Chapter 62

AN INVESTIGATION OF THE CAUSES OF CUTTER ROOF FAILURE IN A CENTRAL PENNSYLVANIA COAL MINE: A CASE STUDY

by John L. Hill, III and Eric R. Bauer

Geologist, U.S. Bureau of Mines
Pittsburgh, Pennsylvania

Mining Engineer, U.S. Bureau of Mines
Pittsburgh, Pennsylvania

ABSTRACT

Cutter roof failure is a specific type of ground control problem which frequently results in massive roof failure. It is a common occurrence in coal mines of the Northern Appalachian Coal Basin, causing delays in production and posing a safety hazard to mine personnel. The Bureau of Mines is conducting research on the causes of cutter roof failure to gain a basis from which to prevent its occurrence and to support such roof when failure does occur.

Research conducted in a coal mine of central Pennsylvania has revealed a correlation between the occurrence of clastic dikes and formation of cutter roof failure. In-mine mapping of ground conditions showed an increase in roof failure in areas of high frequencies of clastic dikes. Rock pressure monitoring around clastic dikes registered the greatest amount of roof loading near the intersection of dikes with the rib. Load cells measuring horizontal pressure changes in the roof indicated that the greatest pressure changes were occurring perpendicular to entry headings when clastic dikes were present. Analysis of rock pressure monitoring shows that the roof behaved as two cantilever beams when severed by a clastic dike. Additional roof supports such as trusses and cribbing were found to effectively support the roof in areas of clastic dikes and prevent cutter roof failure. However, these methods were only successful when employed shortly after mining.

INTRODUCTION

Occurrences of cutter roof failure during development mining have been observed in increasing numbers. In response to this, the Bureau of Mines is investigating the causes of this type of roof failure, which can deteriorate to a major roof fall if additional support is not applied. The uniqueness of this problem has limited the techniques available for its treatment. The approach of trial and error treatment has proven unsatisfactory in many cases, as the causes are often different from mine to mine.

Cutter roof failure initially begins as a fracture along one or both roof-rib lines of an entry and propagates nearly vertically into the roof (fig. 1). When the fracture breaks to a height above the anchor horizon, or along a weak bedding plane, massive roof failure may occur. Figure 2 is an example of severe cutter failure and figure 3 illustrates the end result of such cutter development.

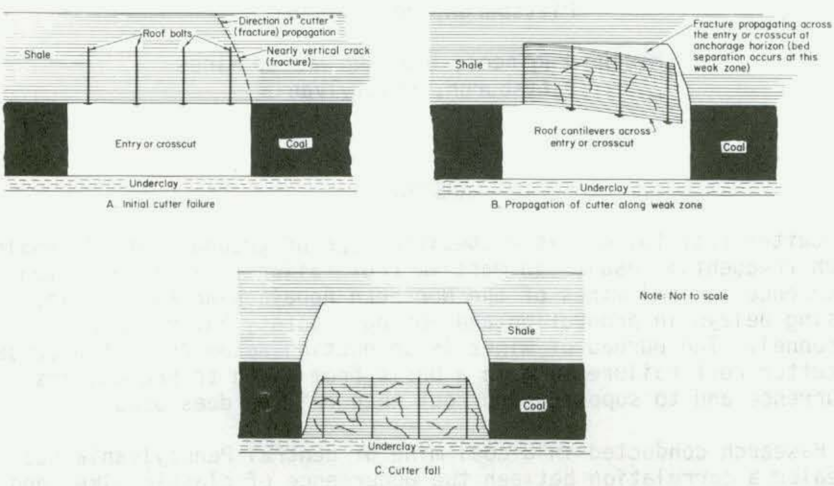

Fig. 1. Cutter roof failure diagram (modified from Kripakov, 1982; Nichols, 1978; Stefanko, 1983).

