 | ------------------- | ------------ | 17,800 S., 1,000 W. | 7 |
| 289 | 14 | 6:01 p.m. | 1.9 | 39,000 N., 44,400 E. | 7 | ------------------ | ------------- |
| 290 | 15 | 2:37 a.m. | 2.0 | 39,700 N., 51,800 E. | 6 | ------------------ | ------------- |
| 291 | 15 | 10:16 a.m. | 1.5 | 40,000 N., 55,400 E. | 6 | ------------------ | ------------- |
| 292 | 15 | 12:39 a.m. | 1.8 | 37,800 N., 49,700 E. | 7 | ------------------ | ------------- |
| 293 | 19 | 2:04 p.m. | 1.7 | 38,200 N., 53,000 E. | 3 | ------------------ | ------------- |
| 294 | 19 | 8:47 p.m. | 1.8 | ------------------- | ------------ | 16,300 S., 2,600 E. | 1 |
| 295 | 19 | 10:04 p.m. | 1.7 | ------------------- | ------------ | 10,600 S., 4,200 W. | 3 |
| 296 | 19 | 11:21 p.m. | 1.9 | ------------------- | ------------ | 16,500 S., 300 W. | 3 |
| 297 | 21 | 1:09 a.m. | 1.9 | ------------------- | ------------ | 16,400 S., 5,300 W. | 1 |
| 298 | 21 | 5:16 a.m. | 2.2 | ------------------- | ------------ | 18,900 S., 300 W. | 7 |
| 299 | 21 | 5:22 a.m. | 1.6 | ------------------- | ------------ | 13,300 S., 3,200 W. | 3 |
| 300 | 21 | 5:26 a.m. | 1.8 | ------------------- | ------------ | 16,300 S., 2,600 E. | 3 |
| 301 | 21 | 9:32 a.m. | 1.8 | ------------------- | ------------ | 12,200 S., 300 W. | 1 |
| 302 | 21 | 11:30 p.m. | 1.8 | ------------------- | ------------ | 15,800 S., 600 E. | 2 |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time (MDT) | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| 303 | May 22 | 2:57 a.m. | 1.9 | ------------------ | ------------- | 16,500 S., 300 W. | 3 |
| 304 | 22 | 5:26 a.m. | 1.8 | 60,000 N., 49,700 E. | 7 | ------------------ | ------------- |
| 305 | 22 | 9:47 a.m. | 1.8 | ------------------ | ------------- | 15,100 S., 1,100 E. | 3 |
| 306 | 22 | 11:47 p.m. | 1.8 | ------------------ | ------------- | 17,700 S., 2,400 E. | 3 |
| 307 | 23 | 2:05 a.m. | 1.5 | ------------------ | ------------- | 15,100 S., 200 W. | 3 |
| 308 | 23 | 3:34 a.m. | 1.5 | ------------------ | ------------- | 15,600 S., 1,100 E. | 2 |
| 309 | 23 | 6:36 a.m. | 1.6 | 37,100 N., 55,300 E. | 7 | ------------------ | ------------- |
| 310 | 23 | 11:02 a.m. | 1.8 | ------------------ | ------------- | 16,300 S., 3,900 E. | 1 |
| 311 | 23 | 11:31 a.m. | 1.7 | ------------------ | ------------- | 11,800 S., 600 W. | 1 |
| 312 | 23 | 5:24 p.m. | 1.7 | ------------------ | ------------- | 11,000 S., 1,000 W. | 1 |
| 313 | 23 | 5:32 p.m. | 1.9 | ------------------ | ------------- | 15,000 S., 1,100 E. | 3 |
| 314 | 24 | 10:53 p.m. | 1.6 | ------------------ | ------------- | 10,700 S., 4,800 E. | 1 |
| 315 | 25 | 6:07 a.m. | 1.9 | ------------------ | ------------- | 21,300 S., 2,300 E. | 7 |
| 316 | 26 | 11:28 a.m. | 1.6 | ------------------ | ------------- | 14,300 S., 200 W. | 3 |
| 317 | 26 | 10:03 p.m. | 1.5 | 37,300 N., 56,600 E. | 7 | ------------------ | ------------- |
| 318 | 28 | 1:54 a.m. | 1.9 | 36,500 N., 56,100 E. | 7 | ------------------ | ------------- |
