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WALLROCK REACTIONS TO MINING BEYOND A PRECONDITIONED ZONE AT THE STAR MINE, BURKE, IDAHO

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

by

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DESTRESSING IN ADVANCE OF MINING

APRIL 1980

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Rock preconditioning in advance of mining was shown to be an effective means of rock-burst control based on the results of a field demonstration carried out on the 7700 level of the Hecla Mining Company's Star mine. Mining through the preconditioned zone was characterized by greatly reduced rates of released seismic energy and no bumping or rock bursting occurred within the preconditioned zone.

Mining above the preconditioned zone was characterized by greatly increased rates of released seismic energy and rock bursting, particularly where the vein became very narrow in waste zones. This increased incidence of rock bursting points out the need for stope preconditioning to be carried out on an entire stope block basis.

The data obtained from the monitoring of the mining above the preconditioned zone on the 7700 level will be extremely useful in evaluating any future stope block preconditioning experiments on the lower levels of the Star mine.

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FOREWORD

This report was prepared by Wilson Blake, Consulting Mining Engineer, Hayden Lake, Idaho, under USBM Contract No. H0262039. The contract was initiated under the Metal and Nonmetal Health and Safety Research Program. It was administered under the technical direction of SMRC, with Mr. W. C. McLaughlin acting as the Technical Project Officer. Mr. W. P. Battle was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period March 1978 to March 1979. This report was submitted by the author on April 7, 1980.

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SECTION 1

INTRODUCTION

One of the hazards associated with deep mining is the occurrence of rock bursts. In the Coeur d'Alene mining district of northern Idaho rock bursting has become a severe operational problem. The trend in this district is for the ore, particularly the rich silver ore, to increase in value with depth; hence, the rock bursting will continue. Despite worldwide efforts to control bursting since the turn of the century, the problem has persisted and in some districts is the limiting factor in mining economically.

In the Coeur d'Alenes cooperative government-industry research programs during the last 15 years have led to a better understanding of the causes of rock bursting (see references 1 and 8). This in turn has resulted in a number of practical techniques aimed at decreasing the rock-burst hazard (see references 2, 3, 4, 6 and 7). Rock preconditioning to control rock bursting is the latest concept which is currently being field tested at the Hecla Mining Company's Star Mine, Burke, Idaho. Under this concept a premined ore block is blast fractured such that its basic material properties are irreversibly altered. The rock preconditioning results in providing stress relief fractures that allow the rock mass to become self-destressing as high stresses attempt to build up around subsequently mined openings. In the Coeur d'Alenes the massive quartzite layers, which are normally very rock-burst prone at failure, tend to yield slowly and nonviolently when this massive characteristic is broken up by blast fractures.

Rock preconditioning is an extension of destressing; but the destress drilling and blasting is carried out on a much larger scale during stope development and under normal stress field conditions. By contrast, destressing is carried out locally to relieve a critical high stress area where the occurrence of a rock burst may be imminent. Thus, the goal of preconditioning is to prevent the close-in rock-burst hazard from developing; whereas, the goal of destressing is to stress relieve an already existing rock-burst hazard.

The initial rock preconditioning field test was carried out under Bureau of Mines Contract H0262039, "Destressing in Advance of Mining". The results of this work, see reference 5, indicated that mining in a preconditioned zone was characterized by a greatly reduced release of seismic energy, which, in turn, indicates a reduced rock-burst hazard. This result was encouraging enough to warrant consideration of a much larger rock preconditioning experiment; therefore, this contract was extended so that the wall rock reaction to mining beyond the preconditioned zone could be monitored. This data could then be used as a reference base for comparison with data obtained from future preconditioning experiments.

This report describes the vein and wallrock reaction to mining above the preconditioned zones in numbers 7 and 10 main vein stopes on the 7700 level of Hecla's Star Mine.

SECTION 2

ORGANIZATION

This work, carried out under an extension of Bureau of Mines Contract No. H0262039, was a cooperative research program between the Bureau of Mines, Hecla Mining Company, and the contractor. Hecla provided the test site, underground access and transportation, power, water, compressed air, an underground instrumentation facility, drillers and equipment for diamond drilling of instrumentation holes, surface office space, and engineering support. In addition, Hecla made data from its minewide rock-burst monitoring system available for detailed analyses. The Bureau of Mines, through the Spokane Mining Research Center, provided funding, engineering personnel, instrumentation, data analysis, finite-element modelling studies, material properties testing and technical guidance. The contractor coordinated activities between Hecla and the Bureau, gathered and analyzed data from the instrumentation program, analyzed data from Hecla's RBM system, and evaluated all the data with respect to the effectiveness of the preconditioning field demonstration.

SECTION 3

MINING METHOD AT STAR MINE

The Star-Morning vein system is mined with a timbered, overhand cut-and-fill method. The ore body on each level is developed by a lateral drift some 125 feet out in the wall and parallel to the vein. Crosscuts are driven through the vein on nominal 200-foot centers. A blind stoping method is used with cribbed raises carried in the fill. Stopes are prepared for mining by opening up a timbered raiseup area and then driving a first floor or I-drift some 20 feet above the level. Stoping is then carried out in 10-foot cuts by horizontal breast-down rounds. All cuts are timbered as mined to provide temporary wall and back support because of heavy ground. Once a floor is mined, the crib is raised, the mined-out floor is sanded, then mining commences on the next floor.

SECTION 4

MINING AND ROCK BURSTING AT THE STAR MINE

A review of available reports on past rock bursting at the Star Mine, dating back to the early 1940's, indicated that bursting did occur during the mining of the upper levels, but this bursting was infrequent causing only occasional minor damage. The occurrence of this bursting appeared to be related to burst-prone mining geometries--pillars, remnants and converging mined openings. This bursting was more or less randomly located throughout the orebody, but with some relationship to waste zones.

As the bottom of the old Morning workings was approached on the 6700 level the incidence and severity of bursting increased. With the development of the 6900 level, in the high stress zone below the Morning workings, severe bursting was encountered in raising up and in driving first floors. Similar conditions, although not as severe, were encountered on the 7100 level; and a recurrence of heavy bursting accompanied the development and mining of the 7500 level.

In general, serious bursting at the Star began with the development and mining of the 6900 level and has continued with subsequent levels. This bursting has been concentrated in two areas--bursting accompanying raiseup and first floor mining, particularly in the pillar between converging floors, and bursting associated with sill pillars. This pattern of rock bursting is demonstrated on figure 4-1, which shows the locations of damaging bursts accompanying the mining of the 7500 level. Of the some 35 bursts occurring 28 or 80% were associated with first floor or sill pillar geometries.

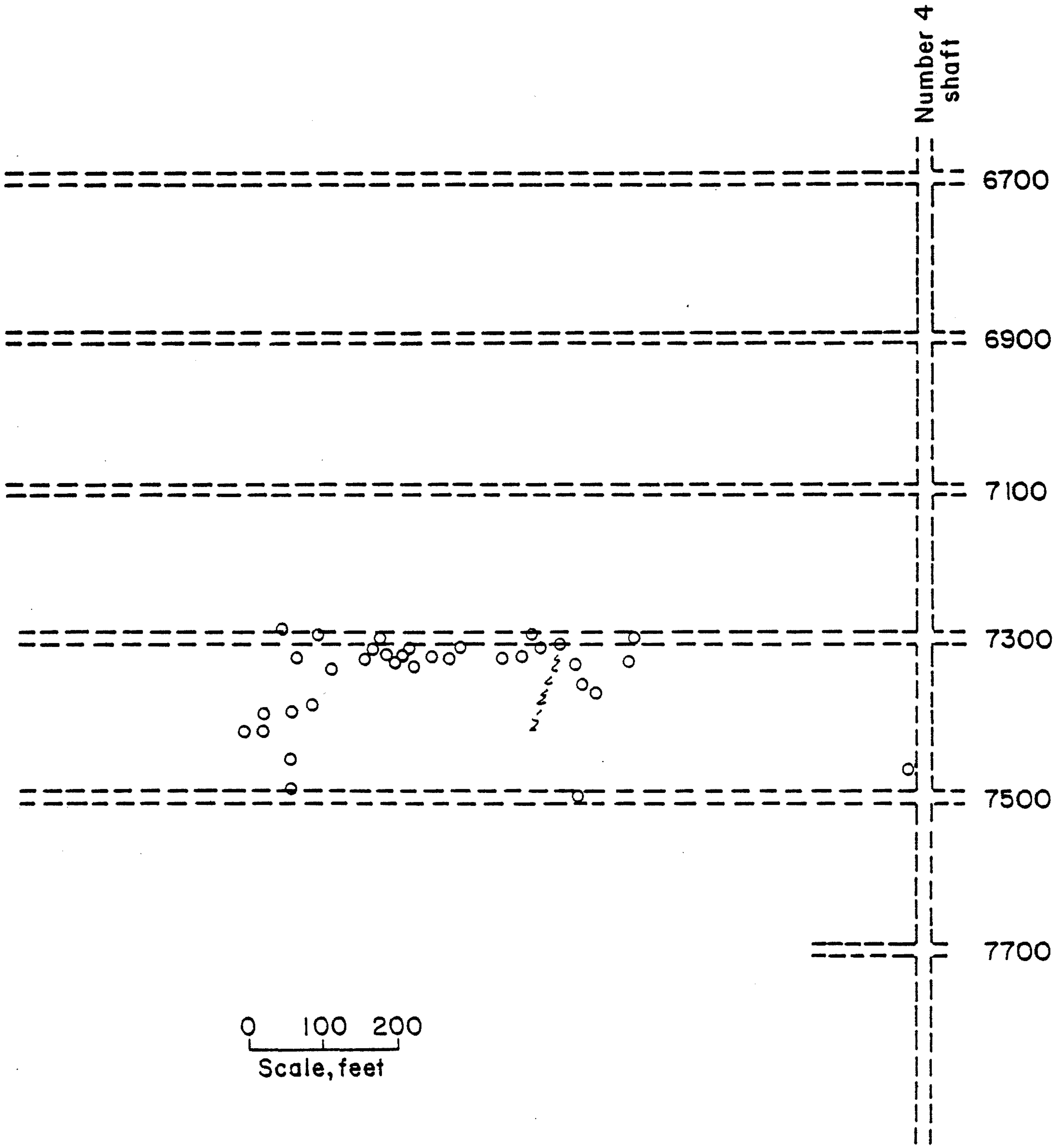


Figure 4-1 Location of Rock Bursts Accompanying the Mining of the 7500 Level, Star Mine

