U.S. Geological Survey.

[Reports. Open file]

Geology Applied to the Study of Coal Mine Bumps at Sunnyside, Utah. by Osterwald, Frank W. & Dunrud, C.R.

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGY APPLIED TO THE STUDY OF COAL MINE BUMPS AT SUNNYSIDE, UTAH

By

F. W. Osterwald and C. R. Dunrud

1964

OPEN FILE REPORT

GEOLOGY APPLIED TO THE STUDY OF COAL MINE BUMPS AT SUNNYSIDE, UTAH[1/]

by F. W. Osterwald and C. R. Dunrud[2/]

ABSTRACT

Coal mine bumps are a serious hazard to life and property in the mines of east-central Utah. Research into geologic factors associated with these bumps indicates that the bumps are spatially and genetically related to structural and stratigraphic features. Some bumps are directly related to stress accumulation along faults, either from natural causes or as a result of mining. Frictional properties of bedding planes between coal and roof rock, and between some rock units within the roof, directly affect the deformation of coal ribs, and hence the incidence of bumps. These frictional properties are related to the lithology of the roof rocks as well as to the sedimentary structures within the rocks. Commonly a sequence consisting of 1- 3 ft of carbonaceous siltstone, about 2- 3 ft of rider coal, and several feet of massive siltstone or sandstone overlies the main seam. The sequence causes difficult roof conditions in the mines, difficult mining conditions, and directly or indirectly many bumps.

INTRODUCTION

Coal mine bumps, which are violent spontaneous failures of coal or other rocks in mine faces, ribs, roofs, and floors, have caused many deaths and extensive property damage in the United States. In seeking a better understanding of the factors causing bumps the U.S. Geological Survey has studied relationships between geologic features and coal mine bumps at Sunnyside, Utah, for about 5 years. This work was originally undertaken at the request of and in cooperation with the U.S. Bureau of Mines, and since 1961, has been carried on by the Geological Survey with continuing informal cooperation in the field. The work has yielded results which indicate that if certain geologic features are given careful attention during planning, the danger from bumps may be reduced and the efficiency of mining operations increased. Some of the information on which this paper is based results from a series of bumps in June 1964 in which 2 men were killed, 7 were injured, and part of 1 mine was abandoned. Other information contained in the paper was acquired earlier in the investigations, but the significance of previously observed geologic relations has been clarified by the recent bumps.

1/ Publication authorized by Director, U.S. Geological Survey.

2/ Geologists with the U.S. Geological Survey, Denver, Colo.

The Sunnyside district (Fig. 1) is about 25 miles east of Price, Utah, in the Book Cliffs coal field. The district includes the Sunnyside mines of Kaiser Steel Corporation, the Columbia and Geneva mines of United States Steel Corporation and the Book Cliffs mine of the Book Cliffs Coal Company. Several of the large mines support a major part of the steel industries in Utah and southern California. The high quality of bituminous coking coal in the Blackhawk Formation of Late Cretaceous age justifies mining under conditions that commonly are extremely difficult.

The general geology of most of the Sunnyside district was described by Clark.[1] Within the mining area the coal beds dip east and northeast beneath the Book Cliffs (Fig. 1). In general, dips are steeper near the face of the Book Cliffs than they are east and northeast of the Cliffs. The beds strike northwest in the northern part of the district, changing southward along the Book Cliffs to an approximate north strike near the Geneva mine. Two steeply dipping fault sets in the district trend about northwest and northeast, generally paralleling two of the prominent joint sets. Maximum stratigraphic separation on the faults is about 150 ft; most separations are much smaller. These faults apparently are loci along which stress accumulates, either from natural causes or by readjustment due to mining. Small movements sometimes take place along the faults during bumps.

Within the Blackhawk Formation, the main coal bed is underlain by a siltstone and sandstone layer about 100 ft thick. Above the coal, channel sandstones and siltstones, both of which contain abundant slump and other sedimentary structures, are interbedded with shale, carbonaceous siltstone, thin coal beds, and lenses of black limestone. The main coal bed commonly splits,[2] and locally 2 levels are worked; these are referred to by the miners as the "Lower Sunnyside" and "Upper Sunnyside" seams. The deformation of mine workings and the incidence of bumps in the Sunnyside district are strongly influenced by the rocks overlying the coal seam.[6]