| 319 | 28 | 11:36 a.m. | 1.6 | ------------------ | ------------- | 21,300 S., 700 W. | 2 |
| 320 | 28 | 5:45 p.m. | 1.5 | 39,000 N., 56,200 E. | 7 | ------------------ | ------------- |
| 321 | 28 | 8:34 p.m. | 1.7 | ------------------ | ------------- | 16,500 S., 1,300 E. | 5 |
| 322 | 28 | 9:42 p.m. | 1.8 | 42,000 N., 57,600 E. | 5 | ------------------ | ------------- |
| 323 | 29 | 6:12 a.m. | 1.6 | 41,300 N., 57,600 E. | 7 | ------------------ | ------------- |
| 324 | 29 | 1:04 p.m. | 1.5 | 45,300 N., 54,000 E. | 3 | ------------------ | ------------- |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MDT) | | | | | |
| 325 | May 30 | 2:06 a.m. | 1.7 | ------------------ | ------------ | 18,600 S., 6,300 E. | 7 |
| 326 | 31 | 6:56 a.m. | 1.8 | ------------------ | ------------ | 13,500 S., 1000 E. | 1 |
| 327 | 31 | 8:27 a.m. | 1.6 | ------------------ | ------------ | 11,000 S., 1,800 E. | 1 |
| 328 | 31 | 7:42 p.m. | 1.8 | ------------------ | ------------ | 16,000 S., 1,000 E. | 3 |
| 329 | 31 | 8:36 p.m. | 1.7 | ------------------ | ------------ | 15,200 S., 800 E. | 3 |
| 330 | Jun 1 | 8:04 a.m. | 1.9 | 58,800 N., 40,700 E. | 7 | ------------------ | ------------ |
| 331 | 2 | 1:31 a.m. | 1.7 | 40,300 N., 54,900 E. | 7 | ------------------ | ------------ |
| 332 | 2 | 7:54 p.m. | 1.6 | 60,500 N., 50,000 E. | 7 | ------------------ | ------------ |
| 333 | 3 | 12:38 a.m. | 1.7 | ------------------ | ------------ | 17,900 S., 1,500 E. | 7 |
| 334 | 3 | 1:40 a.m. | 1.8 | ------------------ | ------------ | 17,800 S., 3,000 E. | 7 |
| 335 | 3 | 9:54 p.m. | 1.7 | 39,800 N., 58,400 E. | 7 | ------------------ | ------------ |
| 336 | 4 | 9:59 a.m. | 1.8 | ------------------ | ------------ | 19,800 S., 5,100 E. | 1 |
| 337 | 4 | 11:48 a.m. | 1.8 | ------------------ | ------------ | 12,300 S., 700 E. | 1 |
| Recording system inoperative June 5-August 1 | | | | | | | |
| 338 | Aug 2 | 6:35 p.m. | 2.6 | ------------------ | ------------ | 11,500 S., 1,900 W. | 6 |
| 339 | 3 | 10:10 a.m. | 1.8 | ------------------ | ------------ | 13,800 S., 1,900 W. | 7 |
| 340 | 3 | 5:44 p.m. | 2.0 | 58,200 N., 43,500 E. | 6 | ------------------ | ------------ |
| 341 | 4 | 1:50 p.m. | 1.9 | 57,600 N., 43,600 E. | 7 | ------------------ | ------------ |
| 342 | 4 | 2:10 p.m. | 2.1 | 58,500 N., 43,600 E. | 6 | ------------------ | ------------ |

Table 4 .--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| Tremor No. | Date | | Time | Richter magni-tude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|---|
| | | | (MDT) | | | | | |
| 343 | Aug | 4 | 6:29 p.m. | 1.8 | 58,400 N., 42,000 E. | 6 | ------------------ | ------------ |
| 344 | | 5 | 10:29 p.m. | 2.2 | 58,200 N., 42,500 E. | 7 | ------------------ | ------------ |
| 345 | | 6 | 3:19 a.m. | 2.3 | ------------------ | ------------ | 13,200 S., 1,500 E. | 2 |
| 346 | | 6 | 5:43 a.m. | 1.8 | ------------------ | ------------ | 13,600 S., 300 E. | 1 |
| 347 | | 6 | 6:18 p.m. | 1.8 | ------------------ | ------------ | 15,500 S., 200 E. | 1 |