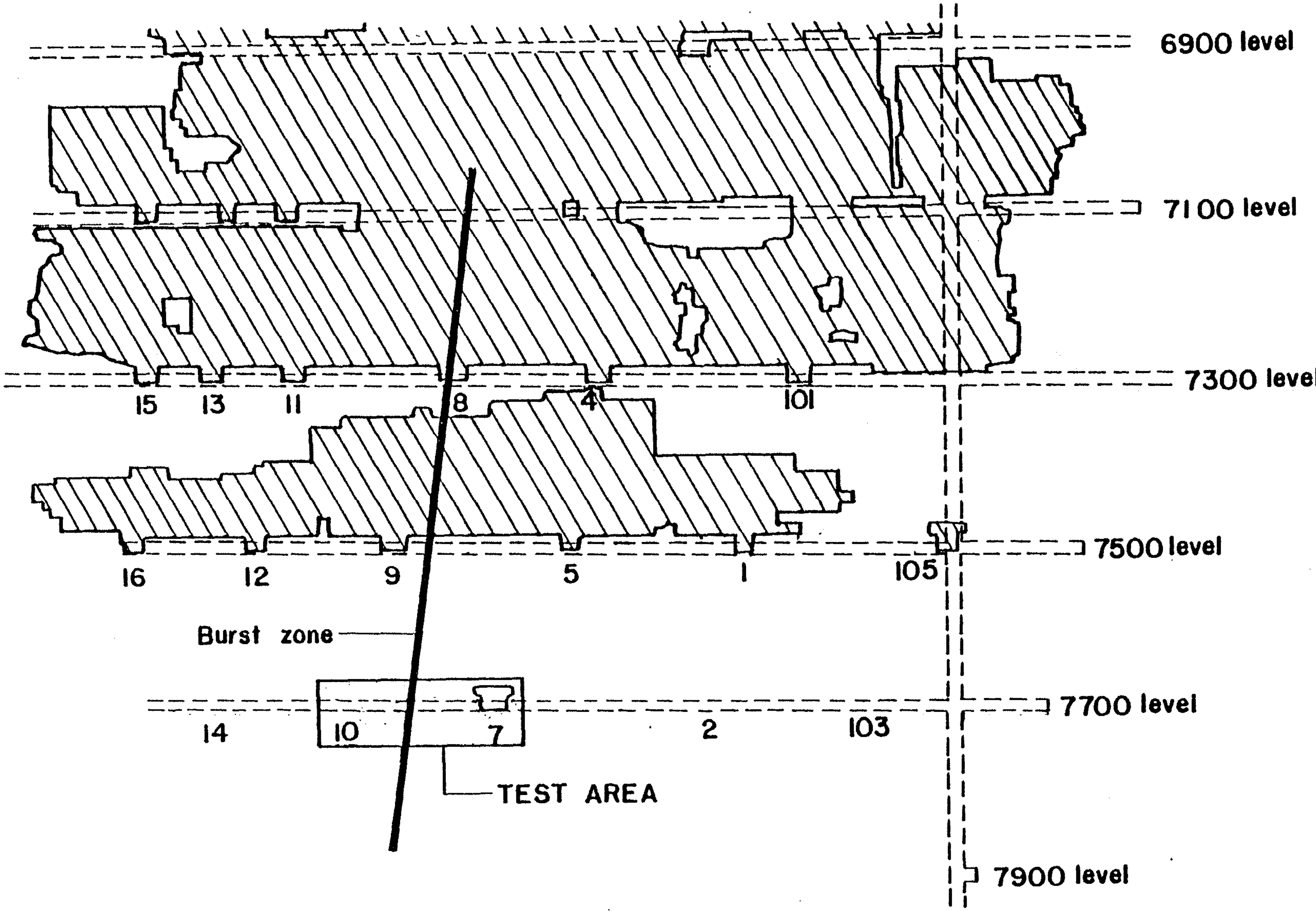
SECTION 5

INITIAL PRECONDITIONING DEMONSTRATION

To demonstrate the feasibility of rock preconditioning as a means of rock burst control, a block of ground along the main vein of Hecla's Star mine was selected as a test site. This area was along the downward extension of the principal bursting zone at the Star as shown on figure 5-1. The destressing in advance of mining or rock preconditioning experiment was carried out on the 7700 level between numbers 7 and 10 crosscuts as this level was being developed for production. The goal of this demonstration was to allow the initial mining on the 7700 level to begin in a destressed or preconditioned zone, and later mining from the 7900 level to end in a preconditioned and self-destressing pillar.

5.1 DESTRESS DRILLING AND BLASTING

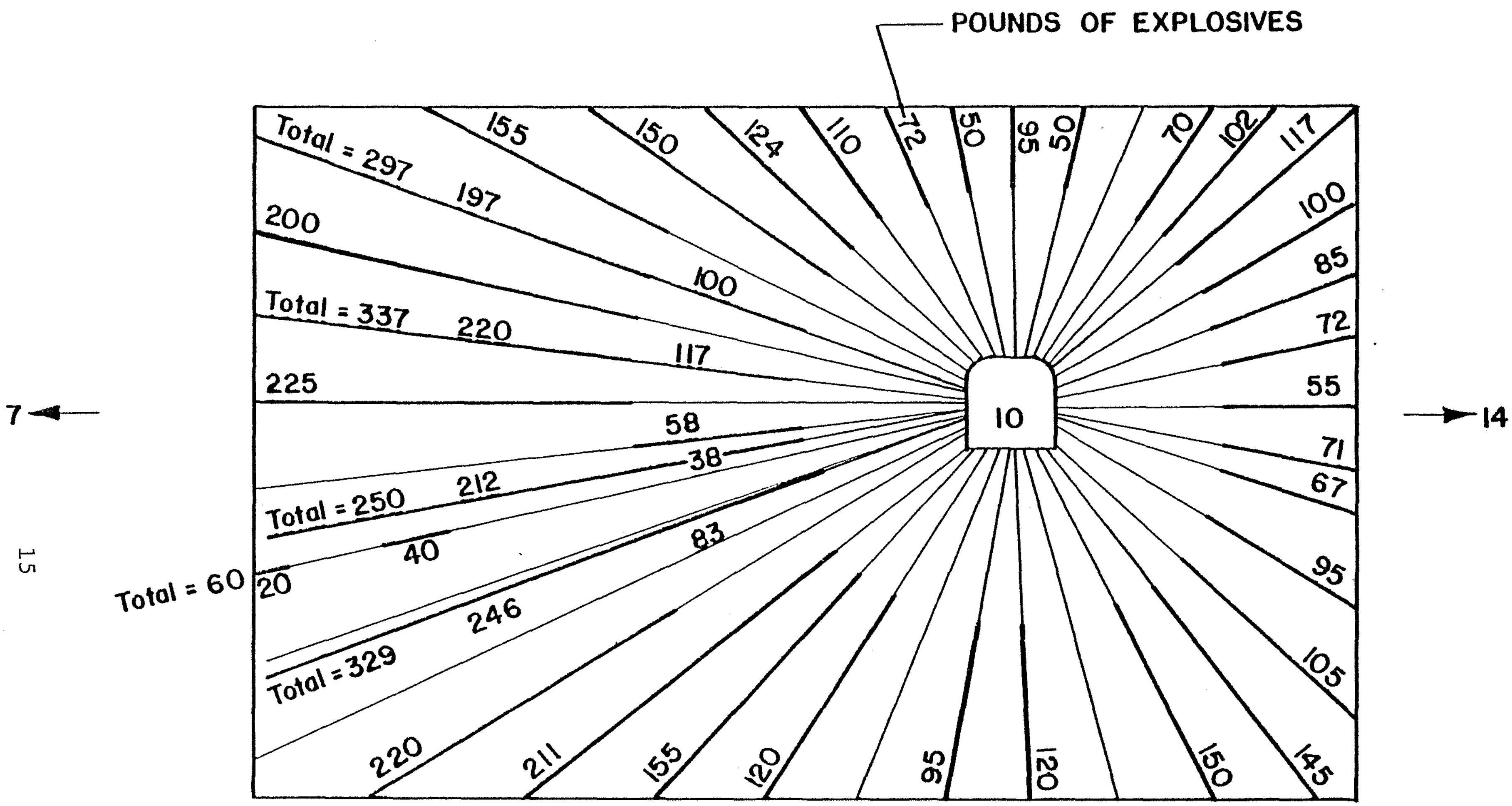
The field demonstration involved the blast fracturing or stope preconditioning of a block of ground some 250 feet along the strike and 40 feet above and below the main vein on the 7700 level. The preconditioning was accomplished by a single ring of drill holes loaded and blasted from each of the two crosscuts. Figures 5-2 and 5-3 show the drilling patterns and pounds of explosive blasted in each hole. The blast holes were drilled with an in-the-hole hammer and were a nominal 4 inches in diameter. It was expected that this preconditioning would cause any high stress or burst-prone zone to become self-destressing as mining progressed through the blast-fractured zone, and that any high stresses would be shifted out in the wall rock. In this manner, the hazard from the close in bursting would be greatly reduced or eliminated, and the occurrence of any far out bursting would result in little or no damage in a stope.