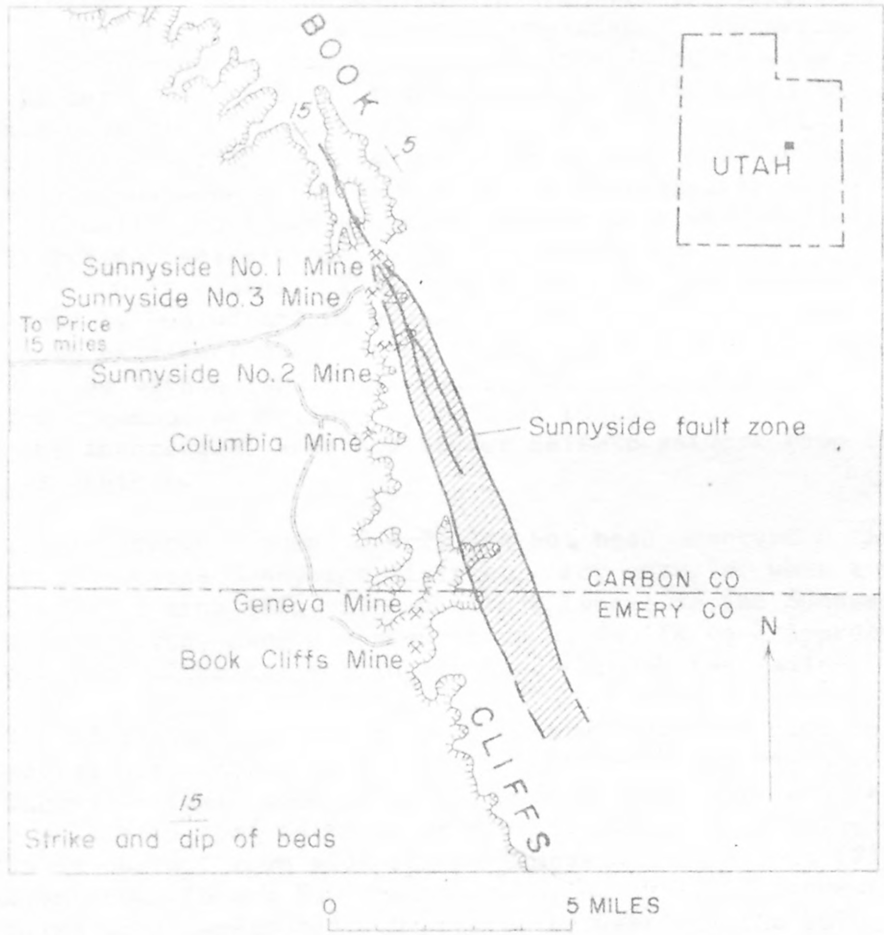

Figure 1.--Index map of Sunnyside district, Carbon and Emery Counties, Utah.

RELATION OF BUMPS TO FAULTS

Several lines of evidence suggest a spatial and possibly a genetic relationship between faults and bumps, but this relationship is difficult to establish. Most areas are mined rapidly and abandoned, hence many faults cannot now be observed. Other workings which cut faults, although open, are strongly supported, so that the faults are not visible. Patterns of mining operations in the district are extremely complicated, and natural relationships obscured. Furthermore, apparent spatial relationships between bumps and faults may be merely the result of differential loading from an extremely variable thickness of overburden above the coal. Measurements of fault movement associated with bumps are difficult to make because many locations are inaccessible and because it is hard to predict exactly which places might move. Finally, most bumps can be located only with seismographs, but with our present seismic monitoring network bumps can be located only within about a 500-ft radius. This network and its use are described in a companion paper by Dunrud and Osterwald.[3] Centers of many tremors, some of which are known by direct observation to be bumps, have been determined seismically to be within 1000 ft of faults (Fig. 2). Although a center 1000 ft from a fault cannot be definitely related to the fault, we assume it to be because the theoretical accuracy of our seismic network (500 ft radius) is not always achieved.

The relation between bumps and faults has been observed during mining in some workings of the Sunnyside district. For example, when a slope in the Sunnyside No. 2 mine (Fig. 3) and a rock tunnel in the Sunnyside No. 1 mine were being driven, many bumps occurred as faults were approached, but few bumps occurred after the workings passed through the faults.[4,5]

A series of surface and underground observations was made to study possible spatial and genetic relationships between bumps and movements along the Sunnyside fault zone (Fig. 1). Index marks were scribed in July 1960 on the ends of 5 roof bolts in an old air return which crosses several small faults in the upthrown side of the Sunnyside fault zone (Fig. 4). After a violent bump in the No. 1 mine on May 6, 1961, distances between the index marks were remeasured. Distances between all the bolts had changed, and the total distance across the measured span was shortened by 0.027 ft as shown by the numbers in parentheses on Fig. 4, implying that movement occurred within the fault zone, probably during the bump. We cannot say definitely that this movement occurred during the bump without having had continuous recording instruments with accurate timing. The area in which the measurements were made is no longer accessible, and no additional measurements are possible.