| 348 | | 6 | 6:37 a.m. | 1.8 | ------------------ | ------------ | 14,200 S., 400 E. | 1 |
| 349 | | 6 | 10:06 a.m. | 2.0 | 58,200 N., 41,500 E. | 7 | ------------------ | ------------ |
| 350 | | 6 | 3:07 p.m. | 2.0 | ------------------ | ------------ | 12,500 S., 800 W. | 2 |
| 351 | | 6 | 9:43 p.m. | 2.2 | ------------------ | ------------ | 15,000 S., 200 W. | 3 |
| 352 | | 6 | 11:23 p.m. | 1.9 | ------------------ | ------------ | 13,400 S., 400 W. | 3 |
| 353 | | 7 | 2:22 a.m. | 2.1 | ------------------ | ------------ | 14,600 S., 3,200 E. | 1 |
| 354 | | 7 | 3:07 a.m. | 2.1 | ------------------ | ------------ | 16,000 S., 1,300 E. | 1 |
| 355 | | 7 | 3:39 a.m. | 1.9 | ------------------ | ------------ | 13,900 S., 300 E. | 1 |
| 356 | | 8 | 7:11 a.m. | 2.1 | 61,800 N., 46,100 E. | 7 | ------------------ | ------------ |
| 357 | | 8 | 7:29 a.m. | 1.8 | ------------------ | ------------ | 15,200 S., 100 E. | 2 |
| 358 | | 8 | 7:57 p.m. | 1.9 | ------------------ | ------------ | 15,200 S., 100 E. | 1 |
| 359 | | 10 | 4:58 p.m. | 1.8 | 58,700 N., 43,000 E. | 5 | ------------------ | ------------ |
| 360 | | 12 | 9:07 a.m. | 2.4 | 38,500 N., 56,000 E. | 6 | ------------------ | ------------ |
| 361 | | 12 | 11:04 a.m. | 2.1 | 58,700 N., 42,500 E. | 6 | ------------------ | ------------ |
| 362 | | 12 | 12:14 p.m. | 1.9 | 58,200 N., 42,600 E. | 6 | ------------------ | ------------ |
| 363 | | 13 | 12:25 a.m. | 2.4 | ------------------ | ------------ | 14,400 S., 200 W. | 1 |
| 364 | | 13 | 7:29 p.m. | 2.3 | 61,300 N., 48,600 E. | 6 | ------------------ | ------------ |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MDT) | | | | | |
| 365 | Aug 14 | 5:09 a.m. | 1.7 | ------------------ | ------------ | 11,500 S., 2,000 E. | 1 |
| 366 | 14 | 7:36 a.m. | 2.2 | ------------------ | ------------ | 14,300 S., 1,300 E. | 1 |
| 367 | 14 | 9:58 p.m. | 1.7 | 39,300 N., 54,100 E. | 5 | ------------------ | ------------ |
| 368 | 14 | 10:06 p.m. | 1.9 | 59,200 N., 42,900 E. | 7 | ------------------ | ------------ |
| 369 | 15 | 12:01 a.m. | 2.3 | 58,300 N., 43,100 E. | 7 | ------------------ | ------------ |
| 370 | 17 | 10:26 a.m. | 1.9 | ------------------ | ------------ | 13,400 S., 800 E. | 1 |
| 371 | 18 | 6:02 p.m. | 1.9 | ------------------ | ------------ | 20,200 S., 4,600 E. | 3 |
| 372 | 19 | 4:47 a.m. | 2.0 | 59,500 N., 50,400 E. | 7 | ------------------ | ------------ |
| 373 | 22 | 12:17 p.m. | 2.2 | 40,100 N., 58,400 E. | 7 | ------------------ | ------------ |
| 374 | 22 | 3:50 p.m. | 2.3 | ------------------ | ------------ | 14,400 S., 200 W. | 1 |
| 375 | 23 | 10:06 p.m. | 2.3 | 40,100 N., 56,500 E. | 7 | ------------------ | ------------ |
| 376 | 24 | 2:45 a.m. | 2.1 | ------------------ | ------------ | 13,600 S., 300 E. | 1 |
| 377 | 24 | 1:47 p.m. | 1.9 | ------------------ | ------------ | 15,200 S., 700 W. | 1 |
| 378 | 25 | 8:39 a.m. | 2.1 | ------------------ | ------------ | 25,600 S., 4,600 E. | 1 |
| 379 | 25 | 10:00 a.m. | 2.1 | ------------------ | ------------ | 15,000 S., 200 W. | 5 |
