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SEISMIC ACTIVITY IN THE SUNNYSIDE MINING DISTRICT, CARBON AND EMERY COUNTIES, UTAH, DURING 1968

By

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SEISMIC ACTIVITY IN THE SUNNYSIDE MINING DISTRICT, CARBON AND EMERY COUNTIES, UTAH, DURING 1968

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Abstract

More than 20,000 local earth tremors were recorded by the seismic monitoring network in the Sunnyside mining district during 1968. This is about 40 percent of the number of tremors recorded by the network in 1967. In 1968 a total of 281 tremors were of sufficient magnitude to be located accurately--about 50 percent of the number of tremors in 1967 that were located accurately.

As in previous years, nearly all the earth tremors originated near, or within a few thousand feet of, the mine workings. This distribution indicates that mine-induced stress changes caused most of the seismic activity. However, over periods of weeks and months there were significant changes in the distribution of seismic activity caused by tremors that were not directly related to mining but probably were caused by adjustment of natural stresses or by a complex combination of both natural and mine-induced stress changes.

In 1968 the distribution of tremor hypocenters varied considerably with time, relative to active mining areas and to faults present in the mine workings. During the first 6 months, most tremors originated along or near faults that trend close to or through the active mine workings. However, in the last 6 months, the tremor hypocenters tended to concentrate in the rock mass closer to, or around, the active mining areas. This shift in concentration of seismic activity with time has been noted throughout the district many times since recording began in 1963, and is apparently caused by spontaneous releases of stored strain energy resulting from mine-induced stress changes. These spontaneous releases of strain energy, together with rock creep, apparently are the mechanism of adjustment within the rock mass toward equilibrium conditions, which are continually disrupted by mining.

Although potentially hazardous bumps were rare in the Sunnyside mining district during 1968, smaller bumps and rock falls were more common in a given active mining area whenever hypocenters of larger-magnitude earth tremors concentrated near it.

Introduction

The seismic activity in the Sunnyside mining district during 1968 is

summarized in this report in order to present a current record of the seismic activity and its relation to coal mine bumps and to other coal mining problems. Timely comparisons also can be made between patterns of seismic activity during 1967 and 1968, which can in turn be compared with patterns in previous years.

The number of earth tremors recorded during 1968 was only about 40 percent of the total recorded during 1967. More than 20,000 local earth tremors were recorded in 1968, whereas more than 50,000 were recorded in 1967 (Barnes and others, 1969). Of the 1968 total, 281 earth tremors (table 1) were larger than about 1.0 (range 1.1 to 3.3) on the Richter magnitude scale and could be accurately plotted. A total of 540 tremors were plotted in 1967.

Seismic monitoring network

The Sunnyside seismic monitoring network and procedures for locating earth tremor hypocenters (map positions and focal depths) were described previously (Barnes and others, 1969; Maberry, 1966; Dunrud and Osterwald, 1965). Starting in 1968, the magnetic recording tapes have been analyzed at the recording site. Prior to that time the tapes were analyzed in Denver, Colorado. The tremors were estimated to be located within ±500 to ±1,000 feet of their actual location.

Seismic activity

The level of seismic activity in the Sunnyside mining district varied more than tenfold during 1968 (figs. 1 and 2). Two patterns are evident from these variations. First, the daily number of earth tremors increased, decreased, then increased again at regular intervals that averaged about a week in duration. Second, the general level of tremors also varied in a less regular manner over periods that ranged from a few weeks to a few months. The shorter, more regular pattern apparently is related to coal mining. Earth tremors commonly were more numerous during the work week and less numerous on weekends or during other idle periods. The longer, less regular pattern shows variations which were not related directly to coal mining but which seem to have been caused by natural stresses that may combine in a complex way with mine-induced stress changes.

Differences as well as similarities in the long-term pattern of seismic activity are evident when the seismic activity in the north part of the Sunnyside mining district (fig. 1) is compared with that in the south part (fig. 2). For example, the daily number of tremors reached a peak in the northern part of the district during late January and early February and again during late March and early April, whereas the number of tremors in the southern part of the district steadily declined from a very high level in late January to a low level in April. However, earth tremors were at a low level in both parts of the district during much of April and again in October. Differences in pattern again occurred in late November and December, when the daily number of tremors rose to a

high level in the northern part of the district, but remained at a rather low level in the southern part of the district. Activity in the southern part of the district is not known from December 5 to 23 because the station was inoperative then.

The larger-magnitude earth tremors--the tremors of sufficient magnitude that their hypocenters can be located--varied in number throughout the mining district by as much as seven times, when compared on a month-by-month basis, and they varied by more than two times when compared on a quarter-by-quarter basis (table 1). Furthermore, the tremor activity was locally at a relatively high level while elsewhere in the district it was at a low level. The tremor activity also was low throughout the district at certain times. For example, 36 larger-magnitude tremors originated in the Columbia-Geneva mine area during February--nearly three times the number that originated near the Sunnyside mines during the same period. During November, conversely, 22 larger-magnitude tremors originated near the Sunnyside mines but only six originated in the Columbia-Geneva mine area. The level of activity was low throughout the district during April, when only seven larger-magnitude tremor hypocenters were plotted.

The number of larger-magnitude earth tremors commonly increased during periods when the total seismic activity increased and decreased when the total seismic activity decreased (figs. 1 and 2). However, there were many larger-magnitude tremors in the northern part of the district during late October and early November--a period when the total seismic activity was relatively low (fig. 1). Also, the larger-magnitude tremors were numerous in the southern part of the district during late February and early March, when the total activity decreased to a very low level (fig. 2).

Long-period changes in the daily number of the larger-magnitude earth tremors, as well as changes in the total daily number of tremors, do not necessarily coincide in time in the northern and southern parts of the district (table 1; figs. 1 and 2). This lack of coincidence was characteristic of the seismic activity in 1967 (Barnes and others, 1969, p. 2) as well as in previous years. Studies of the districtwide seismic activity since 1963 indicate that in a particular locality earth tremors tend to increase in number and also in magnitude, then they decrease there and build up in another locality over periods ranging from a few hours to a few weeks. These spatial and temporal changes in tremor origins probably result from districtwide, mine-induced stress changes, modified by local geologic conditions, local mining methods, and variations in the local natural stress field.