Longitudinal projection S 79 E
Shaded area is mined out

0 100 200
Scale in feet

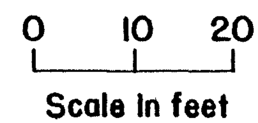
Figure 5-1 Star Mine Main Vein Below 6900 Level



KEY

Dark lines show loaded holes

Figure 5-2 Blasted Destress Holes No. 10 Crosscut 7700 Level, Star Mine



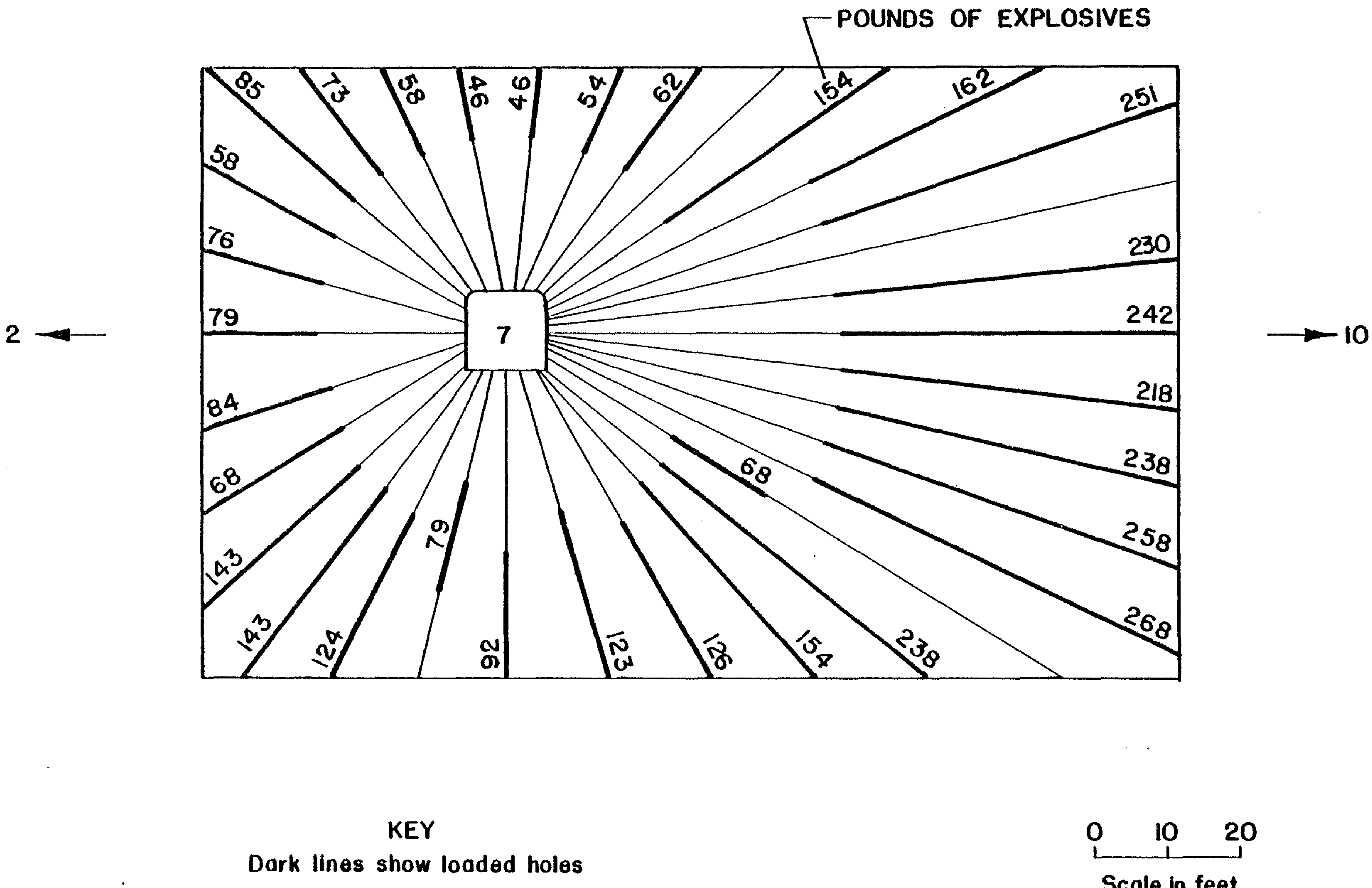


Figure 5-3 Blasted Destress Holes No. 7 Crosscut
7700 Level, Star Mine

5.2 RESULTS OF PRECONDITIONING

While an extensive instrumentation program was carried out to monitor the response of the stope and the adjacent wall rock to the mining through the preconditioned zone, the data from the Hecla rock-burst monitoring system, RBM, proved to be the data that was most useful in evaluating this field test. Figure 5-4 shows graphs of the seismic energy released by mining in the two preconditioned stopes. The R stands for raiseup mining while the numbers refer to each successive mining floor or cut. It is apparent from this data that the stope preconditioning resulted in greatly reduced seismic energy being released during the first floor mining. No rock bursting occurred during the mining in a preconditioned zone. The seismic energy data confirmed the visual and mining observations which indicated that the preconditioning was very effective in reducing the rock-burst hazard during first floor mining.

A detailed description of this rock preconditioning demonstration has been previously reported in USBM RI 8381, "Rock Preconditioning to Prevent Rock Bursts--Report on a Field Demonstration", reference 5.

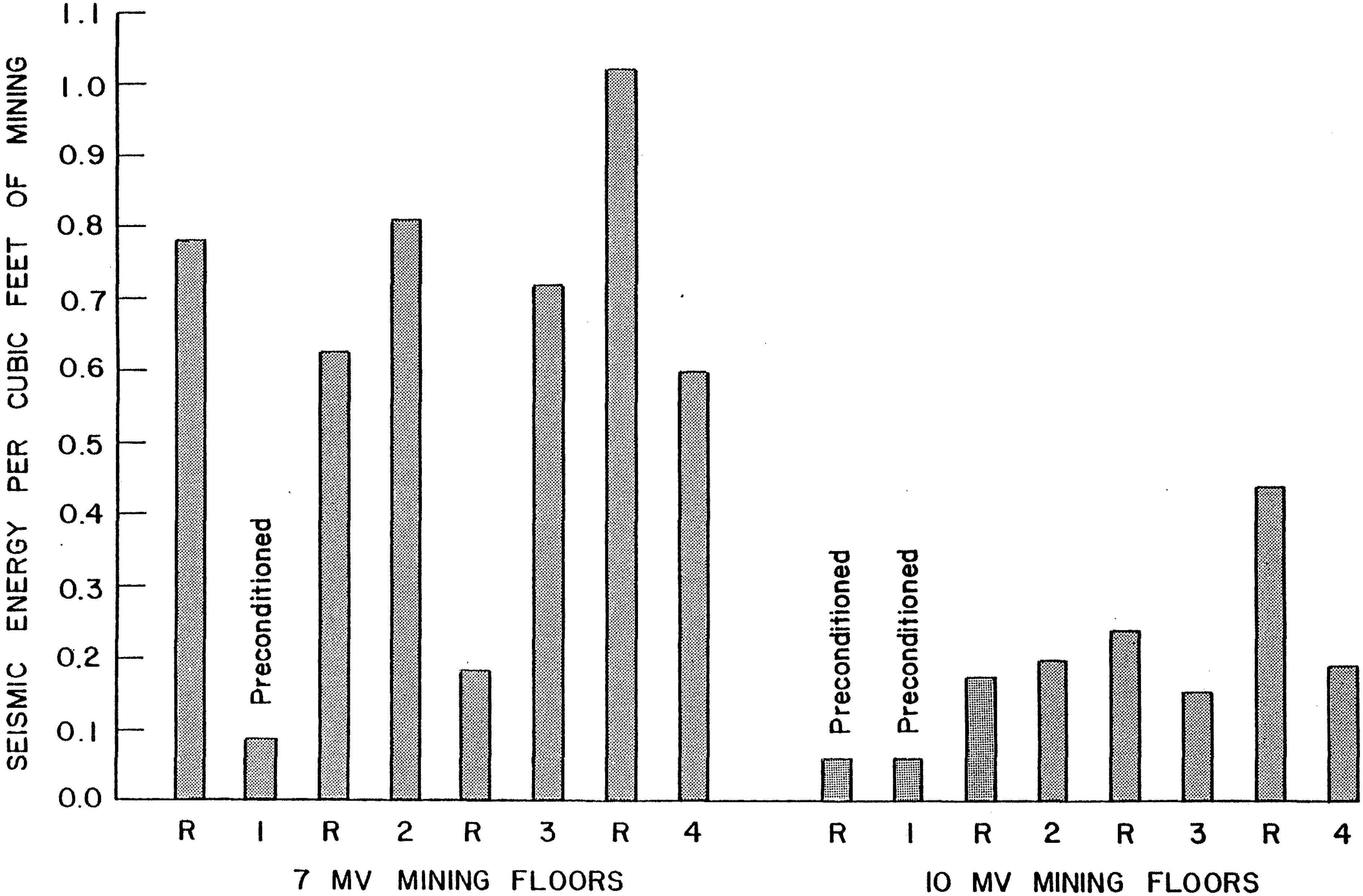


Figure 5-4 Seismic Energy Versus Mining, 7700 Level, Star Mine

SECTION 6

MINING BEYOND PRECONDITIONED ZONE

As the mining progressed through the preconditioned zone the release of seismic energy increased and rock bursting occurred.

6.1 MINING AND ROCK BURSTING

Figure 6-1 shows a vertical section along the main vein at the Star indicating the preconditioned zones, the mining progress through 1978, and the occurrences of rock bursting. Also shown is the presence of a lower grade or waste zone which runs from the 9 stope area on the 7500 level down through the 7 stope area on the 7700 level. It is apparent that this waste zone, characterized by a narrower and more siliceous vein, is responsible for the increased bursting in the 7 stope area. However, it is also clear that the overall bursting pattern on the 7700 level is quite different from the past bursting pattern as characterized by the bursting associated with the mining of the 7500 level. Figure 6-2 shows the locations of rock bursts associated with the mining of the 7500 and 7700 levels through 1978. Instead of being related to first floor and sill pillars, the bursting now seems to be more associated with the advancing stope face geometry--particularly in waste zones.

The mining and rock burst data for both the 7500 and 7700 levels is summarized in table 6-1. This data emphasizes the fact that the bursting at the Star appears to be more severe with increased depth. In addition, it points out the problem of extrapolating rock burst occurrence from level to level.