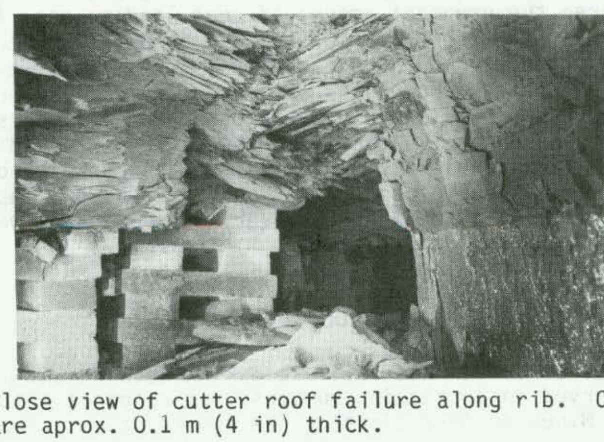

Fig. 2. Close view of cutter roof failure along rib. Crib blocks are aprox. 0.1 m (4 in) thick.

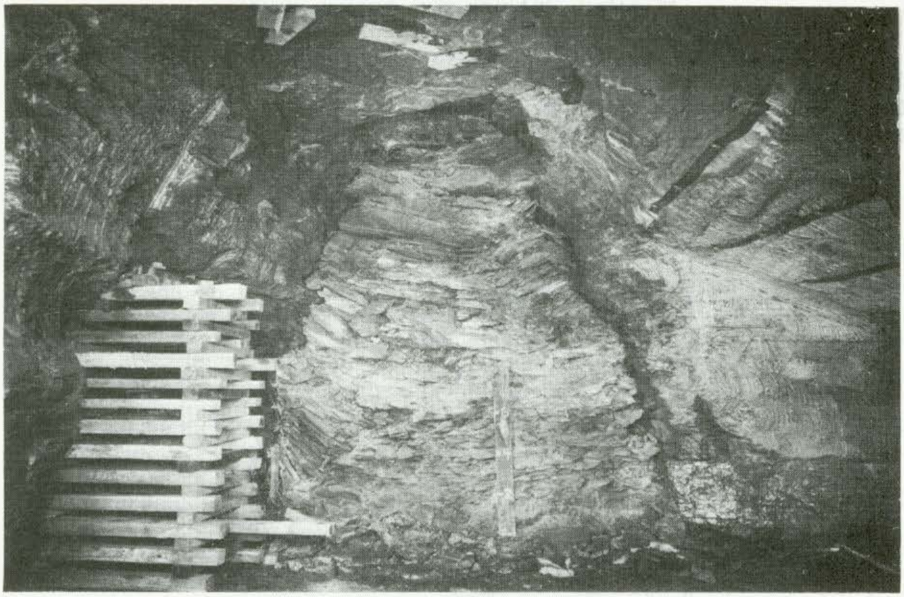

Fig. 3. Roof fall as result of cutter roof failure in study mine. Numbers on board represent feet above floor rock.

Previous research by the Bureau has shown a correlation between cutter roof failure and high horizontal stress fields. Aggson (1979) and Kripakov (1982) conducted studies addressing the particular stress state that would initiate cutter roof using finite element analysis. Research conducted by Thomas (1950) approached cutter development from a purely practical perspective, without any instrumentation. His work is believed to be the earliest attempt to understand cutter development. The influences of the direction of mining and occurrence of clastic dikes on cutter roof failure formation have been observed through detailed mapping by Iannacchione, et.al., (1984).

The occurrence of cutter roof has had a major effect on entry stability at the Greenwich Collieries North Mine of Indiana County, Pennsylvania. The investigation conducted there was comprised of two basic phases which contribute to an understanding of the pressure dynamics surrounding cutter development and the influence of geologic anomalies. The first phase consisted of in-mine mapping of all deformational and geologic features in the area studied. The second phase included the instrumentation of roof and pillars to determine pressure changes near and away from geologic anomalies as mining advanced. Improving entry stability through timing and placement of supports and design of mine configuration was found to effectively reduce cutter development.

GEOLOGIC SETTING AND MINING METHOD

The study area is located within the Appalachian Plateau Province along the axis of the Brush Valley Syncline (fig. 4). Structural relief on the mine property does not exceed 152 m (500 ft), and dips are generally less than 2.5°.