Mining, geologic, and topographic controls on location of tremors and bumps

The coal in the district, which is a major source of coking coal for steel mills in the Western United States, is mined from the Sunnyside

Table 1.--Monthly and quarterly summary of the larger-magnitude earth tremors located in each mine area of the Sunnyside mining district during 1968

Period 1968		Number of tremors plotted in various areas					Total number of tremors	
		Mines of Kaiser Steel Corp.			Mines of U.S. Steel Corp.			
		Sunnyside						
Quarter	Month	#1	#2	#3	Columbia	Geneva	Month	Quarter
	Jan	0	3	6	3	5	17	
1	Feb	2	9	2	19	17	49	
	Mar	8	1	0	5	10	24	
	Totals	10	13	8	27	32	----	90
	Apr	1	1	1	1	3	7	
2	May	4	4	0	5	7	20	
	Jun	2	4	0	1	6	13	
	Totals	7	9	1	7	16	----	40
	Jul	1	2	4	1	6	14	
3	Aug	4	8	2	0	27	41	
	Sep	4	9	0	1	6	20	
	Totals	9	19	6	2	39	----	75
	Oct	1	20	0	1	7	29	
4	Nov	0	21	1	4	2	28	
	Dec	1	8	0	0	10	19	
	Totals	2	49	1	5	19	----	76
							Grand total---	281

coal bed of the Blackhawk Formation of Late Cretaceous age. The bed dips eastward and northeastward at angles ranging from 6° in the south part of the district to 15° locally in the north part of the district. The coal is as thick as 24 feet, but averages about 9 feet. The elevation of the mine workings ranges from about 5,500 to 7,500 feet above sea level; however, most workings are between 6,000 and 7,000 feet above sea level. The coal bed is underlain by a massive sandstone, shale and mudstone, another massive sandstone, and a thick shale. It is overlain by a sequence of alternating mudstones and massive sandstones as much as 4,700 feet thick. Erosion has sculptured the bold Book Cliffs, which stand as high as 2,000 feet above the flats to the west and south, from the dominantly resistant sandstone units associated with the coal sequence. Streams have incised deep canyons and reentrants into the cliffs, causing a very rugged topography near the cliffs; consequently, the overburden thicknesses vary from a few hundred feet to as much as 2,500 feet or more in short lateral distances (Osterwald, 1961; Osterwald and others, 1969). This great overburden thickness and the abrupt changes in thickness with location undoubtedly produce natural stress variations conducive to bumps and other mine stability problems.

The distribution of tremor hypocenters (map position and vertical position of tremor foci) in 1968 indicates that, as in 1967, the tremors were caused by mine-induced stress changes. Epicenters (map position of tremor foci) of 270 of the 281 tremors were located within the map positions of the mine workings of the Sunnyside mining district or less than 2,000 feet from the nearest mine workings (figs. 3, 4, 5, and 6). All 281 tremor epicenters were within 10,000 feet of the mine workings. Foci of nearly all the tremors ranged from a few hundred feet above to 6,000 feet below the elevation of the mine workings.

In the Sunnyside and Columbia mine workings the tremor foci commonly ranged in depth from near the mine workings to 3,000 feet below them, whereas, in the Geneva mine area, the foci generally were deeper, and ranged from 3,000 to 6,000 feet below the elevation of the mine workings.

Tremor foci may form a different depth pattern in the Geneva mine area because the geologic structure is different and more complex than that in the northern part of the district. An east-northeast-trending normal fault zone, which forms the boundary between the Columbia and Geneva mines, also seems to form the boundary between the different structural features in the mining district (figs. 3, 4, 5, and 6). South of this boundary fault zone the faults are less steep than to the north of it; and the southern faults outline two nearly east-trending grabens with an intervening horst. These structures are transected by a northwest-trending fault or fault zone with a large strike-slip component of movement. The southernmost graben also is cut by faults that parallel the trend of the graben. In addition, a deeply buried northwest-trending fault probably is present beneath much of the Geneva mine workings but passes west of the Columbia and Sunnyside mines (Tibbetts and others, 1966, p. D136).

North of the fault zone between the Columbia and Geneva mines the rock mass is transected by steeply dipping, dip-slip normal faults. The north-northwest-trending Sunnyside fault zone transects the Sunnyside mines and the Columbia mine (Osterwald and others, 1969), but passes east of the Geneva mine workings.

Tremor hypocenters tend to be concentrated near active mining areas and are less common near old mine workings (figs. 3, 4, 5, and 6). The distribution of hypocenters, however, varied relative to active mining and to faults during 1968. During the first half of the year most tremor hypocenters were concentrated near faults that passed close to active mining areas (figs. 3 and 4). During the second half of the year they were concentrated closer to the active mining areas (figs. 5 and 6), except for the area east of the north part of the Geneva mine, where tremors continued to center along faults and at fault intersections throughout the year. It appears that stress readjustments due to mining occurred mostly along faults during the first half of the year, but were concentrated in the rock mass around the active mine workings during the second half.

Although damaging and hazardous bumps were rare in the Sunnyside mining district during 1968, smaller bumps, in single pillars or pillar ribs, were more common in a given mining area whenever the foci of the larger-magnitude tremors concentrated in the rock mass near that area. We believe that this is because the source of energy for both earth tremors and bumps is a spontaneous release of strain energy stored in the rock mass or the coal. Strain releases, together with creep and other less violent forms of yield in the subjacent rock mass, provide the mechanism of stress adjustment in an attempt to achieve equilibrium. Equilibrium is not achieved, however, as long as mining excavations continue. The energy generated by bumps usually is much smaller in magnitude than the larger-magnitude tremors because less strain energy can be stored in the yielding rock mass near mining excavations than can be stored in the more solid rock mass at some distance from mine openings (Osterwald and Dunrud, 1966).

Summary of seismic activity by quarter

Some patterns of seismic activity and their relation to faults and to mining by calendar quarter are summarized below (figs. 3, 4, 5, and 6; table 2).

First-quarter seismic activity (fig. 3)

Sunnyside No. 1 mine area.--Most tremor hypocenters occurred a few hundred feet to as much as 2,000 feet from active mining areas in the southeast part of the mine. Most focal depths were near the elevation of the mine workings which ranges from 6,000 to 7,500 feet above sea level, but three were as much as 3,000 feet below sea level.

Sunnyside No. 2 mine area.--Tremor hypocenters were 1,000-9,000 feet from active mining areas, near or along branch faults of the Sunnyside fault zone. Foci generally were near the elevation of the mine workings, which ranges from 6,200 to 7,000 feet above sea level, but two were 3,000-4,000 feet below the mine workings. Two tremor foci were centered along a fault that parallels the Sunnyside fault zone and is exposed near the mouth of Water Canyon.

Sunnyside No. 3 mine area.--Most tremor foci were near the elevation of the mine workings, which ranges from 6,000 to 6,800 feet above sea level, but were remote from active mining areas. Five of the eight tremor foci plotted under the streambed in Number Two Canyon might be related to ground-water injection into the rock mass along mine-induced fractures rather than to stress changes caused by current mining.

Columbia mine area.--The mine has been closed since 1967. Tremor hypocenters occurred generally within the Sunnyside fault zone in the northern part of the mine or within an intensely faulted area transected by two fault sets in the southwestern part of the mine. Focal depths ranged from near the elevation of the mine workings to 5,000 feet below the workings in the northern part of the mine. In the southwestern part of the mine, the foci generally were near the elevation of the mine workings, which ranges from 5,800 to 7,000 feet above sea level.

Geneva mine area.--Most tremor hypocenters were in the northern part of the mine near or along faults or fault intersections away from active mining areas. Focal depths commonly ranged from 2,000 to 6,000 feet below the mine workings, which are between 5,400 and 7,000 feet above sea level.