6.2 STOPE CLOSURE AND ROCK BURSTING

The increased incidence of rock bursting below the 6700 level at the Star and the severe bursting in the 7 stope area on the 7700 level is perhaps reflected in stope closure measurements. Table 6-2

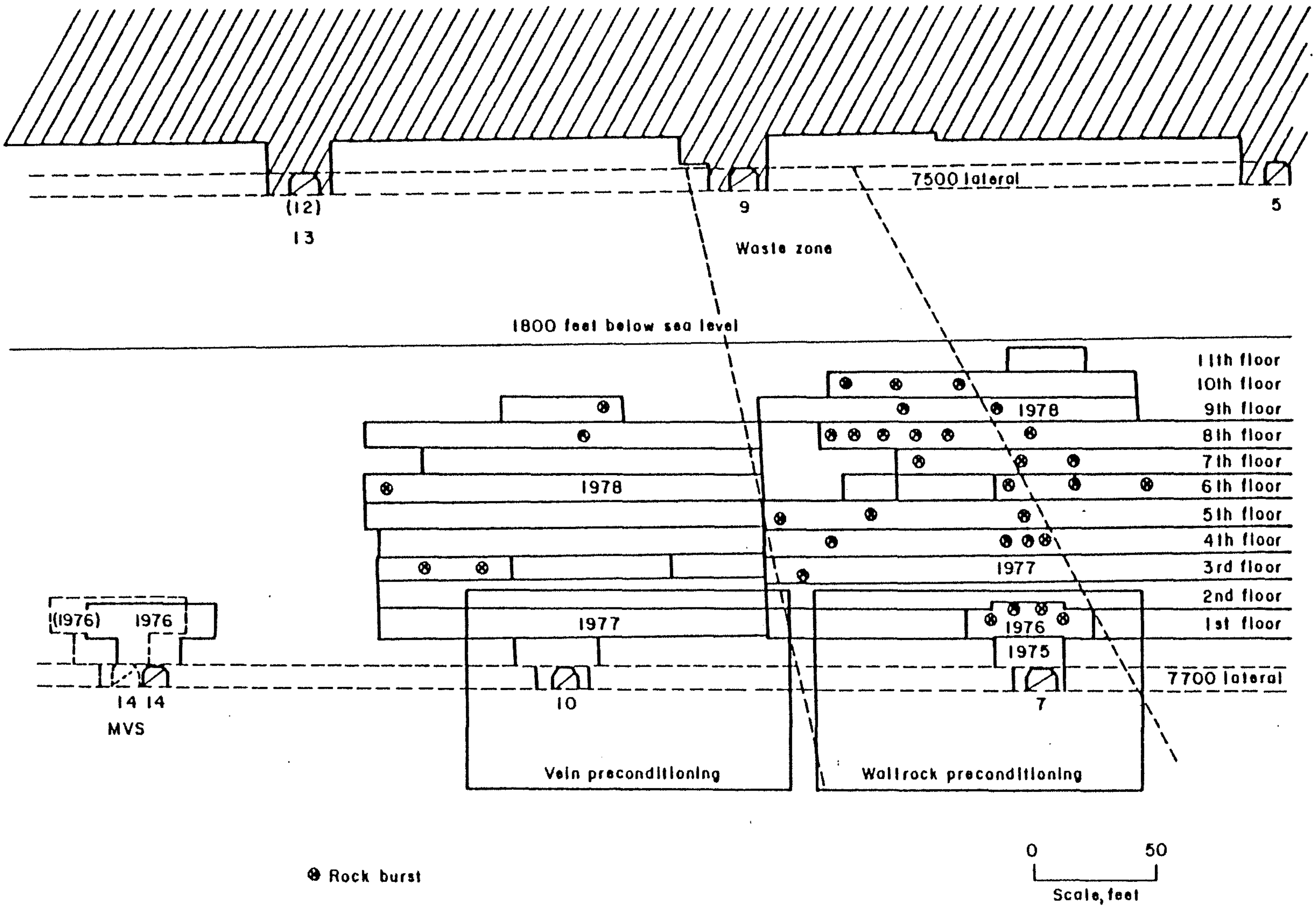


Figure 6-1 Mining Progress and Rock Bursting, 7700 Level, Star Mine

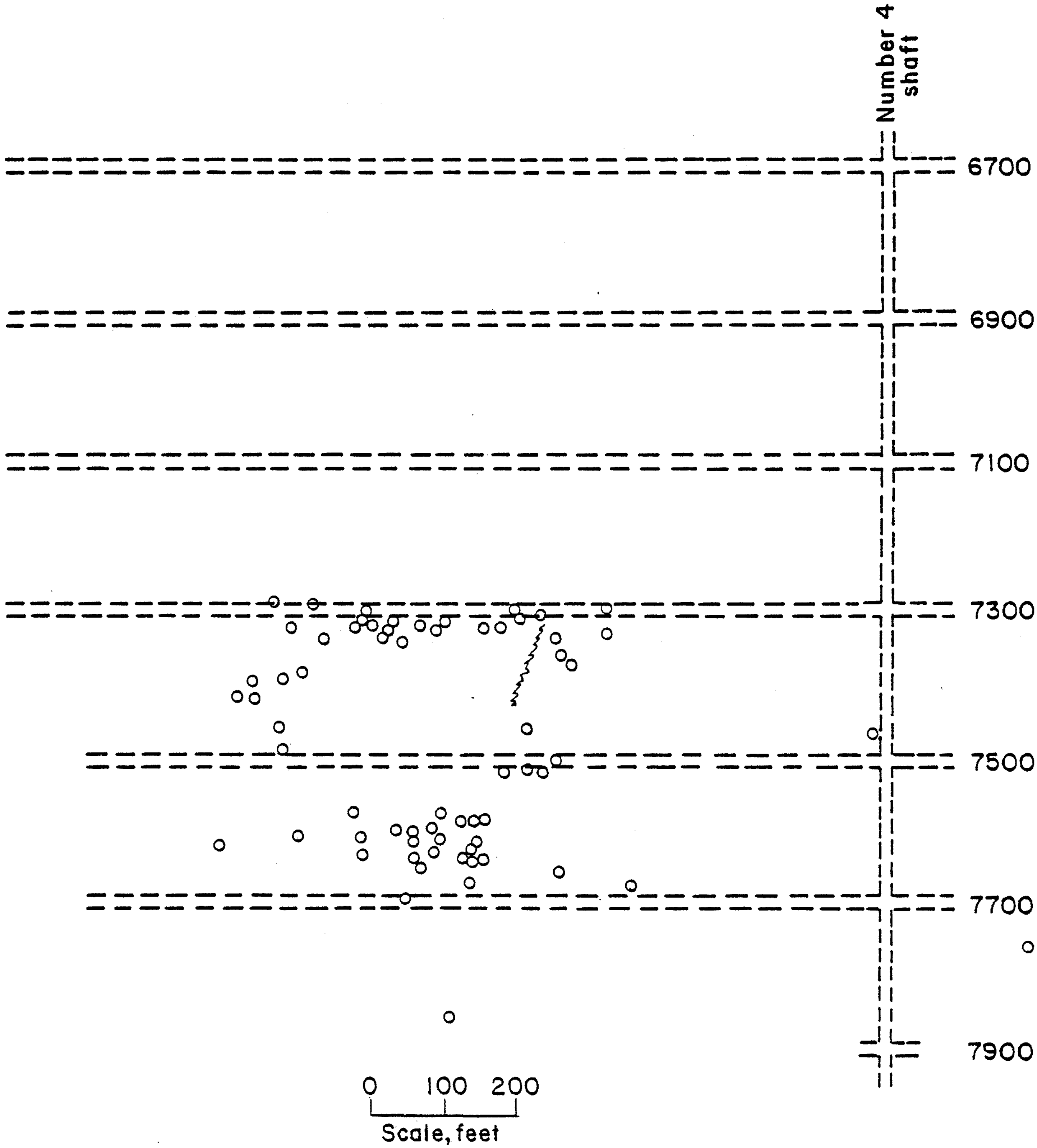


Figure 6-2 Rock Bursting Associated with the Mining of the 7500 and 7700 Levels of the Star Mine

TABLE 6-1. ROCK BURSTING ON MAIN VEIN, STAR MINE

LEVEL	TIME	PERCENTAGE MINED	NUMBER BURSTS	FIRST FLOOR OR SILL NUMBER	FIRST FLOOR OR SILL PERCENTAGE
7500	1974-1978	90	35	28	80
7700	1976-1978	50	32	9	28

TABLE 6-2. STOPE CLOSURE COMPARISONS

LEVEL	STOPE	FLOOR	CLOSURE, INCHES 6 MONTHS	CLOSURE, INCHES 12 MONTHS
6700	5 MV	5	10.0	14.0
7700	7 MV	5	4.5	7.0
7700	10 MV	5	7.3	9.0

shows comparative stope closure measurements on the main vein for the 6700 and 7700 levels. These data show a reduced stope closure on the 7700 level which indicates a stiffer and, therefore, more burst prone vein and wallrock. Similarly, the lower stope closure in 7 stope reflects the narrower vein and siliceous waste zone which is very burst prone.

6.3 MINING AND SEISMIC ACTIVITY

The seismic data resulting from mining above the preconditioned zone is summarized in table 6-3. This data was taken from the Hecla RBM during 1978. In general, this data shows a uniform but very different seismic behavior between 7 and 10 main vein stopes. The narrower and more siliceous vein in the 7 stope area is much more seismically active than the wider and softer vein in the 10 stope area. While this difference is intuitive and was obvious in hindsight, it points out the difficulties of trying to develop seismic pattern characteristics for rock-burst prediction on a minewide basis.

Figures 6-3 to 6-6 show the mining progress and resulting seismic activity event location distributions for each quarter of 1978. In the cumulative energy plot the numbers refer to the energy released within an area expressed as a power of 2^n. That is, a 3 corresponds to 2^3 or 8, and, similarly, a B corresponds to an energy of 4096. In the cumulative event plots the numbers indicate the number of microseismic and seismic events occurring within an area. These data also point out the increased seismic activity associated with the waste zone in the 7 stope area. In addition, they show that the majority of the seismic activity occurs ahead of the advancing mining front and that this activity is shifting slowly and steadily up into the 7500 level pillar.