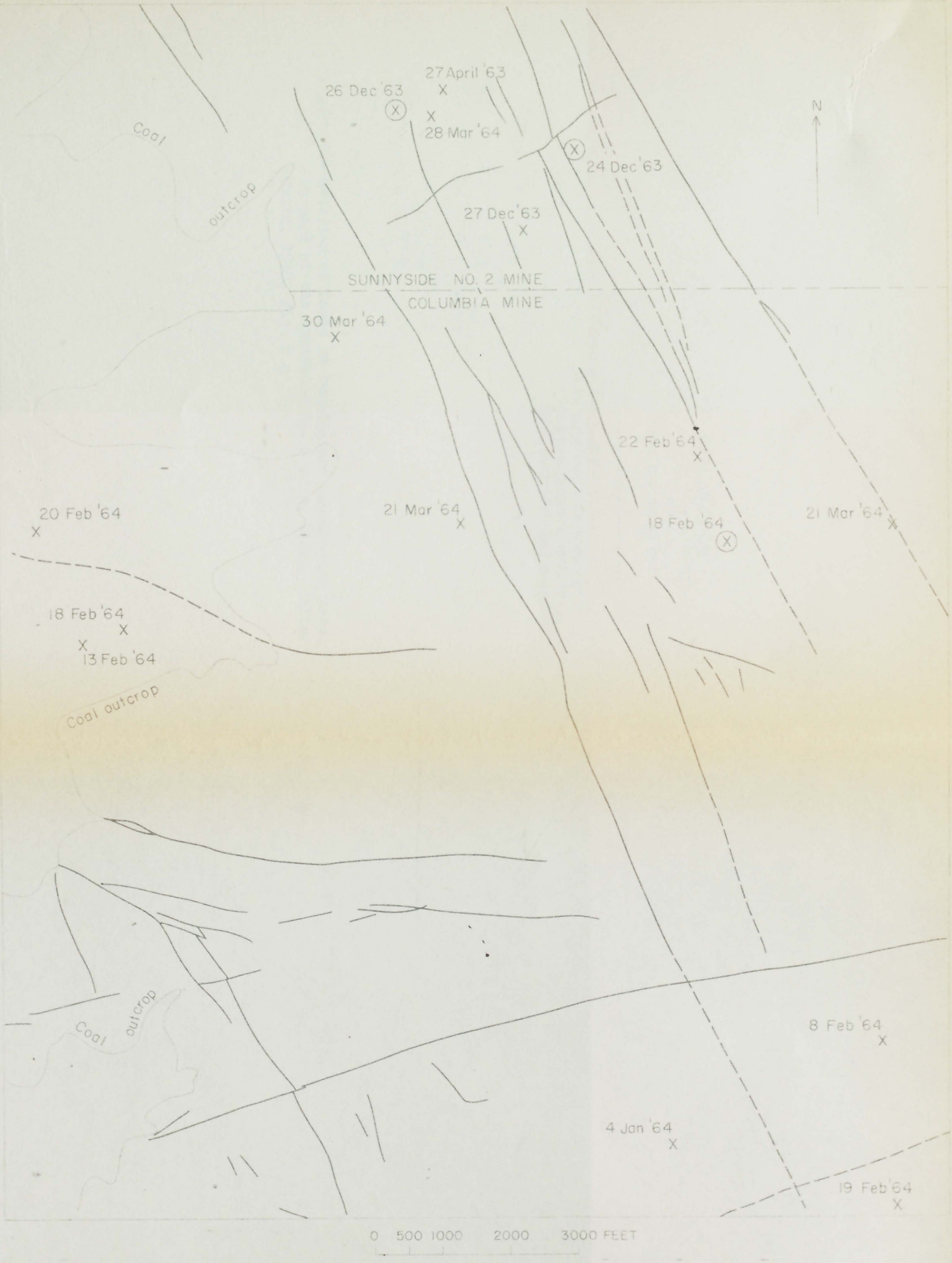

Figure 2.--Horizontal position of faults cutting Lower Sunnyside coal seams at depth in parts at Columbia and Sunnyside No. 2 mines. Locations of seismically recorded tremors indicated by X. Tremors known to be bumps by direct observation indicated by circled X. Lower level mine workings are not shown on map. Cover varies from 0 ft (coal outcrop) to about 2000 ft. Dashed lines indicate inferred faults.

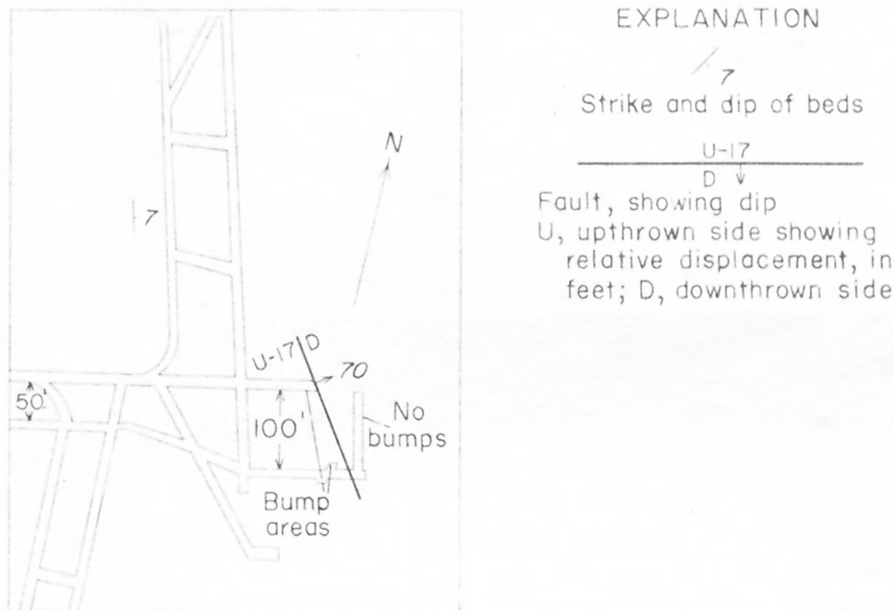

Figure 3.--Relation of fault to bumping and non-bumping areas in part of the Sunnyside No. 2 mine, Utah. (After Watts, 1918, fig. 2.)