Second-quarter seismic activity (fig. 4)

Tremor hypocenters were distributed about the same as in the first quarter, except that there were only about half as many tremors and there was very little activity in the Sunnyside No. 3 mine area.

Sunnyside No. 1 mine area.--Four of the seven tremors originated near the 12th right entry, an active mining area; foci ranged from near the elevation of the mine workings to 2,000 feet below it. Three tremor hypocenters were 5,000-10,000 feet east of the mine workings, near a fault that parallels the Sunnyside fault zone, and at depths ranging from 2,000 to 6,000 feet above sea level.

Sunnyside No. 2 mine area.--The distribution of tremor hypocenters was approximately the same as in the first quarter.

Sunnyside No. 3 mine area.--One tremor was located near the mine elevation at the intersection of the Sunnyside fault zone and the Number Two Canyon streambed.

Columbia mine area:--Three of the seven tremors were centered near faults of the Sunnyside fault zone. The other four were near the fault separating the Columbia and Geneva mines. Tremor foci ranged from 2,000 to 6,000 feet below the elevation of the mine workings.

Geneva mine area.--Most of the 14 tremor hypocenters occurred in the northern part of the mine near mined-out areas and within an area where several east-northeast-trending and northwest-trending faults intersect 1,000-3,000 feet from the active mining area in First Level North (1 N in fig. 4). Three tremors were centered 1,500-4,000 feet north of the active mining area in First Level South (1 S in fig. 4). All tremors occurred at depths ranging from 3,000 to 7,000 feet below the mine workings.

Third-quarter seismic activity (fig. 5)

The seismic activity was concentrated closer to active mining areas than in the first and second quarters.

Sunnyside No. 1 mine area:--Six of the nine tremor hypocenters were clustered near active mining areas and next to barrier pillars on the haulage slope. One was near the Sunnyside fault in the north part of the mine and two were 2,000-3,500 feet east of the mine workings. All tremors originated near the elevation of the mine workings.

Sunnyside No. 2 mine area.--The seismic activity increased noticeably this quarter compared with the two earlier quarters. The activity was concentrated closer to the active mining areas but also continued along faults in the Sunnyside fault zone. Focal depths were near the mine elevation except for two, which were 2,000-3,000 feet below it.

Sunnyside No. 3 mine area.--Three of the six tremor hypocenters were near the active longwall mining area in the southeastern part of the mine. The tremors originated near the mine elevation.

Columbia mine area:--Seismic activity continued to decline from that of the previous two quarters. Only two tremor hypocenters were plotted. One was located on the Sunnyside fault zone in the north part of the mine about 5,000 feet below the mine level; the other was located near the mine level close to the fault separating the Columbia and Geneva mines.

Geneva mine area.--The seismic activity declined in the north part of the mine but increased markedly in First Level South (1 S in fig. 5). More than half of the 41 tremors were centered within 200-3,000 feet of the active mining area. Five tremor hypocenters occurred 500-2,500 feet east of the nearest mine workings near faults and fault intersections of the Sunnyside fault zone and several east-northeast-trending faults. Additional seismic control was available for the Geneva mine area between August 18 and 30, when a temporary monitoring network was operated a few miles to the south (Osterwald and others, 1970).

Fourth-quarter seismic activity (fig. 6)

The seismic activity was low in the Sunnyside No. 1 and No. 3 mines during this quarter but markedly intensified around active mining areas in the Sunnyside No. 2 mine.

Sunnyside No. 1 mine area:--Only two tremor sources were located--one in the mined-out area between 8th and 9th left (8L and 9L in fig. 6) entries, and the other along the 14th right entry. Both foci were near the elevation of the mine workings.

Sunnyside No. 2 mine area:--Most tremor hypocenters were clustered tightly around the active mining areas south of the haulage slope and along the Sunnyside fault zone. Although the epicenters are clustered too tightly for many of the focal depths to be shown in figure 6, most originated within a thousand feet of the mine workings.

Sunnyside No. 3 mine area:--The only tremor large enough to locate was centered in the mined-out area in the north part of the mine near the elevation of the mine workings, close to an east-trending fault.

Columbia mine area:--Five tremors originated in the south part of the mine--two along the Sunnyside fault zone in the eastern part of the mine and three along or near faults in the western part of the mine. Foci ranged in depth from near the mine workings to 4,000 feet below them.

Geneva mine area:--Five tremors originated within the faulted graben in the north part of the mine 0-1,700 feet from active mining areas and 3,000-6,000 feet below the elevation of the mine workings. The remaining 14 tremors originated 1,000-5,000 feet north of the active mining area in First Level South (1 S in fig. 6) at depths ranging from near the elevation of the mine workings to 6,000 feet below the workings.

Acknowledgments

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Table 2.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
First quarter (Jan., Feb., and March)						
	(MST)					
Jan. 5	3:56 a.m.	2.5	----------	----------	18,000 S., 3,000 E.	7
7	1:20 a.m.	1.7 3/	----------	----------	20,000 S., 3,000 E.	0
7	2:22 a.m.	1.6 3/	49,000 N., 53,000 E.	2	----------	----------
8	7:41 a.m.	2.5	----------	----------	4,800 S., 2,100 E.	5
9	12:04 p.m.	1.6	----------	----------	23,800 S., 3,300 E.	0
13	8:11 p.m.	2.0	40,100 N., 53,500 E.	6	----------	----------
14	2:02 p.m.	2.4	51,500 N., 51,400 E.	4	----------	----------
14	10:46 p.m.	1.1	51,600 N., 52,200 E.	6	----------	----------
15	9:24 p.m.	1.7	37,800 N., 54,700 E.	5	----------	----------
16	9:38 p.m.	1.8 3/	----------	----------	11,200 S., 3,200 W.	5
17	11:44 p.m.	1.6	----------	----------	17,900 S., 1,100 E.	-2
18	4:05 a.m.	1.5	----------	----------	15,200 S., 1,600 W.	-1
20	3:34 a.m.	2.1 3/	48,800 N., 52,900 E.	5	----------	----------
25	6:30 p.m.	1.6	49,900 N., 52,600 E.	5	----------	----------
26	2:23 p.m.	2.4	----------	----------	100 S., 4,500 E.	6
29	12:51 p.m.	2.1 3/	41,000 N., 56,300 E.	5	----------	----------
29	2:24 p.m.	2.5 3/	----------	----------	2,800 S., 4,700 E.	4
Feb. 2	6:20 p.m.	2.6 3/	----------	----------	1,800 S., 3,800 E.	5
3	3:15 a.m.	1.8	----------	----------	5,900 S., 600 W.	6
3	6:35 a.m.	1.9	42,100 N., 49,500 E.	6	----------	----------
4	2:26 p.m.	1.7 3/	38,200 N., 54,700 E.	5	----------	----------