| 380 | 25 | 11:22 a.m. | 2.0 | 38,800 N., 55,600 E. | 7 | ------------------ | ------------ |
| 381 | 25 | 1:22 p.m. | 2.1 | ------------------ | ------------ | 16,900 S., 2,300 E. | 1 |
| 382 | 25 | 3:31 p.m. | 2.1 | 58,500 N., 43,600 E. | 6 | ------------------ | ------------ |
| 383 | 25 | 5:23 p.m. | 2.5 | ------------------ | ------------ | 28,200 S., 3,500 E. | 1 |
| 384 | 28 | 10:03 p.m. | 2.0 | ------------------ | ------------ | 15,500 S., 1,000 E. | 1 |
| 385 | 29 | 12:29 a.m. | 2.2 | 59,600 N., 41,800 E. | 7 | ------------------ | ------------ |
| 386 | 29 | 12:59 a.m. | 1.9 | ------------------ | ------------ | 14,800 S., 700 E. | 1 |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| Tremor No. | Date | Time | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| | | (MDT) | | | | | |
| 387 | Sep 10 | 7:15 p.m. | 2.3 | 59,400 N., 41,300 E. | 7 | ------------------ | ------------ |
| 388 | 11 | 12:04 p.m. | 1.6 | 16,500 S., 1,600 E. | 1 | ------------------ | ------------ |
| 389 | 11 | 4:55 p.m. | 1.6 | ------------------ | ------------ | 16,200 S., 2,000 E. | 1 |
| 390 | 12 | 12:04 a.m. | 1.6 | ------------------ | ------------ | 16,200 S., 2,000 E. | 3 |
| 391 | 12 | 3:30 p.m. | 1.7 | 61,300 N., 42,200 E. | 7 | ------------------ | ------------ |
| 392 | 12 | 11:30 p.m. | 2.0 | ------------------ | ------------ | 16,100 S., 300 E. | 3 |
| 393 | 13 | 4:11 p.m. | 1.8 | ------------------ | ------------ | 15,200 S., 700 E. | 3 |
| 394 | 13 | 6:41 p.m. | 2.3 | ------------------ | ------------ | 14,600 S., 300 E. | 1 |
| 395 | 13 | 7:09 p.m. | 1.9 | ------------------ | ------------ | 15,600 S., 1,800 E. | 1 |
| 396 | 14 | 11:07 a.m. | 1.8 | 55,300 N., 49,300 E. | 7 | ------------------ | ------------ |
| 397 | 15 | 12:17 a.m. | 2.3 | 62,900 N., 42,700 E. | 1 | ------------------ | ------------ |
| 398 | 15 | 12:57 a.m. | 2.3 | 59,100 N., 41,600 E. | 6 | ------------------ | ------------ |
| 399 | 15 | 7:27 a.m. | 2.0 | 59,900 N., 41,100 E. | 6 | ------------------ | ------------ |
| 400 | 16 | 11:11 a.m. | 1.9 | 63,800 N., 44,400 E. | 7 | ------------------ | ------------ |
| 401 | 16 | 6:51 p.m. | 2.2 | ------------------ | ------------ | 15,200 S., 1,500 E. | 1 |
| 402 | 17 | 6:44 p.m. | 2.0 | 62,600 N., 40,600 E. | 2 | ------------------ | ------------ |
| 403 | 17 | 6:59 p.m. | 2.1 | ------------------ | ------------ | 13,800 S., 100 W. | 1 |
| 404 | 19 | 12:30 a.m. | 2.3 | 38,300 N., 54,100 E. | 5 | ------------------ | ------------ |
| 405 | 19 | 1:26 a.m. | 2.0 | 62,200 N., 43,900 E. | 7 | ------------------ | ------------ |
| 406 | 24 | 6:29 p.m. | 2.0 | ------------------ | ------------ | 14,600 S., 300 E. | 1 |
| 407 | 24 | 9:29 p.m. | 2.4 | ------------------ | ------------ | 15,700 S., 1,200 W. | 3 |
| 408 | 26 | 10:12 p.m. | 1.8 | 60,100 N., 41,900 E. | 6 | ------------------ | ------------ |