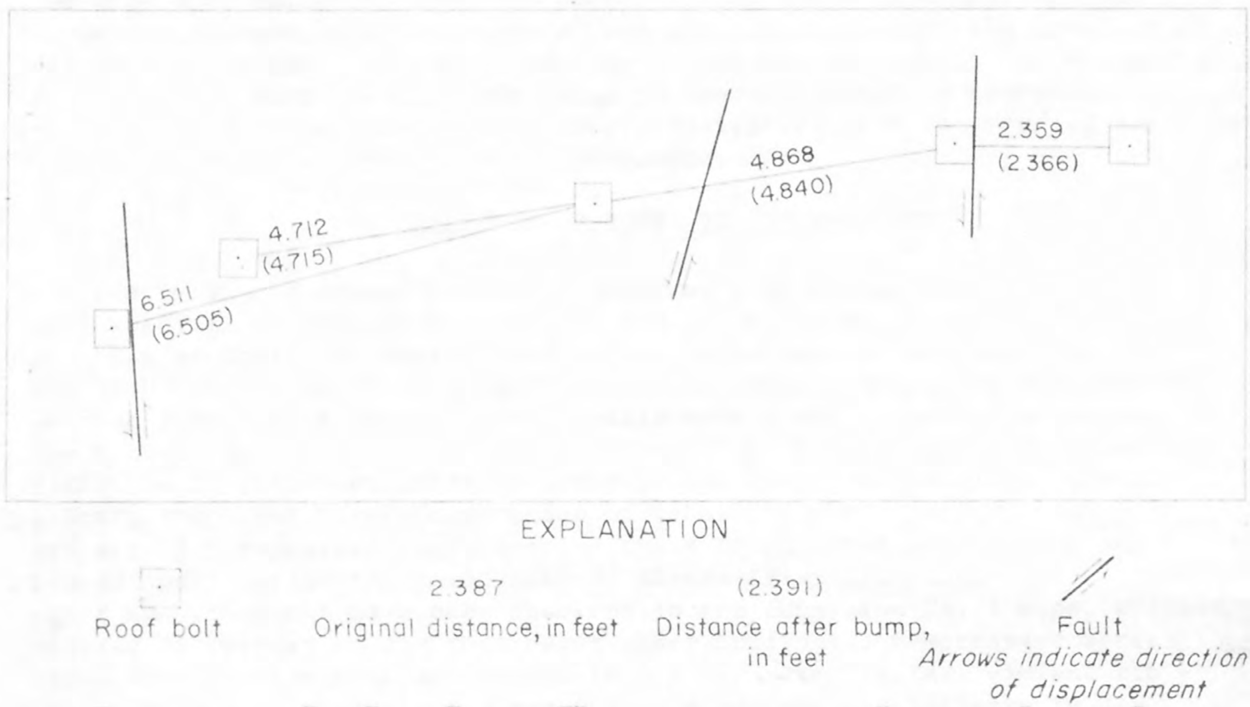

Figure 4.--Distances measured between roof bolts before and after violent bump, May 6, 1961. Vertical section near the roof of northwest side of air return, across small faults in upthrown side of Sunnyside fault zone, in the Sunnyside No. 1 mine, Utah.

Movement on the Sunnyside fault zone that probably occurred during bumps can also be measured at the surface. Rails on the haulage road from the Sunnyside No. 1 mine to the car dump are frequently bent horizontally and vertically where the track crosses the fault zone (Fig. 5). Levels and positions of marked points on the rails were determined in July 1961. A bump occurred along a manway about 20 ft beneath the track on the following day. Levels and positions of the marked points on the track were remeasured immediately. Horizontal movements of as much as 0.1 ft and vertical movements of about 0.05 ft were found. Although bending of the track is commonly attributed by miners to subsidence of loose material into the manway, most bending takes place across a broad area where the track crosses the fault zone (Fig. 6) and is not restricted to the vicinity of the portal. Furthermore, after the July 1961 bump no loose material or evidence of subsidence could be seen in the manway, indicating that the bending resulted from fault movement and not from subsidence.

RELATION OF BUMPS TO STRATIGRAPHY

Early in the investigation we observed that the deformation of coal mine workings at Sunnyside, of which bumps are a part, was dependent on the type of roof rock overlying the coal. Coal moves into openings more easily beneath argillaceous roof rocks than beneath sandstone or siltstone because friction is less beneath argillaceous rocks. This allows stress in the ribs to be easily relieved by many small bumps. In contrast, massive sandstone or siltstone units in the roof may form a rigid plate, thereby placing increased stress components on ribs. If the ribs are strong, or are strongly supported, such massive units in the roof may fail by shear (cave) under horizontal components of stress (Fig. 7). Interrelated roof caves and rib bumps have been observed in the Sunnyside No. 1 mine, wherein massive siltstones in the roof caved under horizontal compressive stress along curved surfaces that flatten in dip downward. Later, violent rib failures (bumps) took place along curved surfaces that increase in dip downward. These were previously described as cymoidal fractures.[6] Similarly, floor heaves and rib bumps that are probably interrelated were observed in the Sunnyside No. 3 mine in September 1964. Large anticlinal floor heaves, similar to those shown in Fig. 8, formed suddenly, simultaneous with the failure of the ribs. Some of these heaves broke along irregular fault planes parallel to the crest. Several days later the ribs in a nearby area failed violently, with only minor floor heaving.