Table 2.-- Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968--Continued

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
First quarter (Jan., Feb., and March)						
	(MST)					
Feb. 4	8:26 p.m.	1.6	----------	----------	12,700 S., 200 W.	1
5	9:23 p.m.	2.2 3/	60,500 N., 48,500 E.	5	----------	----------
6	7:13 a.m.	2.0	----------	----------	1,300 S., 3,600 E.	6
7	12:27 a.m.	1.6	----------	----------	11,300 S., 3,800 E.	6
7	12:57 p.m.	1.6	----------	----------	18,000 S., 2,400 E.	1
8	9:21 a.m.	2.1 3/	----------	----------	16,600 S., 300 E.	1
9	8:11 a.m.	1.8 3/	37,600 N., 55,100 E.	5	----------	----------
9	2:24 p.m.	1.4	----------	----------	12,800 S., 2.900 W.	6
9	5:49 p.m.	2.2 3/	----------	----------	12,000 S., 2.900 W.	5
9	5:59 p.m.	1.5	----------	----------	13,600 S., 2,400 W.	5
9	6:51 p.m.	1.6	----------	----------	15,400 S., 600 E.	5
10	4:58 a.m.	2.7 3/	48,800 N., 54,400 E.	5	----------	----------
10	8:52 a.m.	2.0 3/	38,100 N., 56,200 E.	3	----------	----------
10	5:03 p.m.	1.6 3/	----------	----------	11,800 S., 2,700 W.	7
10	6:15 p.m.	1.3	----------	----------	11,700 S., 3,900 W.	6
12	2:44 a.m.	2.3 3/	48,300 N., 50,800 E.	6	----------	----------
12	9:25 p.m.	1.6 3/	----------	----------	16,200 S., 900 W.	3
13	7:01 p.m.	1.3	----------	----------	18,800 S., 600 E.	-2
14	12:22 a.m.	2.5 3/	----------	----------	15,400 S., 200 W.	6
15	12:09 p.m.	2.2	----------	----------	12,100 S., 2,100 W.	1
15	6:44 p.m.	2.6 3/	----------	----------	12,100 S., 6,000 W.	0

Table 2.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968--Continued

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
First quarter (Jan., Feb., and March)						
	(MST)					
Feb. 16	3.58 a.m.	2.1	----------	----------	12,100 S., 2,400 W.	6
16	7:29 p.m.	2.1 3/	----------	----------	10,100 S., 3,700 W.	6
17	11:38 a.m.	2.5 3/	----------	----------	9,800 S., 4,000 W.	5
19	10:58 p.m.	2.2 3/	----------	----------	11,100 S., 1,300 W.	4
22	12:50 a.m.	2.5 3/	60,400 N., 48,400 E.	5	----------	----------
22	12:53 p.m.	2.1 3/	----------	----------	18,800 S., 3,000 E.	0
24	5:09 a.m.	2.1 3/	----------	----------	19,500 S., 1,800 E.	4
25	11:00 a.m.	2.1	----------	----------	9,500 S., 2,300 W.	6
26	3:27 p.m.	2.1 3/	----------	----------	13,300 S., 200 E.	1
27	8:55 p.m.	2.0 3/	----------	----------	15,900 S., 1,800 E.	1
27	10:27 p.m.	1.9 3/	----------	----------	18,000 S., 2,900 E.	1
28	12:08 p.m.	2.3 3/	----------	----------	15,400 S., 1,500 E.	1
29	5:29 p.m.	2.2 3/	----------	----------	4,100 S., 6,600 E.	1
29	8:00 p.m.	2.0 3/	----------	----------	16,900 S., 2,900 E.	1
Mar. 1	3:45 a.m.	2.2 3/	37,600 N., 55,000 E.	6	----------	----------
2	7:00 p.m.	2.1 3/	59,300 N., 51,300 E.	7	----------	----------
4	11:07 a.m.	1.9 3/	----------	----------	10,000 S., 2,100 W.	5
6	11:35 a.m.	2.4 3/	----------	----------	10,700 S., 1,900 W.	6
7	11:14 a.m.	2.4 3/	----------	----------	10,500 S., 1,700 W.	5
8	10:30 p.m.	2.7 3/	----------	----------	10,800 S., 2,400 W.	6

Table 2.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968--Continued

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
First quarter (Jan., Feb., and March)						
	(MST)					
Mar. 10	1:47 p.m.	2.5	----------	----------	14,000 S., 2,200 E.	-1
11	2.41 p.m.	1.8	----------	----------	16,200 S., 2,200 E.	0
12	9:10 a.m.	2.0 3/	----------	----------	10,900 S., 3,000 W.	3
14	12:29 a.m.	1.8 3/	57,900 N., 52,100 E.	3	----------	----------
16	1:16 p.m.	2.2 3/	----------	----------	13,300 S., 600 W.	1
19	10:06 a.m.	1.9 3/	----------	----------	18,200 S., 1,300 E.	2
19	8:16 p.m.	2.1 3/	----------	----------	16,200 S., 4,800 E.	2
20	1:07 p.m.	2.8 3/	----------	----------	14,800 S., 9,300 E.	-1
21	12:05 p.m.	2.5	----------	----------	13,000 S., 1,000 W.	1
23	7:42 a.m.	1.6 3/	59,600 N., 53,500 E.	4	----------	----------
24	4:05 a.m.	1.9 3/	----------	----------	16,000 S., 700 W.	1
24	8:36 p.m.	1.9 3/	59,600 N., 53,300 E.	4	----------	----------
26	1:45 p.m.	2.4 3/	59,300 N., 53,400 E.	4	----------	----------
26	2:34 p.m.	2.2 3/	56,400 N., 49,900 E.	6	----------	----------
28	2:30 p.m.	2.6 3/	----------	----------	12,400 S., 8,900 E.	1
30	3:27 a.m.	2.0 3/	58,600 N., 52,900 E.	4	----------	----------
30	10:38 a.m.	2.5 3/	----------	----------	16,200 S., 2,000 E.	1
30	5:16 p.m.	1.9 3/	58,100 N., 51,000 E.	6	----------	----------

Table 2.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968--Continued

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
Second quarter (April, May, and June)						
	(MST)					
Apr. 4	6:11 a.m.	2.0 3/	----------	----------	17,500 S., 500 W.	2
4	11:01 a.m.	2.4 3/	----------	----------	12,600 W., 11,400 E.	1
4	7:18 p.m.	2.3 3/	41,500 N., 53,600 E.	1	----------	----------
4	11:25 p.m.	1.8 3/	48,800 N., 49,800 E.	7	----------	----------
5	9:37 a.m.	1.6	----------	----------	16,400 S., 1,100 E.	1
6	5:27 a.m.	1.6	57,400 N., 52,100 E.	3	----------	----------
10	7:50 p.m.	1.5	----------	----------	11,200 S., 3,400 W.	5
	(MDT)					
May 2	12:03 a.m.	2.2	----------	----------	15,600 S., 1,000 W.	2
2	8:26 p.m.	2.0	----------	----------	12,200 S., 2,200 W.	1
5	12:54 a.m.	1.6	----------	----------	20,200 S., 1,700 E.	1
6	12:32 a.m.	1.5	58,700 N., 48,800 E.	3	----------	----------
7	6:44 p.m.	2.5	----------	----------	13,100 S., 2,500 W.	3
7	9:13 p.m.	2.0	----------	----------	20,300 S., 3,500 W.	1
9	4:11 p.m.	2.3	37,800 N., 55,200 E.	7	----------	----------
10	3:38 a.m.	2.7	39,100 N., 54,800 E.	6	----------	----------
11	8:23 a.m.	1.8	----------	----------	16,000 S., 1,100 E.	1
11	8:47 p.m.	2.4 3/	----------	----------	13,900 S., 1,100 E.	2
16	9:41 a.m.	2.2 3/	----------	----------	6,100 S., 3,200 W.	1
17	8:58 p.m.	2.1 3/	----------	----------	12,500 S., 2,600 W.	3