TABLE 6-3. SEISMIC DATA SUMMARY FOR MINING ABOVE PRECONDITIONED ZONE

ITEM	STOPE NUMBER	QUARTER 1978 1	2	3	4
BURSTS	7	3	4	6	4
	10	2	0	1	2
SEISMIC EVENTS	7	24	30	32	13
	10	9	8	9	15
TOTAL NUMBER EVENTS	7	615	1145	1501	819
	10	521	574	1048	934
SUM OF SEISMIC ENERGY	7	29,363	35,263	23,290	16,764
	10	10,596	11,419	11,120	13,283
SUM OF ENERGY PER CUBIC FEET MINING	7	1.06	0.80	0.73	0.76
	10	0.42	0.34	0.24	0.30

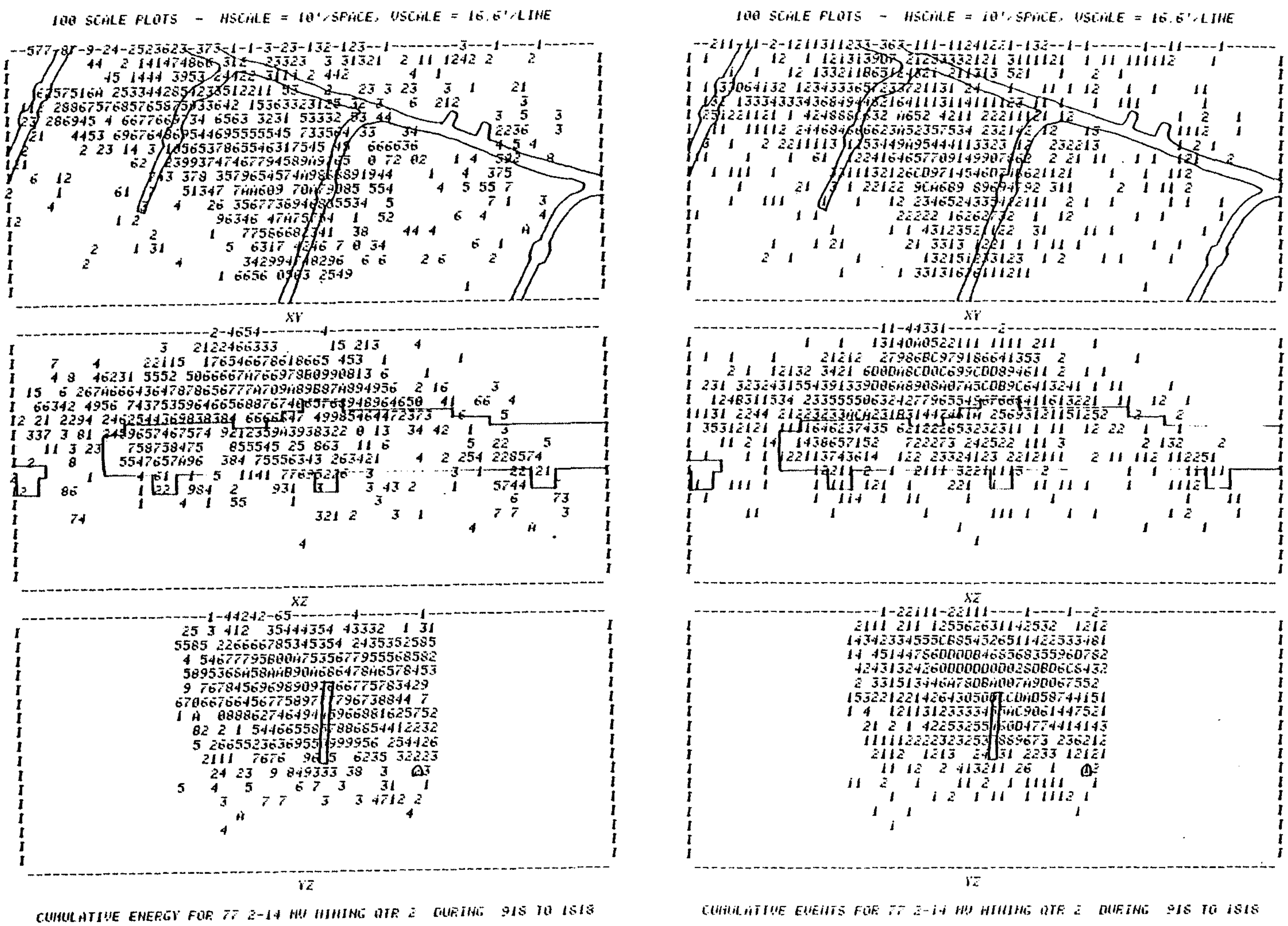
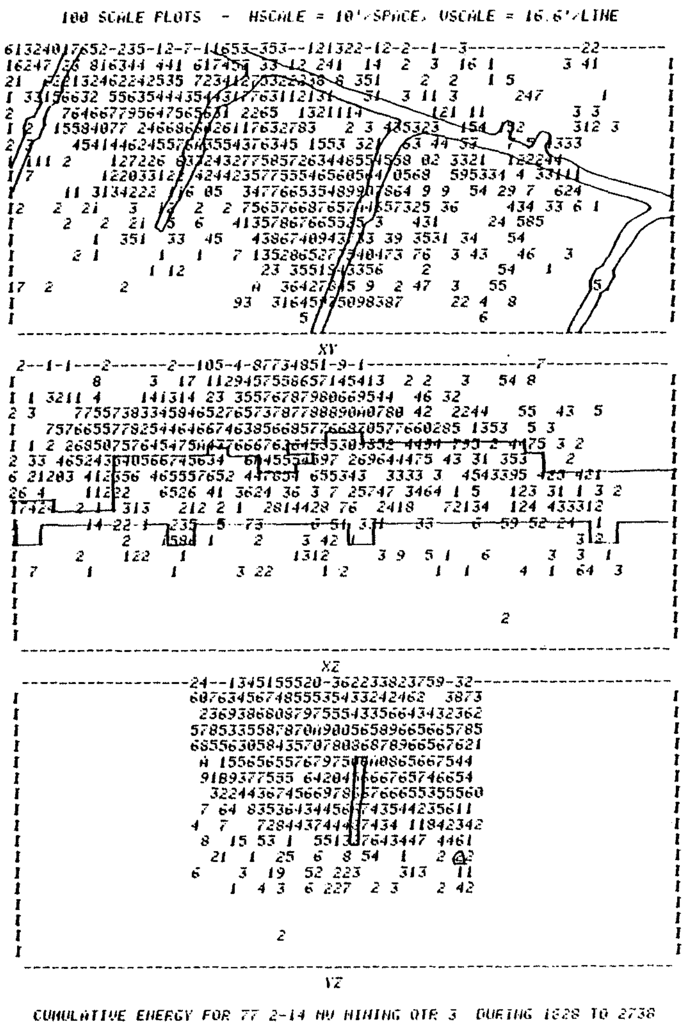


Figure 6-4 Seismic Activity Distribution, Second Quarter 1978, 7700 Level, Star Mine



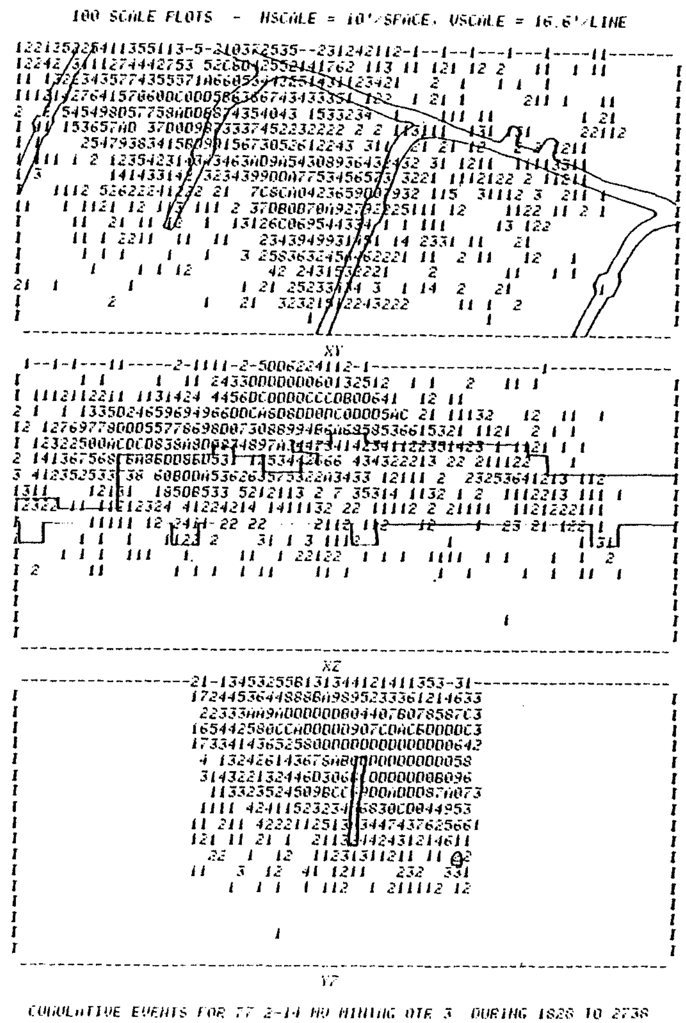


Figure 6-5 Seismic Activity Distribution, Third Quarter 1978,
7700 Level, Star Mine

The hourly time distribution of seismic activity resulting from mining in 7 and 10 stopes, summed for 1978, are shown on figures 6-7 and 6-8. These graphs show the greatly increased seismic activity resulting from the 2 p.m. day shift blasting time. The blasting changes the stope geometry and the resulting stress transfer about this new geometry is accompanied by the release of seismic and microseismic activity. In both stopes it takes some 5 hours for a quasi state of stress equilibrium to be reached following blasting. The time it takes for a stope to reach this self-destressed equilibrium state is measure of the stability of the stope with respect to rock bursting. In general, the longer it takes for a stope to quiet down seismically after blasting the greater is the rock-burst potential. It is for this reason that burst-prone stopes are usually mined on a single shift basis, which allows time for a stope to reach stress equilibrium.

The daily seismic activity accompanying mining during 1978 for 7 and 10 stopes is shown quarterly in figures 6-9 to 6-12 and 6-13 to 6-16. The recording interval is 1300-1300 hours, or 1:00 p.m. to 1:00 p.m. local time. J Day is the Julian calendar. These data show the usual trend where seismic activity is generally associated with active mining. That is, when there is no blasting in a stope there is usually little or no seismic activity. From this data it is also apparent that 7 and 10 stopes are seismically very different, in spite of being adjacent stopes. Further, while there are some cases of definite seismic activity buildups prior to bumping or bursting, there is no characteristic pattern of seismic activity that is diagnostic with respect to the occurrence of a rock burst. This fact, combined with the numerous occurrences of bursting preceded by essentially no seismic or microseismic activity, points out that rock-burst monitoring systems, which are currently the only practical tool available, are not infallible.