no fig 5

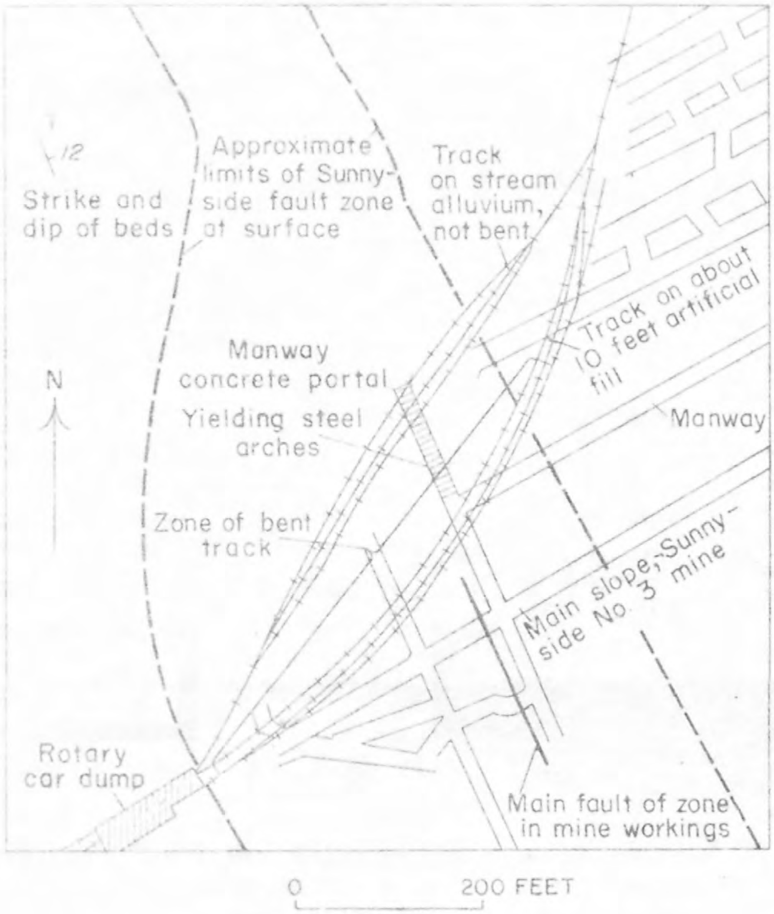

Figure 6.--Relationship of bent track to Sunny-side fault zone above manway, Sunny-side No. 3 mine.

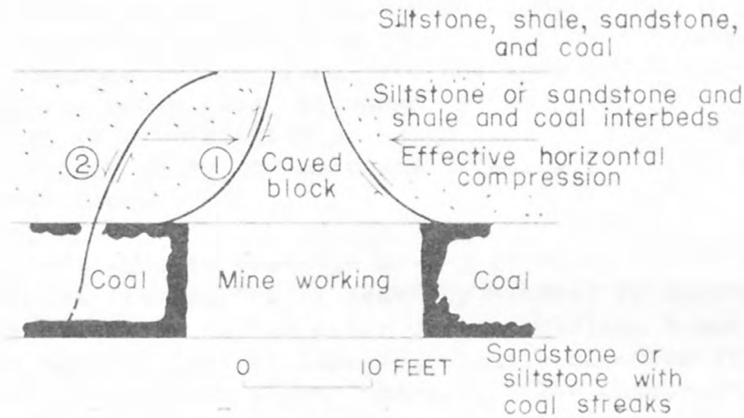

Figure 7.--Shear failure (1) of massive roof rock under inferred horizontal compression, followed by violent shear failure along cymoidal fractures (2) that increase in dip downward.

Ribs in the Sunnyside mines commonly fail in one of two ways. Where coal is free to slip beneath the roof, cymoidal shear fractures form within the ribs, but where coal adheres to the roof the ribs bulge and buckle (Fig. 8). Most bumps result from failure along cymoidal fractures, but loose coal is thrown down from some bulged ribs during bumps. Commonly one rib will fail along cymoidal shear fractures whereas the opposite rib will fail by bulging and buckling, which implies that coal is free to slip beneath the roof in one direction, but not in the other direction. This probably results from original sedimentary features in the bedding surfaces, such as ripple marks, channel fills, load casts, crossbeds, and slump structures, which impart pronounced but variable differences to the frictional properties of the surfaces in different directions. Such directional differences in the frictional properties of bedding surfaces may be the cause for many other observed differences in the deformation of opposite sides of mine workings in the Sunnyside No. 1 mine[6] and in the Sunnyside No. 2 mine.[5] In general, southeast ribs of slopes and downdip ribs of entries and crosscuts are deformed more and show more effects of bumps than northwest ribs and updip ribs, although in many places the reverse is true. Movement of coal into workings also is greater from downdip and southeast ribs than it is from updip and northwest ribs, which gives many workings an asymmetric appearance.