Table 2.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968--Continued

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
Second quarter (April, May, and June)						
	(MDT)					
May 20	12:30 p.m.	1.7 3/	58,300 N., 50,800 E.	7	----------	----------
20	2:06 p.m.	2.1 3/	38,100 N., 54,500 E.	7	----------	----------
21	4:50 p.m.	2.3 3/	----------	----------	7,700 S., 4,000 E.	2
22	6:41 p.m.	2.4 3/	58,100 N., 51,000 E.	7	----------	----------
26	8:03 p.m.	2.6 3/	58,500 N., 51,500 E.	7	----------	----------
27	5:21 a.m.	2.7 3/	36,200 N., 53,600 E.	7	----------	----------
27	3:43 p.m.	2.1 3/	----------	----------	13,500 S., 2,600 W.	3
31	6:45 p.m.	2.3 3/	----------	----------	100 S., 4,400 E.	6
June 1	4:13 a.m.	1.5	----------	----------	14,600 S., 1,700 W.	2
2	12:59 p.m.	3.3	----------	----------	15,600 S., 1,100 E.	1
2	1:03 p.m.	1.6	----------	----------	12,000 S., 300 W.	3
5	12:23 a.m.	2.4 3/	----------	----------	13,200 S., 3,700 E.	1
6	4:23 a.m.	2.3 3/	42,500 N., 53,900 E.	2	----------	----------
7	7:32 a.m.	1.8 3/	----------	----------	14,900 S., 1,400 W.	1
12	2:34 a.m.	1.8 3/	----------	----------	18,400 S., 1,300 E.	1
12	10:55 a.m.	2.3 3/	38,000 N., 54,400 E.	5	----------	----------
12	10:57 a.m.	2.4 3/	38,900 N., 53,100 E.	6	----------	----------
12	4:01 p.m.	2.6	----------	----------	22,800 S., 2,800 E.	0
13	3:33 a.m.	2.0	61,600 N., 56,700 E.	4	----------	----------
18	10:36 p.m.	2.5	39,700 N., 55,200 E.	5	----------	----------
21	9:53 p.m.	2.4	64,400 N., 61,400 E.	4	----------	----------

Table 2.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968--Continued

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
Third quarter (July, Aug., and Sept.)						
	(MDT)					
July 3	6:30 p.m.	2.3	40,600 N., 54,700 E.	4	----------	----------
9	10:30 a.m.	2.6	39,100 N., 60,100 E.	4	----------	----------
10	4:55 a.m.	2.0	----------	----------	11,200 S., 8,000 E.	2
12	3:19 p.m.	2.2	----------	----------	13,200 S., 5,000 E.	1
13	3:58 a.m.	1.8	51,500 N., 55,400 E.	4	----------	----------
14	12:48 p.m.	2.2	----------	----------	19,800 S., 4,800 E.	2
18	1:59 a.m.	1.7 3/	----------	----------	23,300 S., 3,000 E.	0
19	5:39 p.m.	2.3 3/	47,000 N., 58,200 E.	4	----------	----------
22	4:48 a.m.	1.9 3/	----------	----------	22,800 S., 2,800 E.	1
22	6:17 p.m.	1.9 3/	61,300 N., 45,700 E.	5	----------	----------
23	7:05 p.m.	1.9 3/	----------	----------	13,900 S., 600 W.	1
24	12:34 p.m.	2.0 3/	47,400 N., 50,800 E.	5	----------	----------
24	7:45 p.m.	2.2 3/	47,900 N., 58,000 E.	5	----------	----------
31	1:28 a.m.	2.3 3/	----------	----------	4,200 S., 5,400 E.	2
Aug. 1	4:02 a.m.	2.4 3/	46,700 N., 58,500 E.	5	----------	----------
3	1:14 a.m.	1.9 3/	----------	----------	15,800 S., 900 W.	2
3	12:13 p.m.	2.1 3/	38,500 N., 55,400 E.	7	----------	----------
4	2:22 p.m.	1.8	----------	----------	17,600 S., 500 E.	4
5	2:34 p.m.	1.8	59,100 N., 48,700 E.	4	----------	----------
7	8:57 a.m.	2.4	----------	----------	19,600 S., 800 E.	2
8	12:50 p.m.	1.7	----------	----------	14,900 S., 1,100 E.	0
8	2:09 p.m.	1.6	----------	----------	21,700 S., 1,900 E.	1

Table 2.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968--Continued

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
Third quarter (July, Aug., and Sept.)						
	(MDT)					
Aug. 17	2:57 p.m.	2.0	37,500 N., 59,600 E.	5	----------	----------
18	8:54 p.m.	1.9 3/	----------	----------	12,500 S., 5,900 E.	0
19	9:23 a.m.	2.2 3/	38,100 N., 55,900 E.	5	----------	----------
19	1:16 p.m.	2.4	----------	----------	11,600 S., 6,500 E.	0
19	10:22 p.m.	2.1 3/	55,500 N., 53,700 E.	4	----------	----------
21	2:33 p.m.	2.2 3/	----------	----------	24,200 S., 4,200 E.	2
21	5:44 p.m.	2.1 3/	----------	----------	24,300 S., 2,500 E.	3
22	8:38 p.m.	2.1 3/	40,800 N., 53,400 E.	6	----------	----------
23	1:01 p.m.	2.3 3/	39,000 N., 58,000 E.	5	----------	----------
24	1:09 a.m.	2.2 3/	----------	----------	23,700 S., 4,100 E.	4
25	1:25 a.m.	2.7 3/	58,800 N., 48,300 E.	5	----------	----------
26	12:02 a.m.	2.0 3/	----------	----------	24,600 S., 4,800 E.	4
26	7:41 a.m.	2.6 3/	60,000 N., 54,500 E.	6	----------	----------
28	3:26 p.m.	2.0 3/	----------	----------	25,200 S., 3,200 E.	3
28	11:13 p.m.	2.0 3/	----------	----------	23,500 S., 2,800 E.	3
29	2:21 a.m.	2.2 3/	----------	----------	22,600 S., 7,400 E.	4
29	3:32 a.m.	2.8 3/	----------	----------	22,500 S., 6,000 E.	3
29	5:46 a.m.	2.2 3/	----------	----------	21,700 S., 6,000 E.	4
29	4:54 a.m.	2.4 3/	----------	----------	24,300 S., 2,300 E.	2
29	6:36 a.m.	2.0 3/	----------	----------	23,100 S., 5,600 E.	2