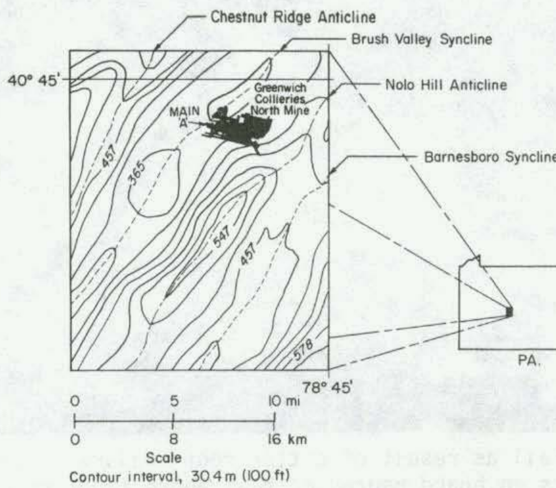

Fig. 4. Structure location map of Greenwich Collieries North Mine. Contours on base of Lower Freeport Coalbed.

The coalbed being mined is the Lower Freeport which is stratigraphically within the Pennsylvania age coal bearing rock of the Allegheny Group. The Lower Freeport Coalbed has an average thickness of 0.9 m (3 ft) and is directly overlain generally by 3 to 4.8 m (10 to 16 ft) of a competent dark gray shale (fig. 5). Above the shale bed is a sandy shale interbedded with shale and sandstone; this unit ranges from 3 to 4 m (10 to 13 ft) in thickness. Intermittently the channel phase Butler Sandstone replaces the shale and sandy shale units. The next stratigraphically higher coalbed is the Upper Freeport with an average interburden of 9 m (30 ft). The maximum overburden above the Lower Freeport Coalbed is 200 m (655 ft). Immediately below the Lower Freeport is a sporadically limey underclay ranging from 1 to 3 m (3 to 10 ft); this, in turn, is underlain by shale.

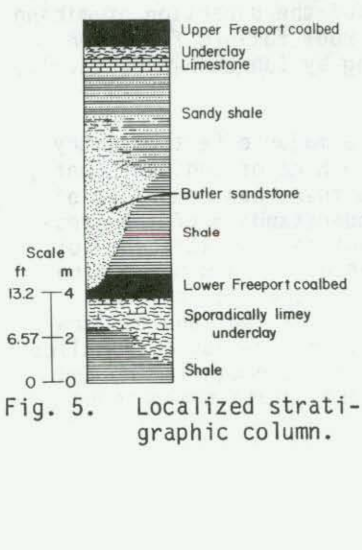

Fig. 5. Localized stratigraphic column.

In the area of the mine being studied coal is being extracted through the use of a drum-type continuous miner. The section employs a system of five to nine entries driven on 18.2 m (60 ft) centers. Entry and crosscut widths are approximately 5.5 m (18 ft) with crosscuts normally driven on 24.3 m (80 ft) centers.

CUTTER ROOF INVESTIGATION

Although cutter roof failure is a mine wide occurrence at the Greenwich Collieries North Mine, unusually severe cutter conditions were being experienced near the face of the Main A heading (fig. 4). This heading will ultimately be used to reach the remaining reserves available; thus, it is important to maintain entry stability for the life of the mine.