| 409 | 27 | 9:56 a.m. | 2.3 | ------------------ | ------------ | 1,600 S., 200 E. | 5 |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| Tremor No. | Date | Time (MDT) | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| 410 | Sep 27 | 10:14 a.m. | 2.3 | ------------------ | ---------- | 12,400 S., 1,700 W. | 5 |
| 411 | 27 | 10:37 a.m. | 2.1 | ------------------ | ---------- | 15,200 S., 1,000 E. | 1 |
| 412 | 27 | 5:40 p.m. | 2.1 | ------------------ | ---------- | 10,700 S., 200 E. | 3 |
| 413 | 28 | 3:09 p.m. | 2.3 | ------------------ | ---------- | 12,200 S., 1,000 E. | 2 |
| 414 | 29 | 6:11 p.m. | 1.8 | ------------------ | ---------- | 12,300 S., 500 E. | 7 |
| 415 | 29 | 10:43 p.m. | 1.9 | ------------------ | ---------- | 11,000 S., 2,000 W. | 7 |
| 416 | Oct 1 | 7:43 a.m. | 2.0 | 56,000 N., 51,500 E. | 5 | ------------------ | ---------- |
| 417 | 3 | 8:22 a.m. | 1.6 | ------------------ | ---------- | 15,700 S., 700 W. | 1 |
| 418 | 3 | 10:05 p.m. | 2.1 | 57,800 N., 43,100 E. | 7 | ------------------ | ---------- |
| 419 | 5 | 5:20 a.m. | 2.1 | ------------------ | ---------- | 17,500 S., 1,300 E. | 3 |
| 420 | 7 | 11:58 p.m. | 2.0 | 58,300 N., 44,500 E. | 7 | ------------------ | ---------- |
| 421 | 9 | 9:17 a.m. | 2.1 | ------------------ | ---------- | 13,600 S., 1,000 E. | 1 |
| 422 | 9 | 5:26 p.m. | 1.8 | 63,800 N., 49,400 E. | 7 | ------------------ | ---------- |
| 423 | 9 | 10:17 p.m. | 2.0 | ------------------ | ---------- | 12,100 S., 400 W. | 1 |
| 424 | 11 | 5:56 p.m. | 2.5 | ------------------ | ---------- | 14,100 S., 500 W. | 3 |
| 425 | 12 | 5:51 p.m. | 2.5 | ------------------ | ---------- | 16,400 S., 3,800 E. | 1 |
| 426 | 14 | 12:59 a.m. | 1.7 | 56,300 N., 43,700 E. | 6 | ------------------ | ---------- |
| 427 | 14 | 1:04 a.m. | 1.7 | 59,500 N., 40,700 E. | 6 | ------------------ | ---------- |
| 428 | 14 | 3:00 a.m. | 2.5 | ------------------ | ---------- | 10,900 S., 1,000 W. | 1 |
| 429 | 14 | 3:45 a.m. | 1.8 | 59,400 N., 44,000 E. | 7 | ------------------ | ---------- |
| 430 | 14 | 2:07 p.m. | 2.6 | ------------------ | ---------- | 14,900 S., 1,300 E. | 5 |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MDT) | | | | | |
| 431 | Oct 17 | 3:51 a.m. | 1.9 | 59,600 N., 38,300 E. | 6 | ------------------ | ------------ |
| 432 | 17 | 1:15 p.m. | 1.9 | 64,800 N., 46,700 E. | 5 | ------------------ | ------------ |
| | | (MST) | | | | | |
| 433 | 28 | 2:40 a.m. | 1.9 | ------------------ | ------------ | 13,400 S., 1,600 W. | 1 |
| 434 | Nov 1 | 10:11 p.m. | 2.1 | ------------------ | ------------ | 15,000 S., 200 W. | 3 |
| 435 | 2 | 5:42 a.m. | 1.7 | 57,300 N., 45,700 E. | 7 | ------------------ | ------------ |
| 436 | 2 | 12:23 p.m. | 2.4 | ------------------ | ------------ | 15,500 S., 200 W. | 1 |
| 437 | 3 | 4:55 a.m. | 1.7 | 66,000 N., 40,900 E. | 1 | ------------------ | ------------ |
| 438 | 3 | 7:29 a.m. | 2.5 | 63,200 N., 41,500 E. | 1 | ------------------ | ------------ |
| 439 | 4 | 1:19 a.m. | 2.0 | ------------------ | ------------ | 18,500 S., 1,600 E. | 1 |
| 440 | 5 | 9:23 p.m. | 2.1 | ------------------ | ------------ | 11,600 S., 900 W. | 3 |