Table 2.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968--Continued

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
Third quarter (July, Aug., and Sept.)						
	(MDT)					
Aug. 29	7:32 a.m.	1.5 3/	----------	----------	22,700 S., 4,800 E.	3
29	8:02 a.m.	1.9 3/	----------	----------	23,900 S., 4,800 E.	4
29	8:45 a.m.	2.5 3/	----------	----------	23,200 S., 3,300 E.	2
29	9:35 a.m.	2.6 3/	59,500 N., 51,900 E.	4	----------	----------
29	12:30 p.m.	2.0 3/	41,300 N., 57,000 E.	4	----------	----------
29	12:54 p.m.	1.6 3/	----------	----------	23,100 S., 2,500 E.	3
29	5:13 p.m.	2.2 3/	----------	----------	24,400 S., 3,400 E.	3
29	5:54 p.m.	1.6 3/	----------	----------	23,700 S., 2,900 E.	3
29	8:47 p.m.	2.0 3/	----------	----------	24,900 S., 3,900 E.	4
29	10:23 p.m.	1.5 3/	----------	----------	26,200 S., 2,700 E.	5
30	11:02 a.m.	1.8 3/	----------	----------	23,900 S., 2,900 E.	4
30	11:50 a.m.	2.1 3/	37,200 N., 55,700 E.	6	----------	----------
30	10:29 p.m.	2.4 3/	39,600 N., 58,500 E.	5	----------	----------
Sep. 1	4:25 p.m.	2.3 3/	----------	----------	14,800 S., 5,000 E.	1
3	12:03 a.m.	2.0 3/	----------	----------	21,500 S., 4,400 E.	1
9	3:26 p.m.	2.6	41,500 N., 60,000 E.	6	----------	----------
10	1:57 a.m.	2.0	43,100 N., 57,500 E.	6	----------	----------
17	12:44 p.m.	2.2	43,900 N., 52,400 E.	4	----------	----------
17	7:14 p.m.	1.7 3/	----------	----------	24,400 S., 3,700 E.	2
24	12:51 a.m.	2.7 3/	64,200 N., 50,200 E.	6	----------	----------
24	2:59 a.m.	2.2 3/	----------	----------	20,500 S., 2,500 E.	2
24	10:38 a.m.	2.4 3/	45,200 N., 55,100 E.	5	----------	----------
24	9:09 a.m.	2.3 3/	45,100 N., 56,100 E.	7	----------	----------

Table 2.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968--Continued

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
			Third quarter (July, Aug., and Sept.)			
	(MDT)					
Sep. 25	7:21 a.m.	2.1 3/	59,600 N., 48,000 E.	4	----------	----------
26	10:29 a.m.	2.1 3/	39,200 N., 61,000 E.	3	----------	----------
26	11:22 p.m.	2.2 3/	----------	----------	23,900 S., 5,000 E.	2
26	11:22 p.m.	2.2 3/	----------	----------	12,300 S., 800 W.	4
27	3:08 a.m.	2.4 3/	60,400 N., 50,900 E.	5	----------	----------
27	9:36 a.m.	2.1 3/	42,200 N., 54,900 E.	7	----------	----------
27	1:18 p.m.	2.2 3/	39,200 N., 57,900 E.	5	----------	----------
27	6:43 p.m.	2.3 3/	38,500 N., 59,400 E.	5	----------	----------
28	4:25 p.m.	1.9 3/	----------	----------	22,100 S., 2,900 E.	1
29	3:43 a.m.	2.4 3/	60,100 N., 55,800 E.	4	----------	----------
			Fourth quarter (Oct., Nov., and Dec.)			
Oct. 3	12:50 p.m.	2.0 3/	38,700 N., 57,200 E.	4	----------	----------
3	11:57 p.m.	1.9 3/	----------	----------	21,400 S., 1,700 E.	1
6	11:38 a.m.	2.0	38,300 N., 53,900 E.	4	----------	----------
8	3:05 a.m.	2.2 3/	40,000 N., 62,800 E.	6	----------	----------
11	11:01 p.m.	2.6 3/	----------	----------	19,300 S., 400 E.	5
12	12:39 p.m.	2.1 3/	----------	----------	21,100 S., 2,000 E.	1
15	9:27 a.m.	2.4 3/	41,000 N., 58,300 E.	4	----------	----------

Table 2.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968--Continued

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
Fourth quarter (Oct., Nov., and Dec.)						
	(MDT)					
Oct. 16	1:21 a.m.	2.2 3/	----------	----------	14,800 S., 700 W.	0
17	12:16 p.m.	2.3 3/	41,900 N., 61,700 E.	4	----------	----------
17	12:53 p.m.	2.6 3/	41,900 N., 61,700 E.	4	----------	----------
17	2:44 p.m.	2.4 3/	39,700 N., 57,200 E.	5	----------	----------
18	3:34 p.m.	2.0 3/	----------	----------	11,600 S., 1,100 W.	2
19	12:33 a.m.	2.4 3/	39,500 N., 58,300 E.	6	----------	----------
19	1:15 p.m.	2.3	----------	----------	13,100 S., 1,800 E.	1
19	8:38 p.m.	2.5 3/	38,900 N., 58,700 E.	5	----------	----------
20	5:07 a.m.	2.3 3/	----------	----------	14,500 S., 900 W.	3
20	7:49 a.m.	2.6 3/	35,600 N., 55,800 E.	6	----------	----------
21	12:35 a.m.	2.3 3/	39,100 N., 58,800 E.	5	----------	----------
21	3:21 a.m.	2.1 3/	59,600 N., 48,400 E.	5	----------	----------
22	7:30 a.m.	2.4 3/	38,900 N., 56,600 E.	5	----------	----------
24	12:09 p.m.	2.2 3/	40,100 N., 55,700 E.	5	----------	----------
25	8:44 a.m.	2.0 3/	38,900 N., 58,100 E.	6	----------	----------
	(MST)					
28	10:08 a.m.	2.2 3/	39,900 N., 58,900 E.	5	----------	----------
29	9:20 a.m.	1.9 3/	38,800 N., 59,000 E.	4	----------	----------
29	11:16 a.m.	2.1 3/	----------	----------	15,000 S., 100 W.	1
29	11:29 a.m.	2.1 3/	39,300 N., 59,300 E.	4	----------	----------
30	3:37 a.m.	2.0 3/	39,200 N., 57,600 E.	5	----------	----------