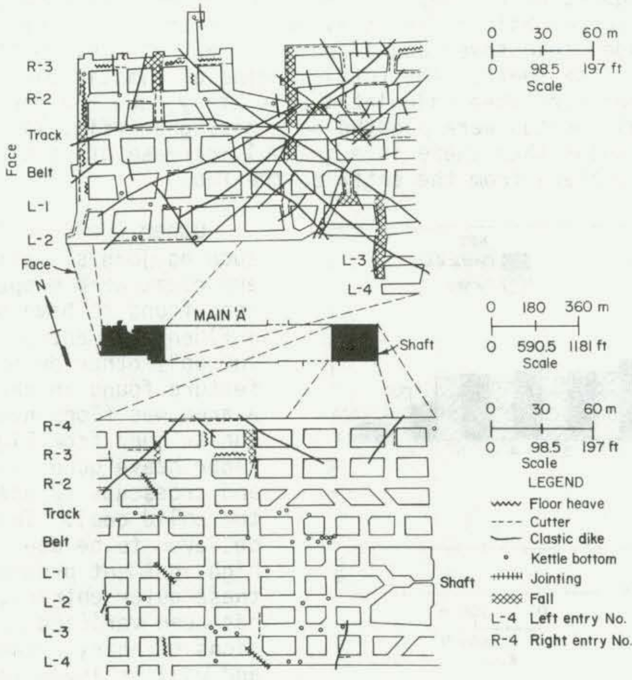

Fig. 6. Geologic structure and deformation map of Face and Shaft areas showing difference in clastic dike and cutter frequencies.

Assessment of Ground Conditions

Detailed mapping of geologic features and deformation due to pressure release phenomena was conducted in the Main A heading from the shaft to the face. Figure 6 is an example of the mapping and illustrates the relation of geologic features to mining-induced deformation. Clastic dikes (commonly known in mining terms as clay veins) ranged in thickness from 30 cm (1 ft) of claystone matrix with fragments of shale and coal to as thin as a filmlike trace of calcite or clay. The dikes were observed (in roof falls) to extend as high as 8 m (26 ft) into the roof rock and would penetrate the coalbed at various angles. Few dikes reached the floor rock. Fractures and slickensides in the roof were associated with the presence of clastic dikes and slickensided faces were often marked with horizontal striations. Cutters normally formed adjacent to clastic dikes, with their deepest penetration (often greater than 60 cm (2 ft)) into the roof directly next to a dike and lesser penetration as distance from the dike increased. When cutter roof failure deteriorated enough to form roof falls, clastic dikes often formed their boundaries (fig. 6). It can also be seen from Figure 6 that frequencies of clastic dikes and cutters are much greater near the face of Main A than they are near the shaft area. Main A was divided into seven equal areas of 2500 m^2 (26,880 ft^2) from the face to the shaft. The total lengths of clastic dikes and cutters in each area were then calculated separately, and the percents of their total lengths were plotted on a histogram (fig. 7). This histogram shows that there is a gradual increase of both clastic dikes and cutters from the shaft to the face.

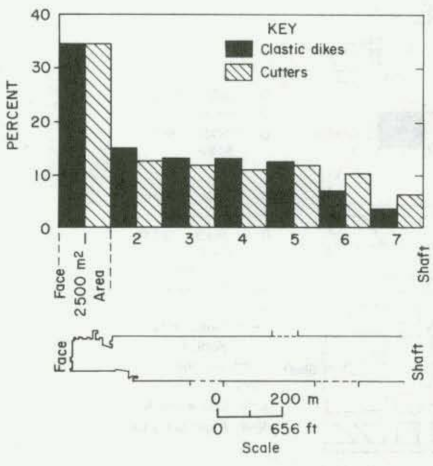

Fig. 7. Percents of total lengths of clastic dikes and cutters in equal areas of 2,500 m^2.

Other geologic features such as joints, kettlebottoms, and cleat were mapped but were found to have no major influence on entry stability. The only other deformational feature found in the Main A area was floor heave. As can be seen from Figure 6, floor heave occurred in entries and crosscuts adjacent to the solid coal. This is believed to be due to rather high abutment pressures in these outer entries, which has been verified by observations of entry advancement and will be investigated further through in situ stress measurements.

Rock Pressure Monitoring

Observations made through mapping revealed that cutters mainly formed adjacent to clastic dikes shortly after mining. This suggested that the disruption of roof integrity, due to the presence of clastic dikes, was contributing to the propagation of cutters. The natural beam of the roof rock, spanning from pillar to pillar, is severed when a clastic dike is present, and this causes the roof to behave as two cantilever beams.