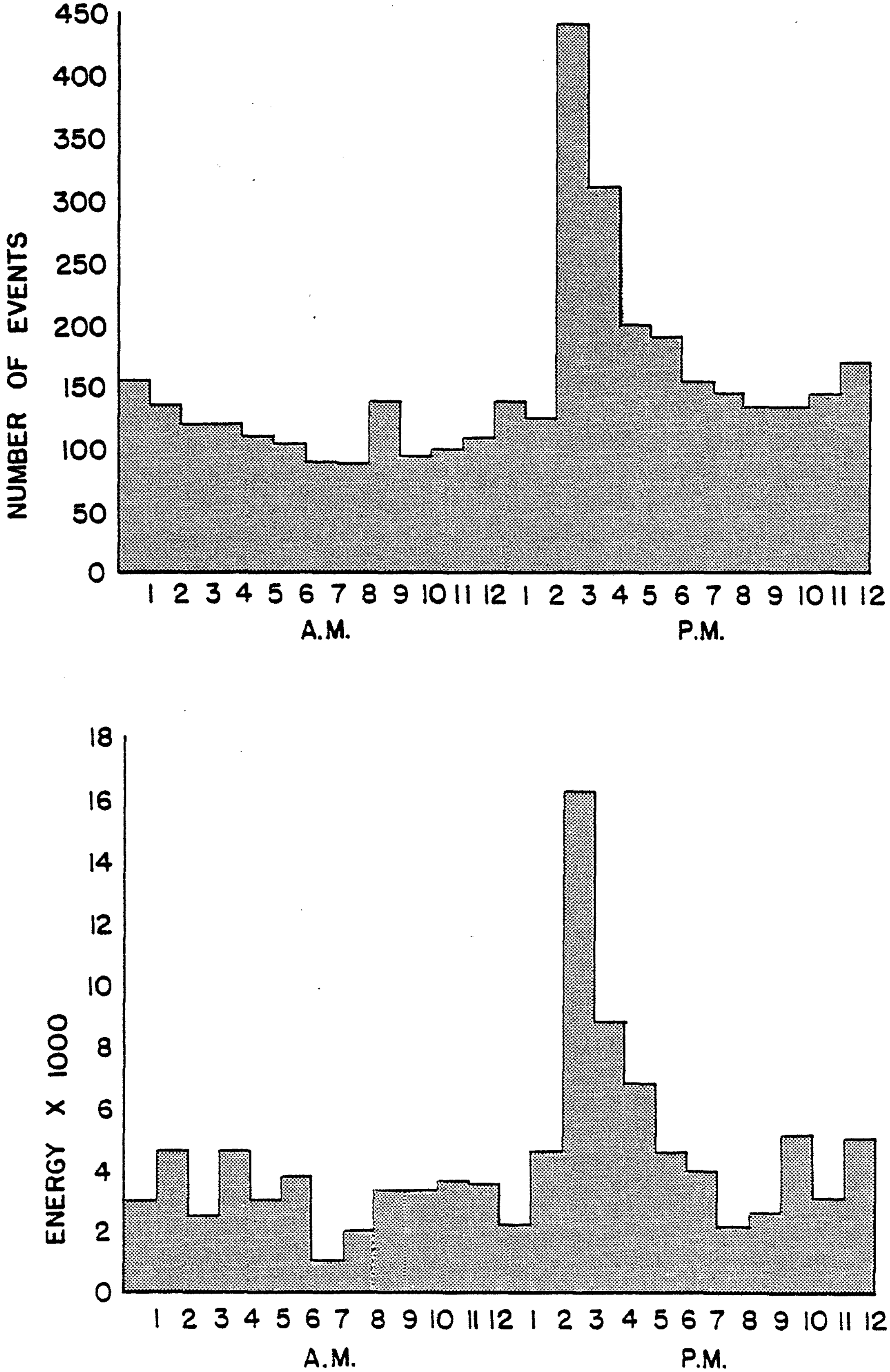


Figure 6-7 Hourly Distribution of Seismic Activity 7 Stope, 7700 Level, Star Mine

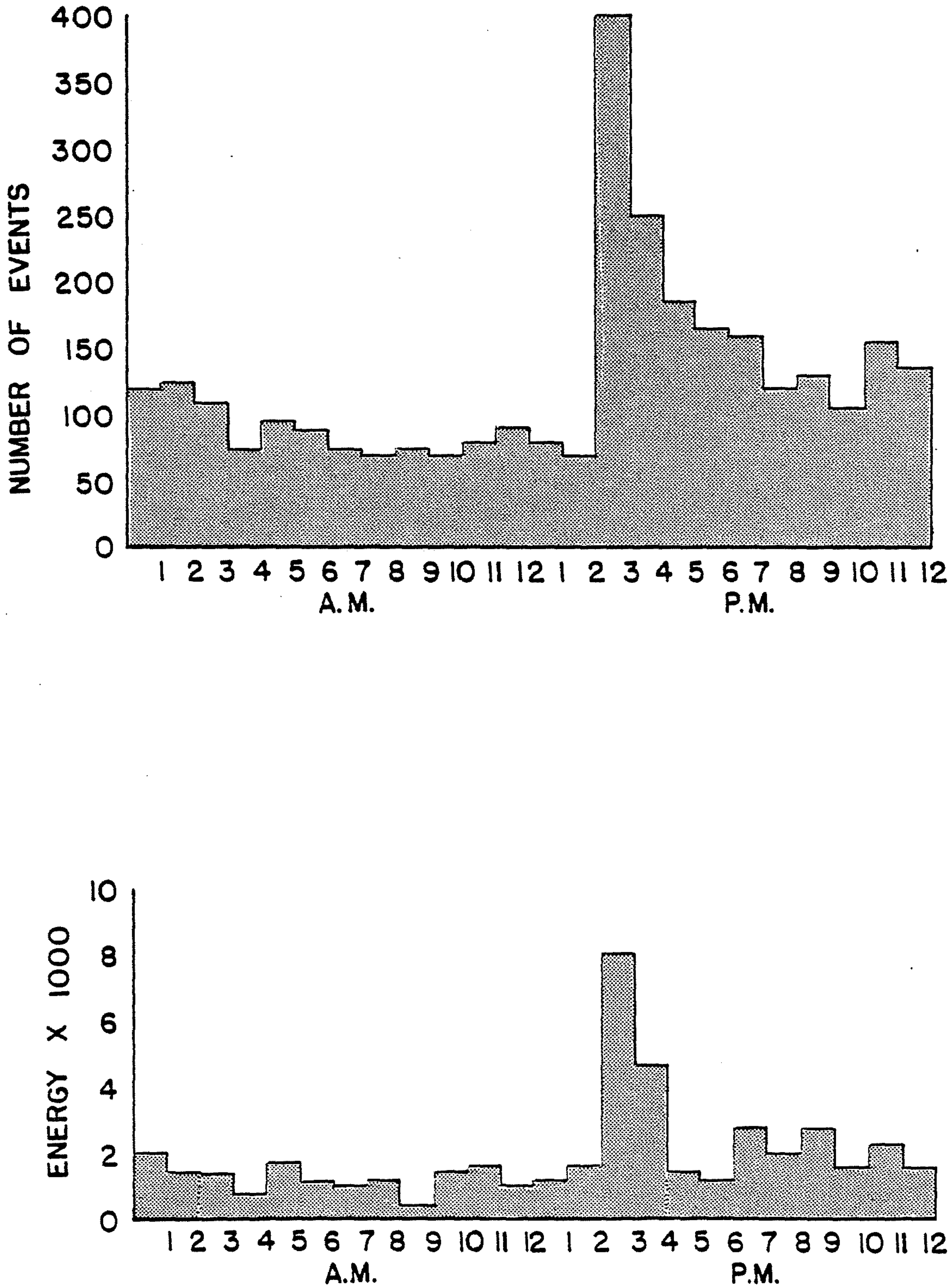


Figure 6-8 Hourly Distribution of Seismic Activity 10 Stope, 7700 Level, Star Mine