Table 2.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968--Continued

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
			Fourth quarter (Oct., Nov., and Dec.)			
	(MST)					
Oct. 30	12:27 p.m.	2.0 3/	40,900 N., 51,600 E.	5	----------	----------
30	1:11 p.m.	1.9 3/	38,700 N., 56,700 E.	4	----------	----------
Nov. 3	1:34 p.m.	2.1 3/	40,600 N., 53,800 E.	4	----------	----------
6	12:11 a.m.	2.2 3/	39,500 N., 59,000 E.	4	----------	----------
6	11:59 a.m.	1.6 3/	----------	----------	20,500 S., 1,900 E.	0
6	12:44 p.m.	2.1 3/	38,400 N., 57,100 E.	4	----------	----------
7	8:10 a.m.	2.3 3/	41,000 N., 57,000 E.	1	----------	----------
8	11:34 p.m.	2.5 3/	39,300 N., 59,300 E.	5	----------	----------
12	4:58 a.m.	2.1 3/	38,700 N., 55,700 E.	6	----------	----------
12	10:03 a.m.	2.1 3/	38,300 N., 56,500 E.	3	----------	----------
13	8:25 a.m.	2.1 3/	----------	----------	19,600 S., 2,600 E.	0
13	10:37 a.m.	2.3 3/	39,500 N., 59,800 E.	4	----------	----------
15	8:25 a.m.	2.1 3/	38,900 N., 58,100 E.	2	----------	----------
15	5:43 p.m.	2.3 3/	40,000 N., 60,200 E.	4	----------	----------
17	7:35 a.m.	2.9	----------	----------	600 S., 21,100 W(?)	1(?)
19	1:49 p.m.	2.5 3/	40,000 N., 57,500 E.	6	----------	----------
19	4:18 p.m.	1.9 3/	41,100 N., 57,500 E.	1	----------	----------
20	11:48 a.m.	2.0 3/	40,900 N., 57,700 E.	3	----------	----------
20	12:22 p.m.	1.9 3/	41,200 N., 57,500 E.	3	----------	----------
21	4:34 a.m.	2.1 3/	----------	----------	9,400 S., 5,000 E.	6
22	2:04 p.m.	2.2 3/	39,600 N., 57,700 E.	6	----------	----------
22	2:23 p.m.	2.3 3/	39,500 N., 58,000 E.	4	----------	----------
22	9:18 p.m.	2.3 3/	38,900 N., 58,100 E.	6	----------	----------

Table 2.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968--Continued

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
Fourth quarter (Oct., Nov., and Dec.)						
	(MST)					
Nov. 24	10:16 a.m.	2.3 3/	38,600 N., 56,100 E.	6	----------	----------
27	12:51 a.m.	2.7 3/	51,600 N., 51,800 E.	5	----------	----------
28	5:25 a.m.	2.6 3/	----------	----------	8,100 S., 100 E.	3
28	7:13 a.m.	2.5 3/	40,100 N., 58,000 E.	4	----------	----------
28	10:36 a.m.	2.6 3/	----------	----------	8,500 S., 1,700 W.	5
28	9:33 p.m.	2.5 3/	39,700 N., 56,400 E.	5	----------	----------
29	3:09 a.m.	1.9 3/	----------	----------	8,800 S., 4,700 E(?)	1(?)
Dec. 1	12:38 a.m.	1.9	----------	----------	22,800 S., 2,400 E.	2
1	10:20 p.m.	2.2 3/	----------	----------	20,800 S., 2,100 E.	1
3	7:33 p.m.	2.2 3/	----------	----------	20,000 S., 1,800 E.	1
3	10:47 p.m.	2.0 3/	----------	----------	20,000 S., 1,800 E.	1
5	11:09 a.m.	2.5 3/	39,100 N., 57,100 E.	5	----------	----------
6	6:09 p.m.	2.0 3/	----------	----------	21,500 S., 2,000 E.	7
7	2:46 p.m.	2.0 3/	----------	----------	13,600 S., 600 W.	3
7	4:32 p.m.	2.5 3/	40,800 N., 58,300 E.	5	----------	----------
8	8:18 a.m.	2.4	----------	----------	17,600 S., 1,900 E.	3
9	11:24 a.m.	2.4 3/	39,000 N., 57,900 E.	6	----------	----------
10	9:06 a.m.	2.6 3/	38,300 N., 57,700 E.	5	----------	----------
12	1:23 a.m.	2.3 3/	----------	----------	20,700 S., 2,700 E.	4
14	11:25 a.m.	2.1 3/	----------	----------	19,100 S., 2,500 E.	2
14	2:30 p.m.	2.5 3/	58,600 N., 52,100 E.	5	----------	----------
15	9:23 p.m.	2.4 3/	40,600 N., 57,500 E.	5	----------	----------

Table 2.--Hypocenters of the larger magnitude earth tremors that occurred in the Sunnyside mining district during 1968--Continued

Date	Time	Richter magnitude	Kaiser Steel Corporation1/ Coordinates in feet	Kaiser Steel Corporation1/ Depth of tremor above or below (-) sea level in thousands of feet	U.S. Steel Corporation2/ Coordinates in feet	U.S. Steel Corporation2/ Depth of tremor above or below (-) sea level in thousands of feet
Fourth quarter (Oct., Nov., and Dec.)						
	(MST)					
Dec. 16	1:07 p.m.	2.4 3/	40,400 N., 57,200 E.	6	----------	----------
18	3:16 p.m.	2.2 3/	----------	----------	19,700 S., 1,700 E.	1
19	10:28 a.m.	1.8 3/	39,700 N., 58,100 E.	5	----------	----------
28	5:12 a.m.	2.3 3/	----------	----------	19,100 S., 2,600 E.	3

1/ Tremors located near Sunnyside No. 1, 2, and 3 mines.

2/ Tremors located near the Columbia and Geneva mines.

3/ Indicates hypocentral solution from seismogram made from magnetic tape--timing accuracy to nearest hundredth of a second; remainder of timing is to nearest tenth of a second.