| 441 | 6 | 8:31 p.m. | 1.7 | 62,800 N., 41,000 E. | 7 | ------------------ | ------------ |
| 442 | 6 | 11:49 p.m. | 1.9 | 55,800 N., 42,400 E. | 7 | ------------------ | ------------ |
| 443 | 7 | 12:16 a.m. | 1.7 | ------------------ | ------------ | 12,200 S., 300 W. | 1 |
| 444 | 7 | 6:00 a.m. | 1.7 | 58,000 N., 49,400 E. | 7 | ------------------ | ------------ |
| 445 | 7 | 6:04 a.m. | 1.8 | ------------------ | ------------ | 12,900 S., 100 W. | 1 |
| 446 | 8 | 12:26 a.m. | 1.8 | 59,600 N., 42,800 E. | 7 | ------------------ | ------------ |
| 447 | 9 | 5:04 p.m. | 2.1 | ------------------ | ------------ | 19,300 S., 1,100 E. | 7 |
| 448 | 10 | 11:20 a.m. | 2.2 | 59,800 N., 48,500 E. | 7 | ------------------ | ------------ |
| 449 | 10 | 4:48 p.m. | 2.3 | 64,600 N., 41,200 E. | 7 | ------------------ | ------------ |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| Tremor No. | Date | Time | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| | | (MST) | | | | | |
| 450 | Nov 12 | 11:21 p.m. | 1.9 | ------------------ | ----------- | 15,000 S., 200 W. | 3 |
| 451 | 13 | 12:51 a.m. | 2.1 | 50,600 N., 55, 600 E. | 3 | ------------------ | ------------- |
| 452 | 13 | 4:44 a.m. | 1.8 | ------------------ | ----------- | 16,400 S., 300 W. | 3 |
| 453 | 13 | 7:47 a.m. | 2.1 | ------------------ | ----------- | 16,200 S., 2,500 E. | 1 |
| 454 | 13 | 10:46 a.m. | 2.1 | 47,300 N., 55,700 E. | 7 | ------------------ | ------------- |
| 455 | 13 | 11:02 a.m. | 2.3 | ------------------ | ----------- | 13,200 S., 1,100 W. | 7 |
| 456 | 14 | 8:48 p.m. | 1.7 | ------------------ | ----------- | 18,900 S., 3,000 E. | 1 |
| 457 | 15 | 1:34 a.m. | 2.0 | 59,800 N., 41,900 E. | 6 | ------------------ | ------------- |
| 458 | 16 | 5:40 a.m. | 2.0 | 61,600 N., 39,500 E. | 7 | ------------------ | ------------- |
| 459 | 16 | 8:02 p.m. | 2.1 | 68,700 N., 44,100 E. | 7 | ------------------ | ------------- |
| 460 | 17 | 5:43 a.m. | 1.7 | 60,800 N., 48,500 E. | 7 | ------------------ | ------------- |
| 461 | 17 | 6:27 a.m. | 1.8 | 67,400 N., 43,800 E. | 7 | ------------------ | ------------- |
| 462 | 17 | 10:00 a.m. | 1.8 | 59,700 N., 50,700 E. | 7 | ------------------ | ------------- |
| 463 | 17 | 11:43 a.m. | 2.1 | ------------------ | ----------- | 1,400 S., 200 E. | 1 |
| 464 | 18 | 1:20 a.m. | 2.2 | 47,200 N., 48,600 E. | 5 | ------------------ | ------------- |
| 465 | 18 | 5:06 a.m. | 2.1 | 57,800 N., 43,700 E. | 7 | ------------------ | ------------- |
| 466 | 21 | 4:25 p.m. | 2.5 | ------------------ | ----------- | 14,100 S., 500 W. | 1 |
| 467 | 22 | 12:37 a.m. | 1.7 | ------------------ | ----------- | 13,600 S., 600 W. | 1 |
| 468 | 22 | 2:51 a.m. | 1.7 | 57,200 N., 43,800 E. | 7 | ------------------ | ------------- |
| 469 | 22 | 3:07 p.m. | 1.8 | 67,200 N., 42,600 E. | 6 | ------------------ | ------------- |
| 470 | 22 | 3:56 p.m. | 2.1 | ------------------ | ----------- | 13,800 S., 300 E. | 1 |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| Tremor No. | Date | Time | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| | | (MST) | | | | | |