The main coal seam is overlain by 1-3 ft of carbonaceous siltstone and 2-3 ft of coal (called "rider seam" by miners) in many places throughout the Sunnyside district. At the sites of many violent bumps, the rider seam is overlain by several feet of massive, tightly cemented siltstone and sandstone which fill former stream channels. The carbonaceous siltstone is cemented in part by carbonate minerals, and contains small vitrain streaks that are parallel to bedding planes and to small slump structures. It is hard, and appears massive, but when compressed it breaks into many small plates with conchoidal fracture. The carbonaceous siltstone commonly fails along linear belts as much as 50 ft long oriented at small angles to the trend of the workings, and moves toward the center of the workings by slipping beneath the rider seam. Within these linear belts the siltstone is sheared and crushed into lenticular plates about 1 in. thick and 3-10 in. wide. At places where landing mats are bolted to the roof, the mats are compressed laterally, where the bolts move closer together, and form loose loops most of which are filled with broken pieces of siltstone. These steep-walled lumps (Fig. 9) are called "baskets full of rocks" by the miners. Horizontal movement of the siltstone beneath the rider coal is clearly shown by nearly right angle bends in roof bolts that have fallen out during bumps. Miners report that the "baskets full of rocks" indicate areas that may bump, but most belts of sheared rocks form before bumping occurs. Lateral movement of siltstone inward toward the workings probably produces cymoidal shear fractures in the ribs as described previously; these fractures commonly form during bumps.

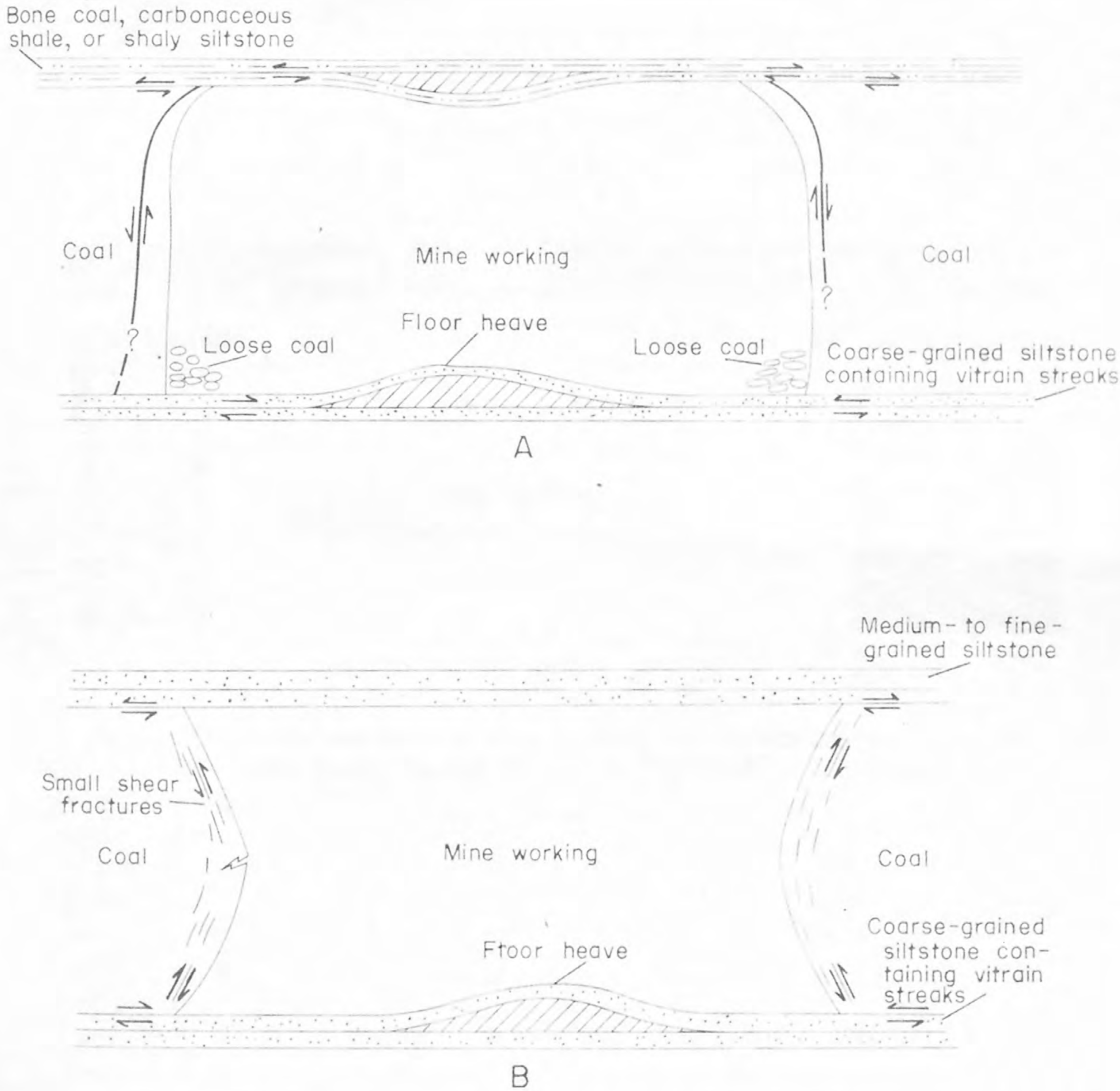

Figure 8.--Relation of common types of rib failures to lithology of roof rocks, Sunnyside district, Utah. A. Cymoidal fractures in rib where coal is free to slip beneath roof of bone coal, carbonaceous shale, or shaly siltstone. B. Bulged and buckled ribs where coal adheres to siltstone or where slip is impeded by sedimentary structures in the roof.