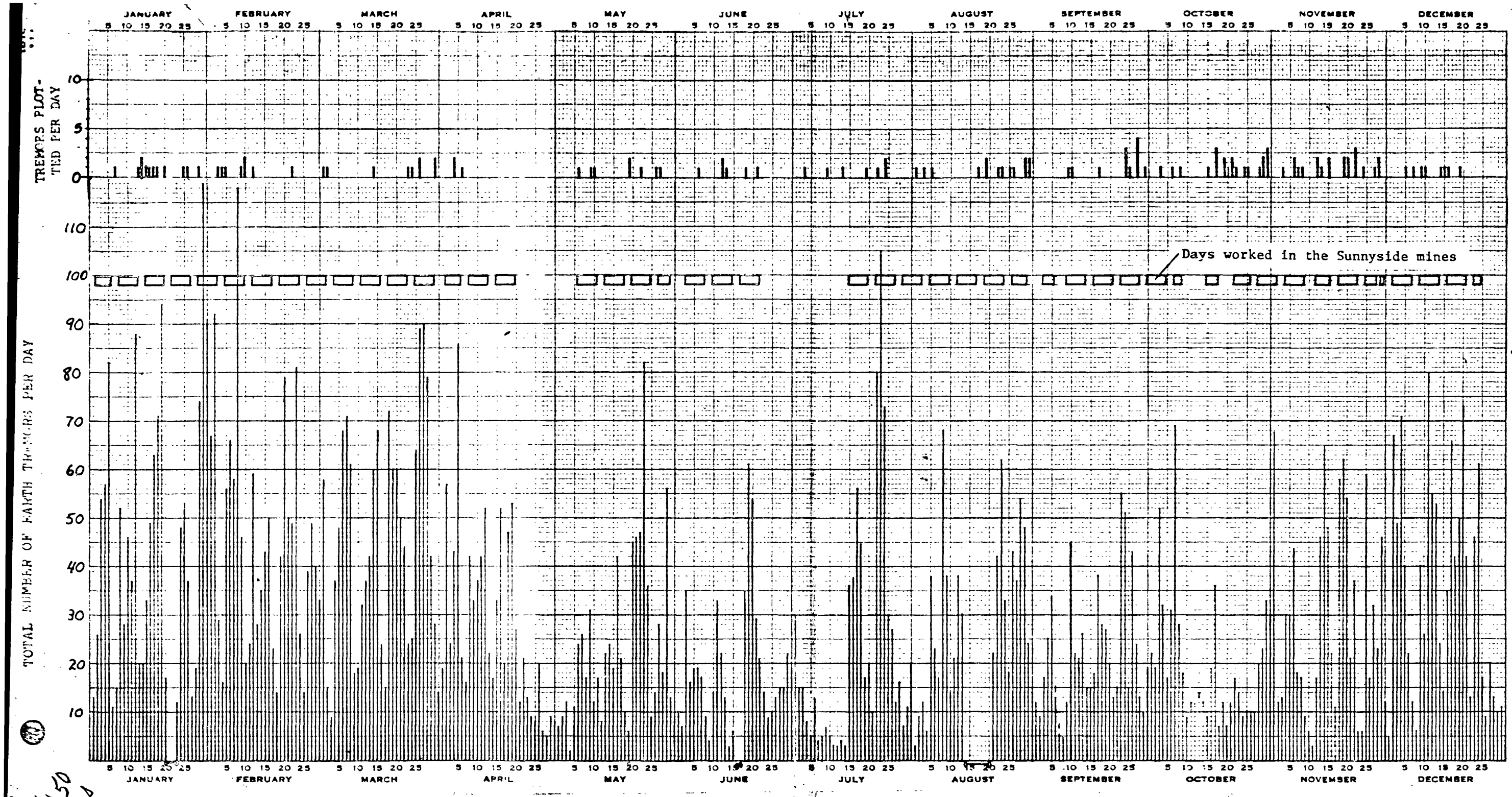

Figure 1. Histogram showing number of earth tremors recorded per day by the Bear Canyon seismic station during 1968, representing the seismic activity in the northern part of the Sunnyside mining district. ⟷ Station inoperative.

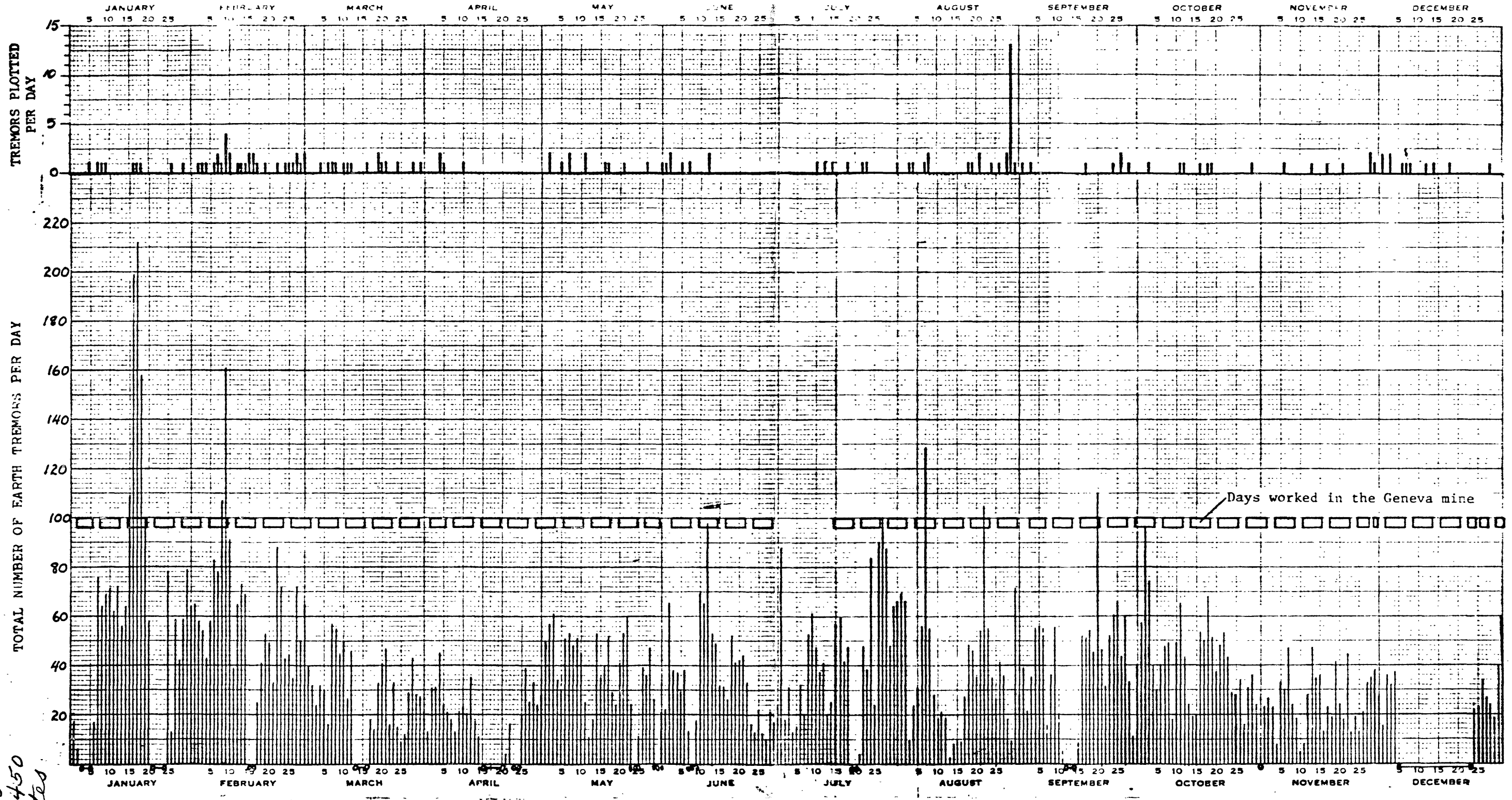

Figure 2.--Histogram showing number of earth tremors recorded per day by the Horse Canyon seismic station during 1968, representing the seismic activity in the southern part of the Sunnyside mining district. ⟷ Station inoperative.