| 471 | Nov 22 | 4:33 p.m. | 1.8 | ------------------- | ----------- | 13,100 S., 600 W. | 3 |
| 472 | 22 | 8:23 p.m. | 1.7 | ------------------- | ----------- | 13,700 S., 1,300 W. | 4 |
| 473 | 23 | 6:24 a.m. | 2.0 | ------------------- | ----------- | 9,700 S., 1,200 W. | 3 |
| 474 | 23 | 10:48 a.m. | 1.8 | ------------------- | ----------- | 14,700 S., 1,000 W. | 3 |
| 475 | 23 | 5:48 p.m. | 1.8 | ------------------- | ----------- | 15,100 S., 600 W. | 2 |
| 476 | 24 | 2:11 a.m. | 2.1 | 57,700 N., 42,600 E. | 7 | ------------------- | ----------- |
| 477 | 24 | 2:19 p.m. | 1.8 | 47,900 N., 56,600 E. | 7 | ------------------- | ----------- |
| 478 | 24 | 5:21 p.m. | 1.7 | ------------------- | ----------- | 14,400 S., 600 E. | 7 |
| 479 | 25 | 6:18 a.m. | 2.2 | 58,300 N., 44,000 E. | 7 | ------------------- | ----------- |
| 480 | 26 | 9:03 a.m. | 2.0 | 56,200 N., 46,500 E. | 7 | ------------------- | ----------- |
| 481 | 26 | 10:43 p.m. | 2.6 | ------------------- | ----------- | 18,900 S., 4,300 E. | 0 |
| 482 | 27 | 6:47 a.m. | 2.0 | ------------------- | ----------- | 18,100 S., 2,100 E. | 0 |
| 483 | 27 | 9:06 p.m. | 2.2 | 58,300 N., 44,000 E. | 6 | ------------------- | ----------- |
| 484 | 28 | 10:33 p.m. | 1.9 | ------------------- | ----------- | 13,500 S., 200 E. | 1 |
| 485 | 29 | 6:33 p.m. | 1.8 | 60,000 N., 43,300 E. | 7 | ------------------- | ----------- |
| 486 | Dec 1 | 11:55 a.m. | 1.7 | 61,400 N., 46,700 E. | 7 | ------------------- | ----------- |
| 487 | 2 | 3:53 a.m. | 1.8 | ------------------- | ----------- | 20,300 S., 2,200 E. | 3 |
| 488 | 2 | 9:43 a.m. | 2.0 | 61,800 N., 40,700 E. | 7 | ------------------- | ----------- |
| 489 | 2 | 11:45 a.m. | 1.8 | 58,000 N., 50,200 E. | 7 | ------------------- | ----------- |
| 490 | 2 | 5:20 p.m. | 2.0 | 48,600 N., 54,500 E. | 7 | ------------------- | ----------- |
| 491 | 3 | 11:07 p.m. | 1.9 | ------------------- | ----------- | 13,200 S., 200 E. | 1 |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| Tremor No. | Date | Time | Richter magnitude | Sunnyside No. 1, 2, and 3 mine areas: Coordinates in feet | Sunnyside No. 1, 2, and 3 mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet | Columbia and Geneva mine areas: Coordinates in feet | Columbia and Geneva mine areas: Depth of tremor focus above or below(-)sea level in thousands of feet |
|---|---|---|---|---|---|---|---|
| | | (MST) | | | | | |
| 492 | Dec 4 | 3:11 p.m. | 2.3 | 59,400 N., 40,800 E. | 7 | ------------------ | ------------ |
| 493 | 4 | 5:00 p.m. | 2.2 | 58,000 N., 42,700 E. | 7 | ------------------ | ------------ |
| 494 | 4 | 8:47 p.m. | 2.1 | 57,600 N., 42,600 E. | 7 | ------------------ | ------------ |
| 495 | 4 | 11:45 p.m. | 2.4 | 57,400 N., 42,200 E. | 7 | ------------------ | ------------ |
| 496 | 4 | 11:47 p.m. | 2.3 | 59,800 N., 41,400 E. | 6 | ------------------ | ------------ |