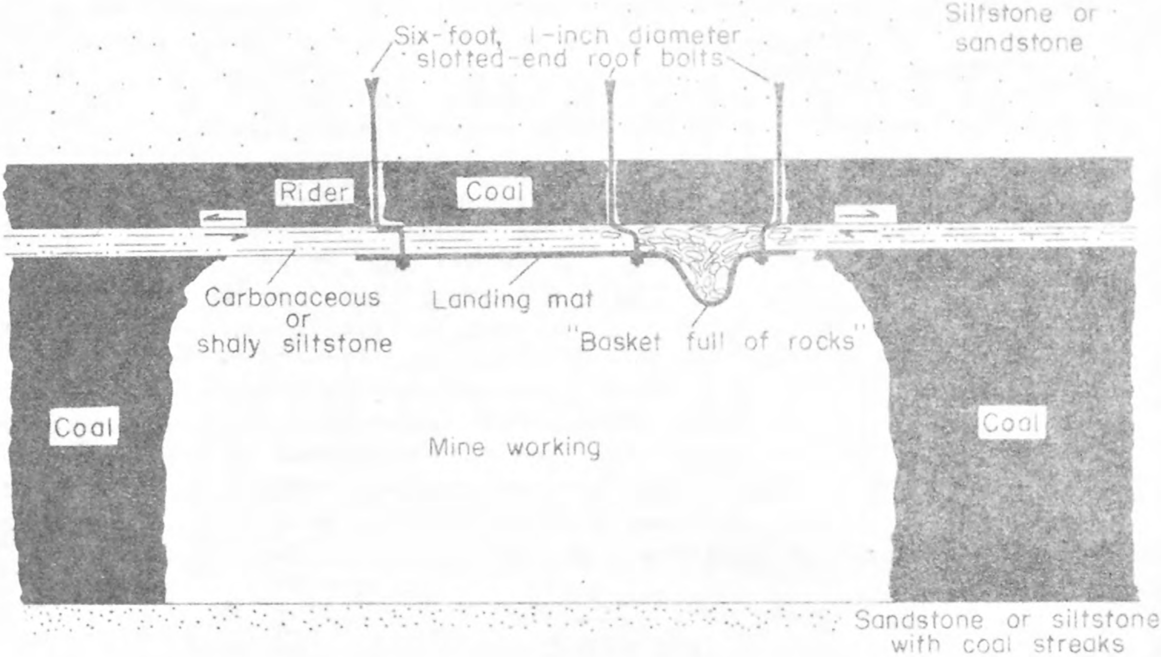

Figure 9.—Cross section showing failure of carbonaceous siltstone roof along linear belt with "baskets full of rocks."

The unfavorable stratigraphic sequence consisting of coal overlain by carbonaceous siltstone, rider coal, and massive siltstone or sandstone has a further effect on bumps and on certain mining practices in the Sunnyside district. During mining operations, attempts are made to remove all coal pillars and allow the roof to cave behind the pillar line. This practice reduces the abutment stress on working faces, and lessens the hazards from bumps. The combination of siltstone, rider coal, and massive siltstone, when roof-bolted, may not cave properly behind a pillar line, especially when a new pillar line is being established, and hence may induce bumps due to increased abutment stress. Good roof conditions and fair pillar extraction can be obtained in some places with few bumps by mining the carbonaceous siltstone and the rider coal with the main seam.

One recent bump in the Sunnyside No. 1 mine illustrates these points (Fig. 10). A new retreating pillar line was started at the northwest end of the 11th left entry, leaving a large barrier pillar. Several rooms were driven, and pillar extraction was proceeding. The roof, however, had only partially caved, and in general, the massive siltstone had not caved. Consequently, additional stress was thrown on the working pillars, and a damaging bump took place at the point shown by X in Fig. 10. The bump consisted of violent failures of both roof and ribs, and probably included compressive shear failure of the roof and failure of ribs along cymoidal fractures. Subsequent geologic mapping showed that there had been considerable movement of carbonaceous siltstone into workings, and that shear zones ("baskets full of rocks") had formed in two directions at very acute angles to directions of the workings.

CONCLUSIONS

Some bumps in the Sunnyside district are related to geologic features. Where stress accumulates along faults, either because of natural causes or as a result of mining, bumps may result within about 1000 ft of faults.[6] Underground and surface movement takes place along faults during bumps. The lithology, smoothness of bedding planes, and stratigraphic succession of rocks overlying the coal influence the deformation of mine workings, the incidence of bumps, and certain mining methods. Close attention to these geologic factors may enable mining engineers to adjust mining practices to varying geologic conditions and hence lead to more economical and safer mining.