In an attempt to measure and quantify the cantilever beam effect, hydraulic diaphragms (load cells) were placed in the roof strata to measure pressure changes parallel and perpendicular to the entries as mining advanced. An individual load cell measures pressure changes in only one direction; thus two cells were used to measure mutually perpendicular horizontal pressure changes. The cells were set in the roof strata to a height of 1 m (3 ft) from the mine roof surface, which placed them approximately halfway between the anchor horizon and mine roof surface. The load cells had an initial setting pressure of approximately 1800 kPag (260 psig) to ensure a solid contact with the strata. The pressure was read as gage pressure because barometric pressure was not considered to cause significant change.

Later, hydraulic U-cells were placed on bolts in monitored areas along with the load cells. The U-cells measure bolt loading and were installed on the regular mining cycle as bolts were installed. The bolts being used in Main A are of the point anchor resin, tension rebar type. Since the U-cells were installed as the bolts were being installed, their setting pressure was determined by the amount

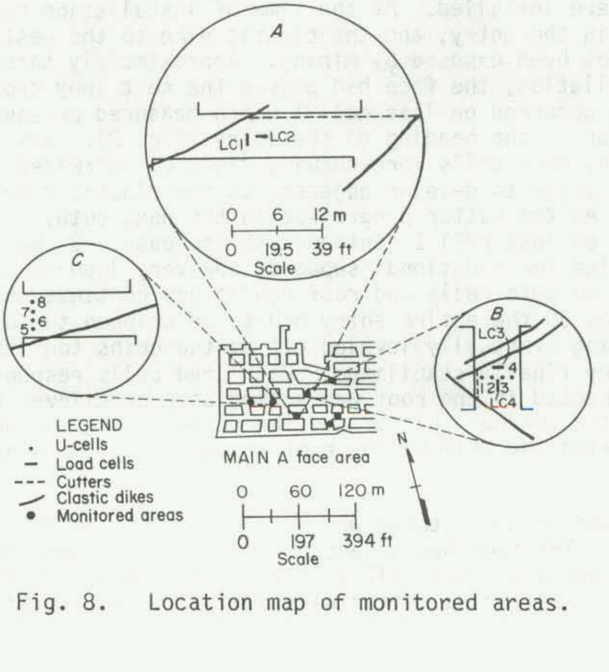

Fig. 8. Location map of monitored areas.

of torque applied by the bolting machine. This torque ranged from 271 to 406 Nm (200 to 300 ft/pounds), which resulted in a U-cell reading of 3960 to 5000 kPag (575 to 723 psig).

All instruments were installed in fresh cuts at the furthest advance of mining in that particular entry or crosscut.

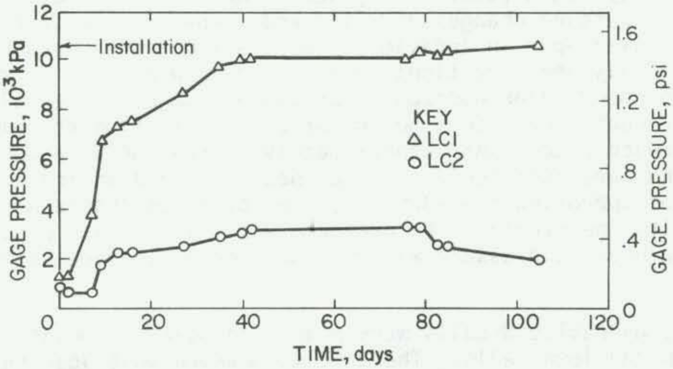

Fig. 9. Behavior of load cells 1 and 2.

The first area monitored was in the L-1 entry of Main A; two load cells were installed (fig. 8, A). The entry had been advanced to a position approximately 3 m (10 ft) west of load cell 1 when the cells were installed. At the time of installation no cutter had formed in the entry, and the clastic dike to the west of the cells had not been exposed by mining. Approximately three days after installation, the face had passed the next inby crosscut, and loading occurred on load cell 1 which measured pressue changes perpendicular to the heading of the entry (fig. 9). Six days after installation, both cells were showing signs of increased loading as a cutter began to develop adjacent to the clastic dike just inby the cells. As the cutter progressed to the next outby clastic dike, the loading on load cell 1 continued to increase. By day 10 posts were installed for additional support; however, loading continued to increase on both cells and roof conditions continued to deteriorate. On day 30 the entire entry had to be cribbed to control the roof. Loading eventually leveled off as the cribs took the load, and the entry finally stabilized. Both load cells responded as would be expected if the roof was acting as a cantilever beam with support on the southern pillar and the cutter along the northern pillar allowing the beam of the roof to bend (fig. 8, A and fig. 9).