| 497 | 5 | 11:41 a.m. | 2.0 | 58,200 N., 42,300 E. | 7 | ------------------ | ------------ |
| 498 | 5 | 5:32 p.m. | 1.9 | 38,300 N., 55,200 E. | 7 | ------------------ | ------------ |
| 499 | 7 | 7:07 p.m. | 1.7 | 63,400 N., 49,300 E. | 7 | ------------------ | ------------ |
| 500 | 8 | 4:36 a.m. | 1.9 | 38,600 N., 59,000 E. | 7 | ------------------ | ------------ |
| 501 | 8 | 9:36 a.m. | 2.2 | 59,000 N., 44,200 E. | 7 | ------------------ | ------------ |
| 502 | 10 | 1:41 a.m. | 2.1 | 58,900 N., 47,000 E. | 7 | ------------------ | ------------ |
| 503 | 13 | 1:49 p.m. | 1.9 | ------------------ | ------------ | 18,800 S., 400 E. | 1 |
| 504 | 15 | 9:27 a.m. | 2.4 | 48,800 N., 53,900 E. | 7 | ------------------ | ------------ |
| 505 | 16 | 4:29 p.m. | 2.1 | 65,400 N., 44,100 E. | 7 | ------------------ | ------------ |
| 506 | 16 | 10:12 p.m. | 1.9 | 57,600 N., 50,700 E. | 7 | ------------------ | ------------ |
| 507 | 18 | 1:00 a.m. | 2.3 | 56,400 N., 43,600 E. | 7 | ------------------ | ------------ |
| 508 | 18 | 2:04 p.m. | 1.7 | 58,500 N., 52,000 E. | 7 | ------------------ | ------------ |
| 509 | 18 | 2:30 p.m. | 2.3 | 48,700 N., 55,100 E. | 7 | ------------------ | ------------ |
| 510 | 18 | 7:16 p.m. | 1.9 | ------------------ | ------------ | 14,800 S., 500 E. | 1 |
| 511 | 19 | 8:13 a.m. | 1.7 | 59,600 N., 40,100 E. | 6 | ------------------ | ------------ |
| 512 | 20 | 1:21 p.m. | 2.3 | 48,800 N., 53,900 E. | 7 | ------------------ | ------------ |
| 513 | 21 | 1:08 a.m. | 2.3 | 63,800 N., 43,300 E. | 7 | ------------------ | ------------ |

Table 4.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1970--Continued

| | | | | Sunnyside No. 1, 2, and 3 mine areas | | Columbia and Geneva mine areas | |
|---|---|---|---|---|---|---|---|
| Tremor No. | Date | Time | Richter magnitude | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet | Coordinates in feet | Depth of tremor focus above or below(-)sea level in thousands of feet |
| | | (MST) | | | | | |
| 514 | Dec 21 | 2:03 a.m. | 1.8 | -------------------- | ------------ | 17,000 S., 1,600 E. | 1 |
| 515 | 21 | 3:24 a.m. | 1.9 | 68,100 N., 39,600 E. | 1 | -------------------- | ------------ |
| 516 | 21 | 7:50 p.m. | 2.0 | 64,100 N., 44,300 E. | 7 | -------------------- | ------------ |
| 517 | 22 | 4:56 p.m. | 1.8 | -------------------- | ------------ | 15,000 S., 1,900 E. | 1 |
| 518 | 22 | 11:38 p.m. | 2.5 | -------------------- | ------------ | 14,200 S., 300 W. | 3 |
| 519 | 24 | 1:59 a.m. | 1.7 | -------------------- | ------------ | 15,200 S., 300 E. | 1 |
| 520 | 24 | 8:13 a.m. | 1.9 | -------------------- | ------------ | 12,200 S., 2,900 E. | 5 |
| 521 | 29 | 5:32 a.m. | 2.5 | -------------------- | ------------ | 8,200 S., 3,100 E. | 1 |
| 522 | 29 | 3:12 p.m. | 2.3 | -------------------- | ------------ | 10,000 S., 1,700 W. | 1 |
| 523 | 30 | 12:09 p.m. | 1.8 | -------------------- | ------------ | 9,600 S., 2,600 E. | 1 |
| 524 | 31 | 8:50 a.m. | 1.8 | -------------------- | ------------ | 17,400 S., 800 W. | 1 |