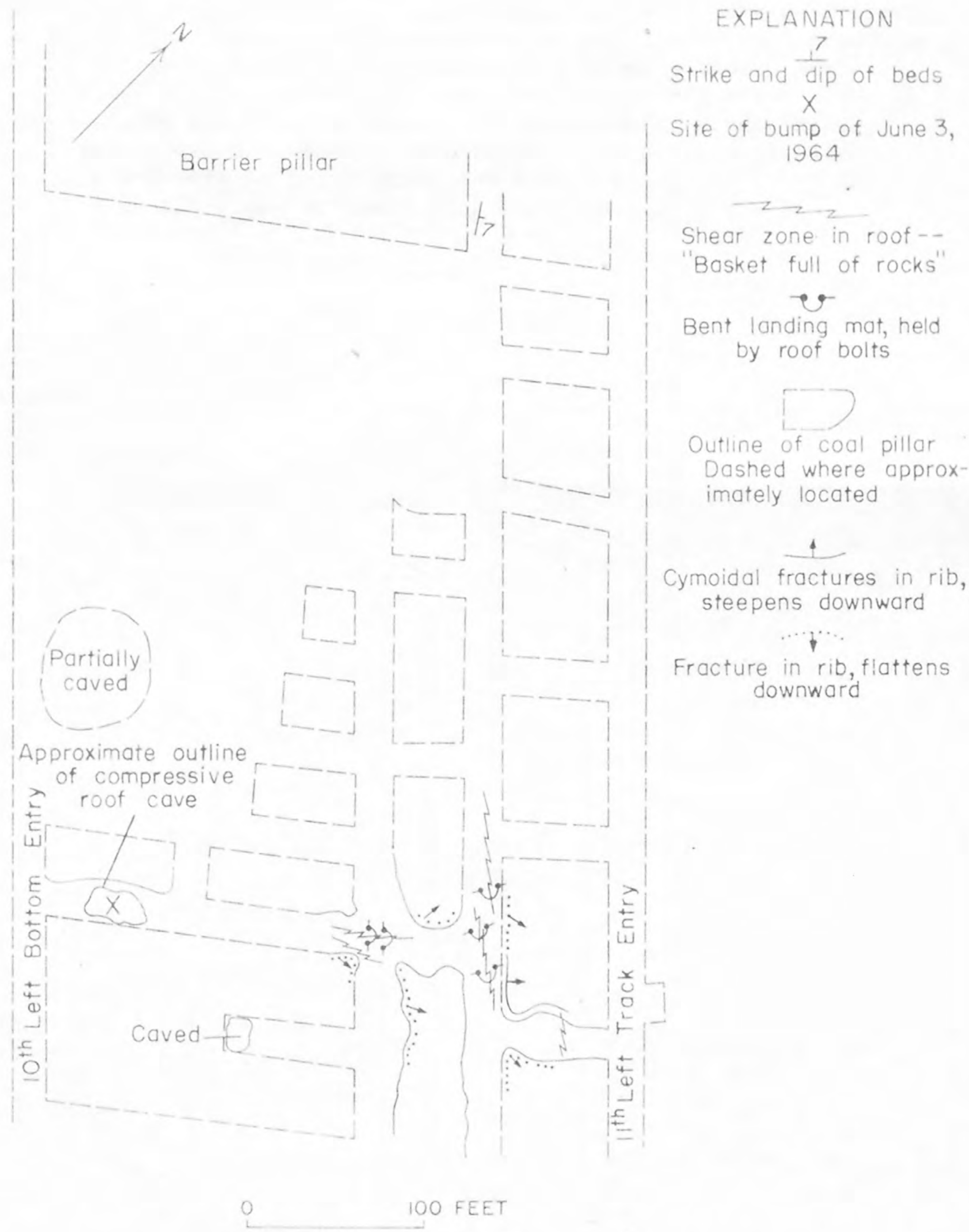

Figure 10.--Map of the northwest end of the 11th left entry, Sunnyside No. 1 mine, Utah.

ACKNOWLEDGMENTS

We thank D. J. Varnes, of the U.S. Geological Survey for continuing help, encouragement, and advice since the beginning of the work. John Peperakis and R. M. von Storch allowed the authors free access to the properties under their control and have materially aided the work through many technical discussions. Lynn F. Huntsman and J. B. McKean provided engineering information, mine maps, and survey notes. Thanks are also due Mr. Huntsman and Mr. McKean for many discussions of mutual problems, from which we have benefited greatly. Thomas McCourt, Joseph Harvey, Frank Markosek, and James Cassano, mine superintendents in the district, made possible our work in their mines and helped immeasurably by discussing many problems in the light at their long experience with bumps.

REFERENCES

[1]F. R. Clark: Economic geology of the Castlegate, Wellington, and Sunnyside Quadrangles, Carbon County, Utah, USGS Bull. 793, 1928, 165 p.

[2]Harold Brodsky: The Mesaverde Group at Sunnyside, Utah, USGS Open-file Report, 1960, 70 p.

[3]C. R. Dunrud and F. W. Osterwald: Seismic study of coal mine bumps at Sunnyside, Utah, SME-AIME paper, 1965.

[4]A. C. Watts: An unusual "bounce" condition, Coal Age, 1918, vol. 14, p. 1028-1030.

[5]John Peperakis: Mountain bumps at the Sunnyside mines, Mining Engineering, 1958, vol. 10, p. 982-986.

[6]F. W. Osterwald: USGS relates geologic structures to bumps and deformation in coal mine workings, Mining Engineering, 1962, vol. 14, no. 4, p. 63-68.