The second area monitored was a crosscut between the belt and track entry. The face had advanced to a position approximately 3 m (10 ft) north of load cell 3 (fig. 8, B). Based on the first experience of monitoring cutter development, it was decided that

U-cells would be installed on a row of bolts across the entry to measure bolt loading in addition to using load cells. The clastic dikes just north of the cells had not yet been exposed by mining when all of the U-cells and load cells were installed (fig. 8, B).

Loading of U-cell 1 and load cell 3 occurred as soon as the next 6 m (20 ft) cut into the face was taken from the crosscut which exposed the two clastic dikes (fig. 10 and 11). Load cell 3 measures pressure changes perpendicular to the entry and showed a total increase of approximately 240 KPag (35 psig) in the first day while load cell 4 bled off. Some natural bleed off is expected as the hole deforms if there is no movement in the roof to apply a load to the cell or if extension occurs in the beam of the roof. By the second day the U-cell closest to the inby rib (U-cell 1) showed an increase in load of nearly 2000 KPag (290 psig) as cutter roof failure was beginning to develop along the inby rib between the clastic dikes intersecting the rib (fig. 8, B). From past experience with cutters developing this quickly, it was suggested that supplemental support be installed immediately. Trusses were installed between the rows of bolts, resulting in an immediate decrease in the rate of loading. The addition of trusses effectively reunited the natural beam of the roof and prevented the roof from deteriorating further. Finally loading leveled off (fig. 10 and 11) and the cutter did not become

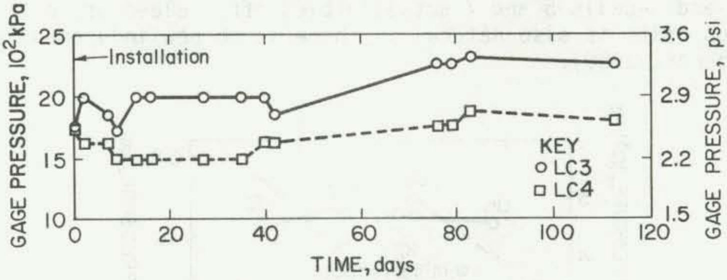

Fig. 10. Behavior of load cells 3 and 4.

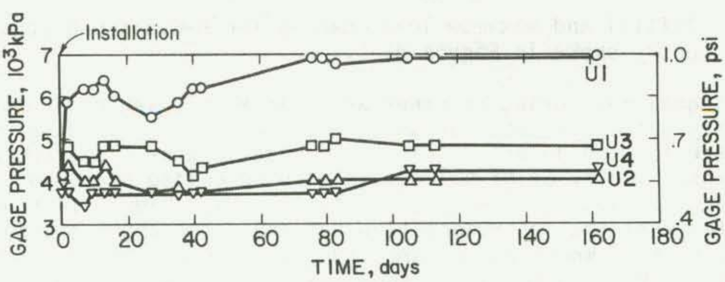

Fig. 11. Behavior of U-cells 1-4.

any more severe. Figure 12 shows the maximum load seen by each U-cell in the crosscut of Figure 8, B. Once again the loading roughly parallels that which would be expected from a cantilever beam (figs. 10, 11, and 12).