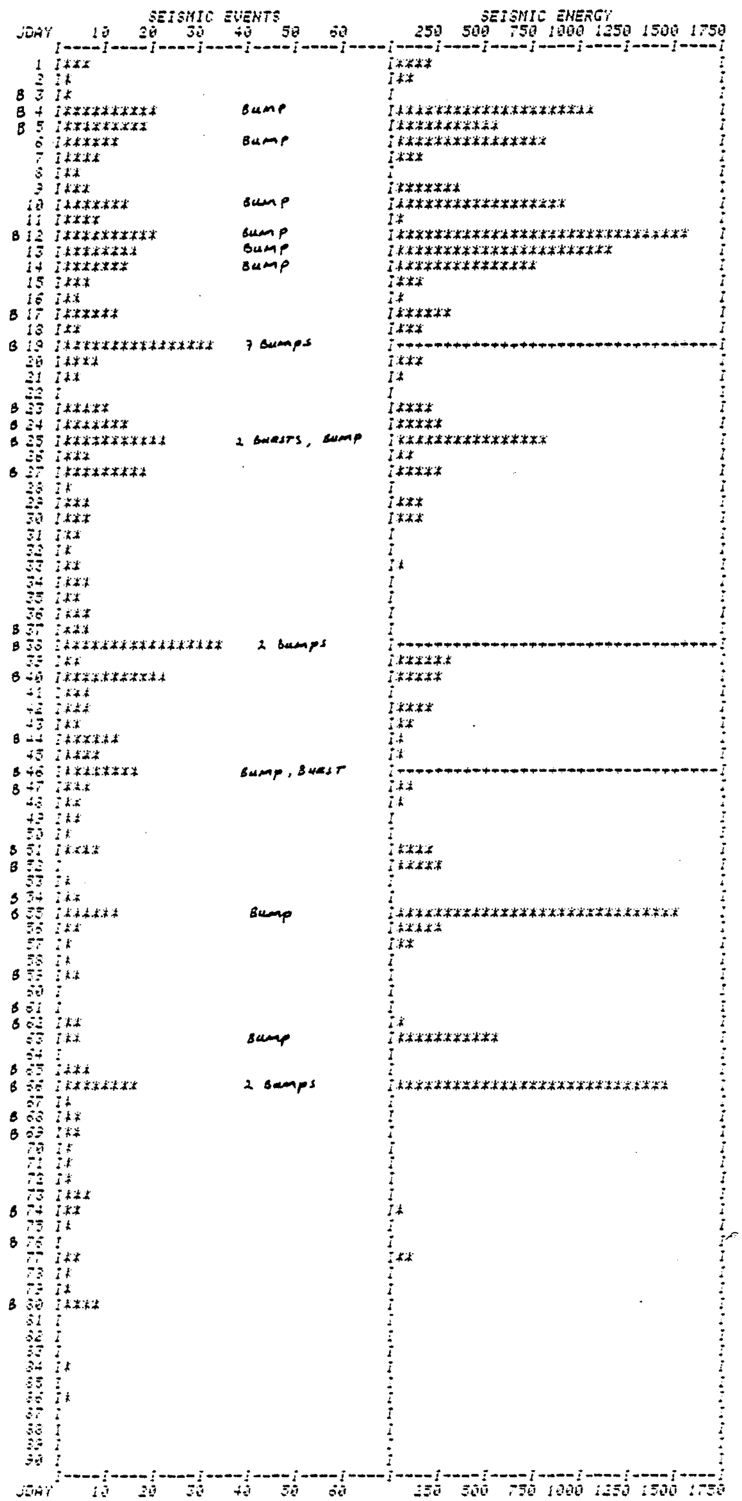


Figure 6-9 Daily Sum of Seismic Activity, 7 Stope, 7700 Level, Star Mine, First Quarter 1978

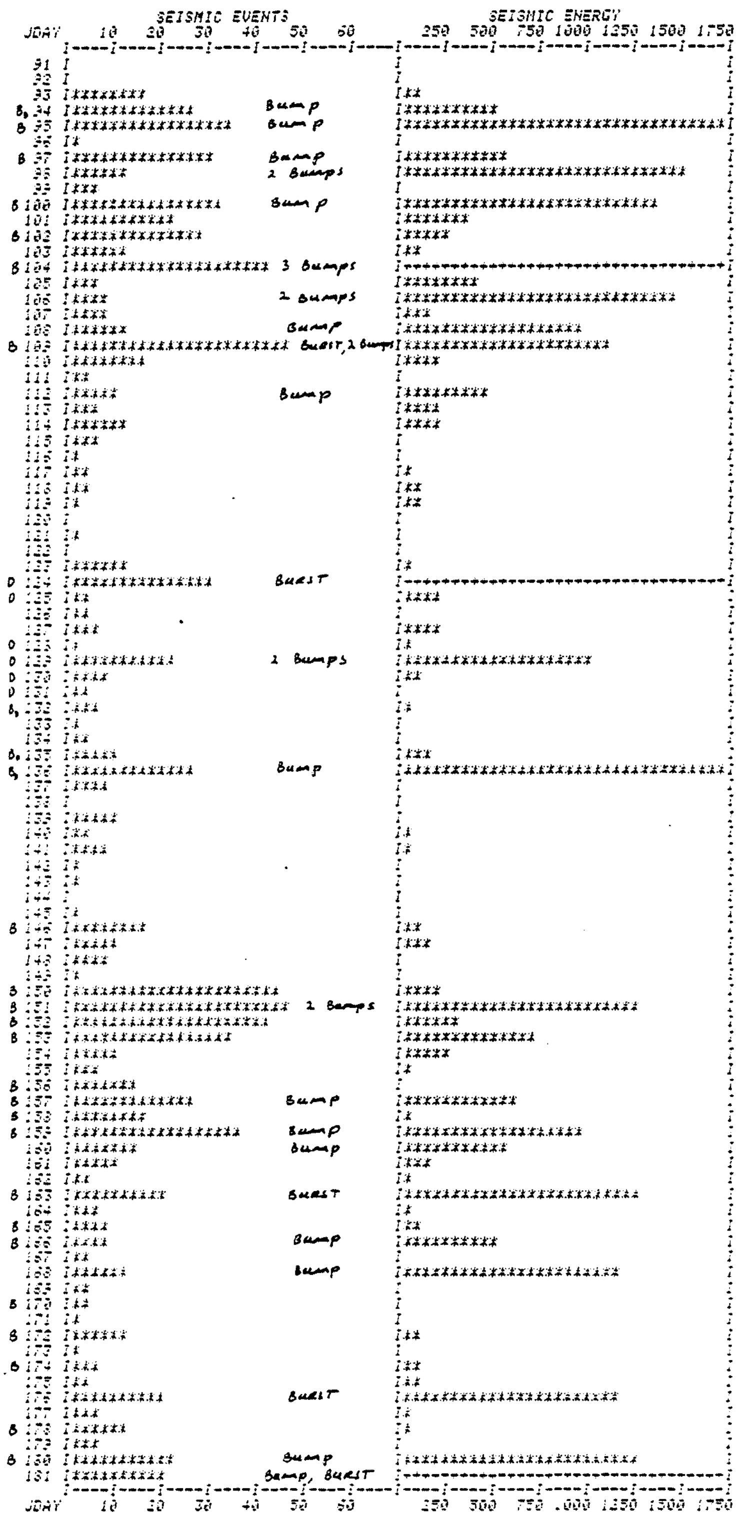


Figure 6-10 Daily Sum of Seismic Activity, 7 Stope, 7700 Level, Star Mine, Second Quarter 1978

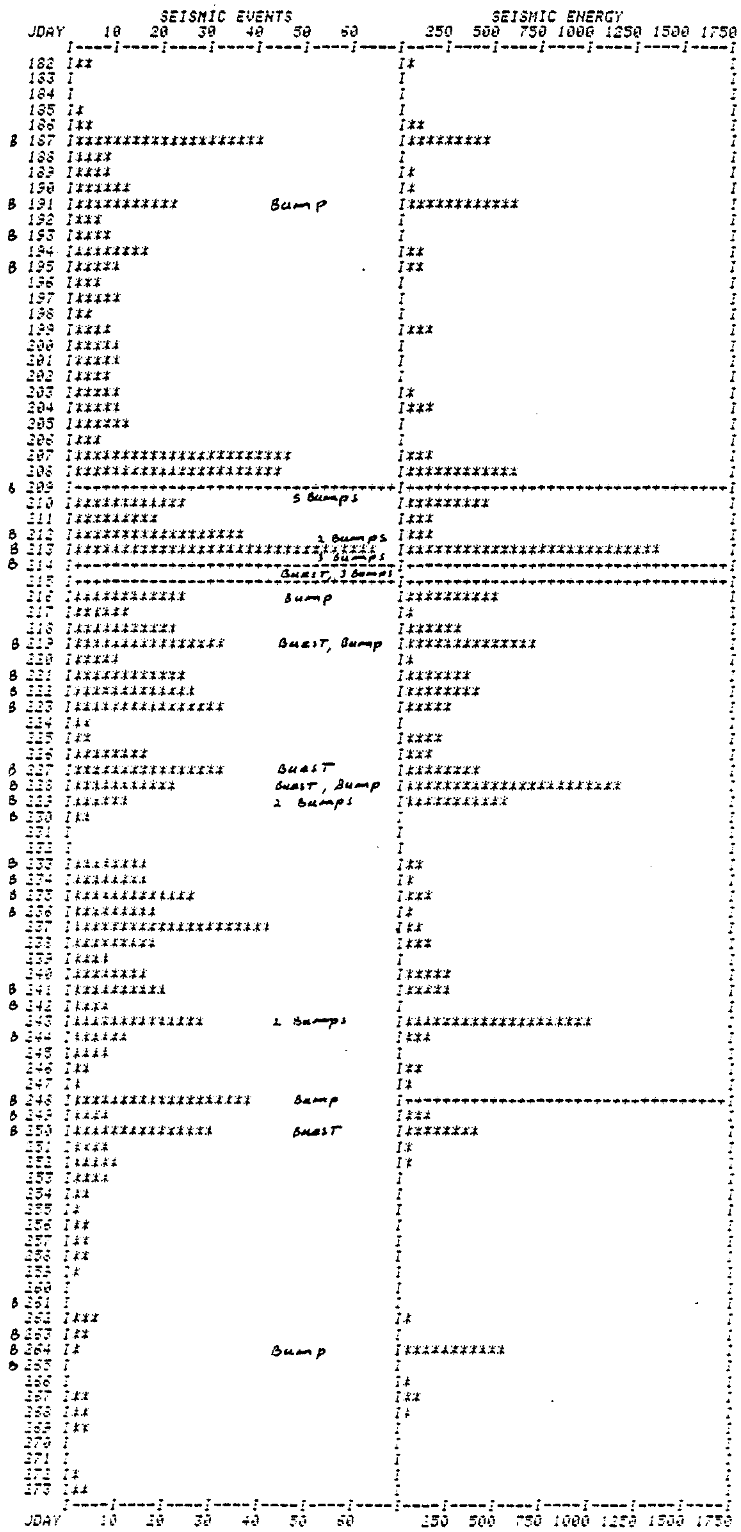


Figure 6-11 Daily Sum of Seismic Activity, 7 Stope, 7700 Level, Star Mine, Third Quarter 1978