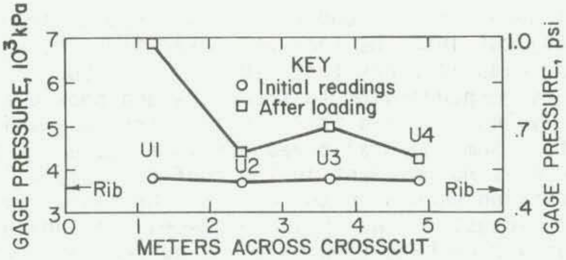

Fig. 12. Initial and maximum loads for U-cells 1-4 across crosscut shown in Figure 8, B.

In the next area (fig. 8, C) trusses were being used on a regular basis and had been successful in deterring the formation of cutters. Shortly after this cut was mined, some rock did fall from the clastic dike in the roof, but this activity ceased once trusses were installed. Figure 13 shows the total loading seen by each U-cell across the entry. Very little total loading occurred on U-cells 6 and 8, and U-cells 5 and 7 actually bled off. Bleed off of loading on bolts is also natural if there is no new inducement of load (Roberts, 1980).

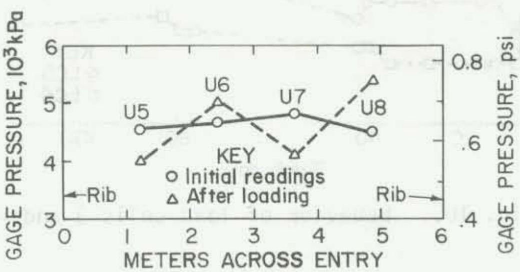

Fig. 13. Initial and maximum load changes for U-cells 5-8 across entry shown in Figure 8, C.

Additional monitoring of other areas in Main A is continuing. Preliminary data from these areas tend to support our findings that cutters are forming in association with clastic-dike-disturbed roof. Initial instrumentation of pillars is also revealing pressure changes around clastic dikes as mining advances. Figure 14 roughly illustrates what the instrumentation has indicated about the formation of cutters. When trusses are added as supplemental support, the clastic dike is effectively supported, allowing the roof to act as a solid beam.

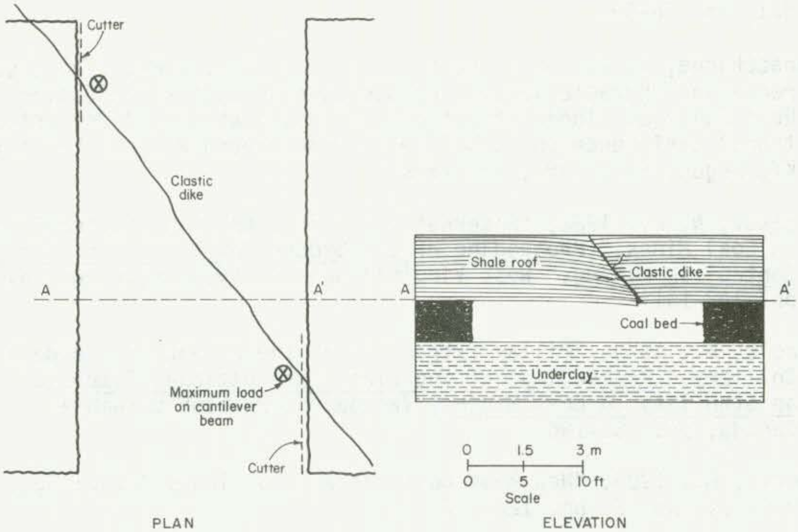

Fig. 14. Roof deflection at clastic dike due to weight of cantilever beam as would be expected from figure 12.

CONCLUSIONS

The increased occurrence of cutter roof failure, in the Main A heading of the study mine, was attributed to the high frequency of clastic dikes. Rock pressure monitoring near clastic dikes revealed that the roof strata were behaving as a cantilever beam. This cantilever beam would initiate cutter roof failure and develop along an entry or crosscut, often extending across several breaks. Staggering of crosscuts prevented the extension of cutters and deterred the occurrence of large falls extending over several breaks. Trusses and cribbing were found to be effective in stabilizing clastic dikes and inhibiting the development of cutter failure when employed immediately after mining.

In situ stress and rock property data will be collected at the mine and may give further insight into the development of cutter roof failure.

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