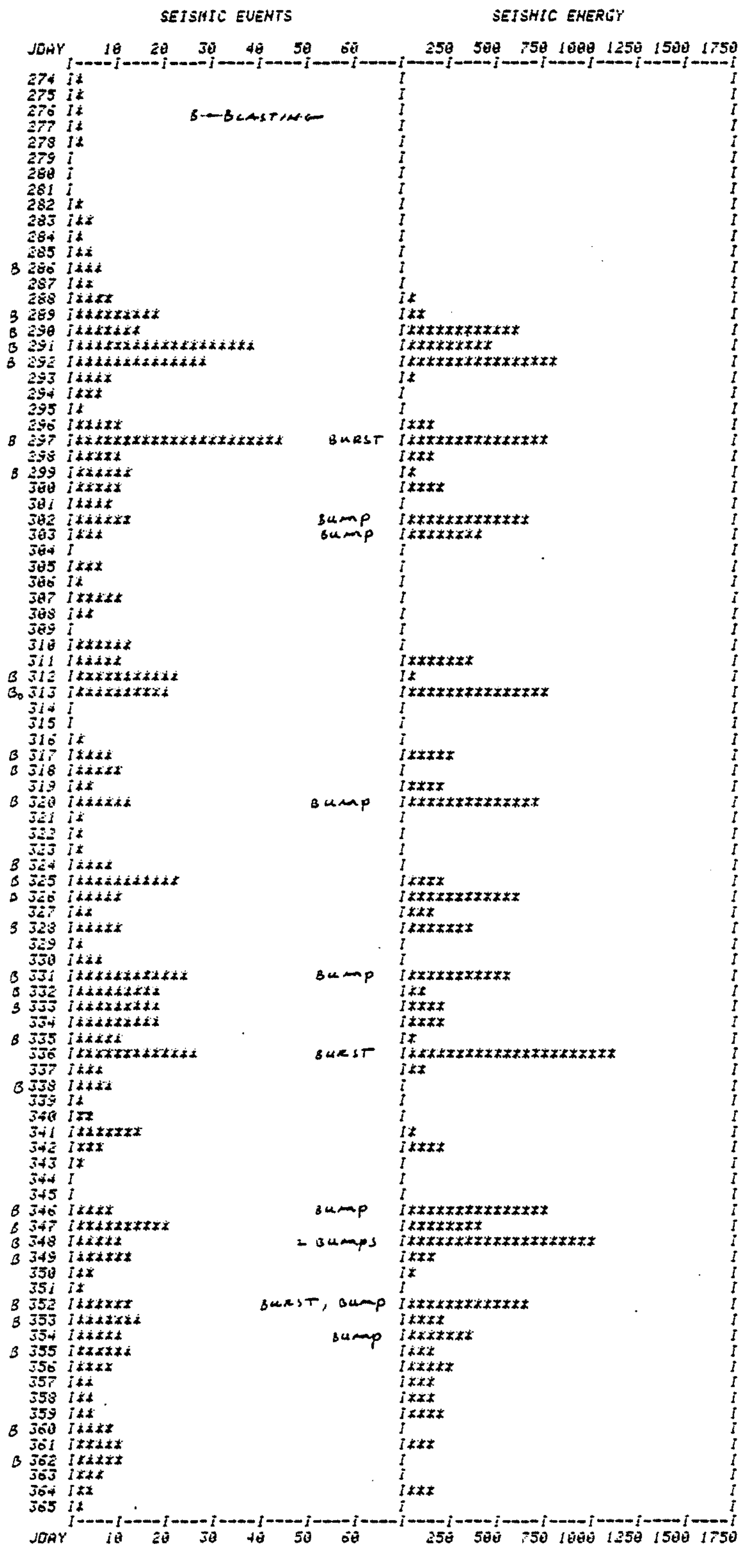


Figure 6-12 Daily Sum of Seismic Activity, 7 Stope, 7700 Level, Star Mine, Fourth Quarter 1978

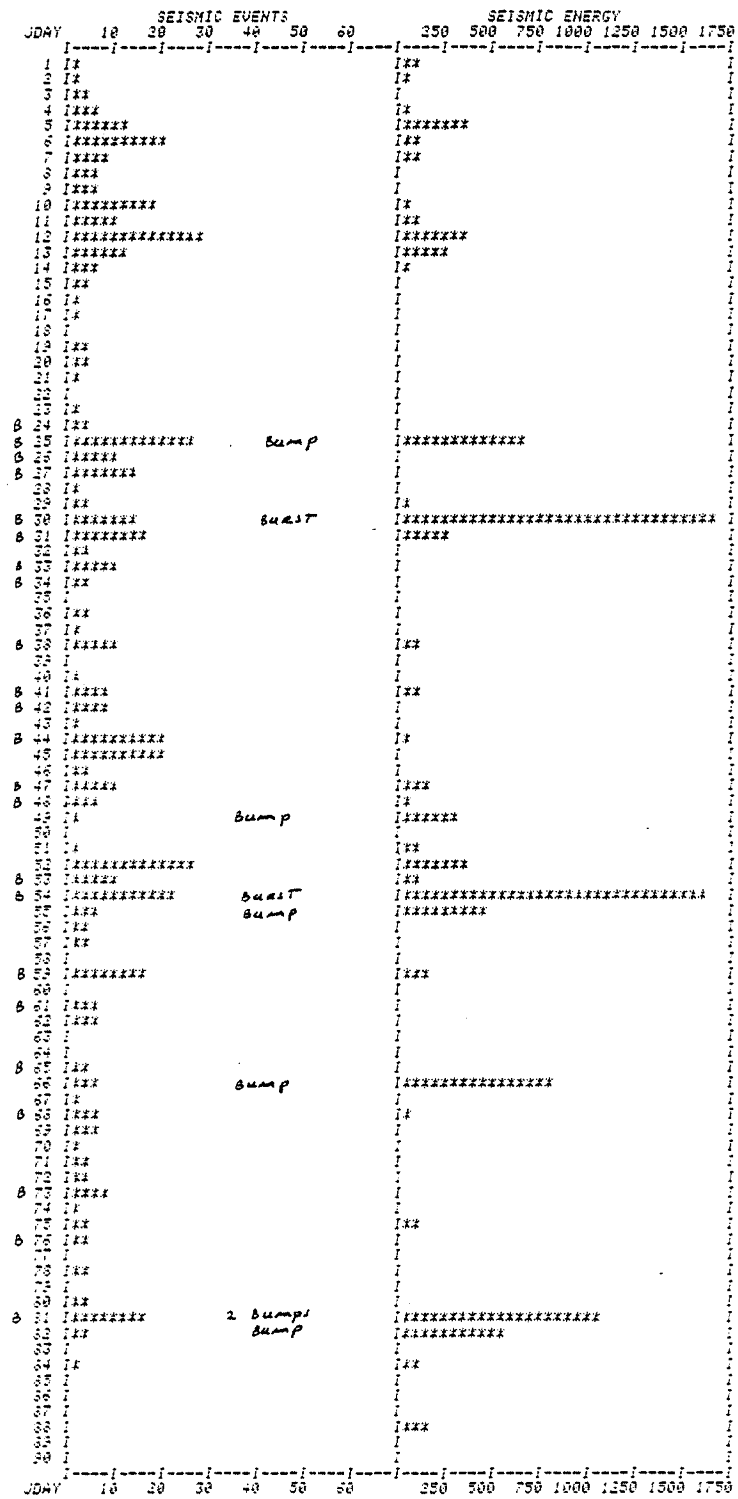


Figure 6-13 Daily Sum of Seismic Activity, 10 Stope, 7700 Level, Star Mine, First Quarter 1978

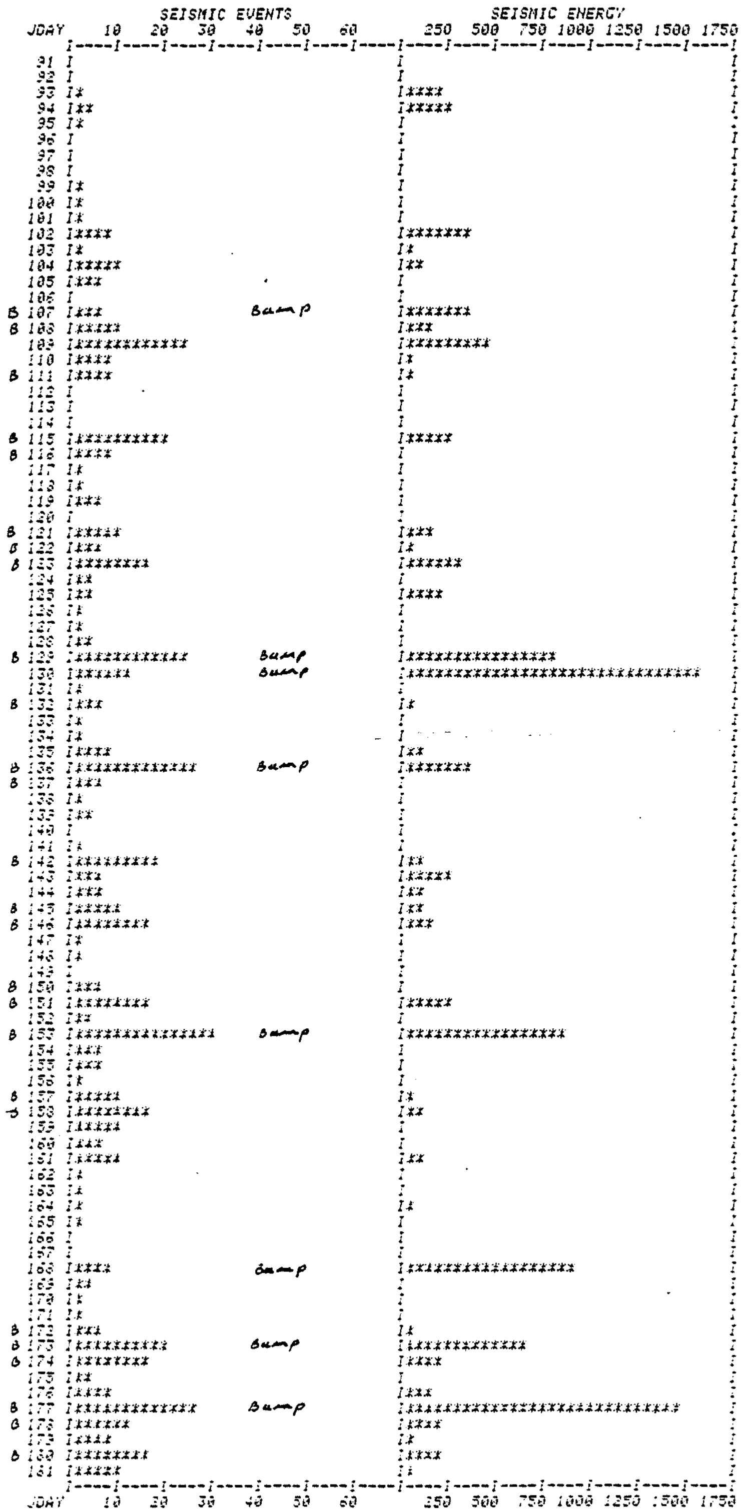


Figure 6-14 Daily Sum of Seismic Activity, 10 Stope, 7700 Level, Star Mine, Second Quarter 1978

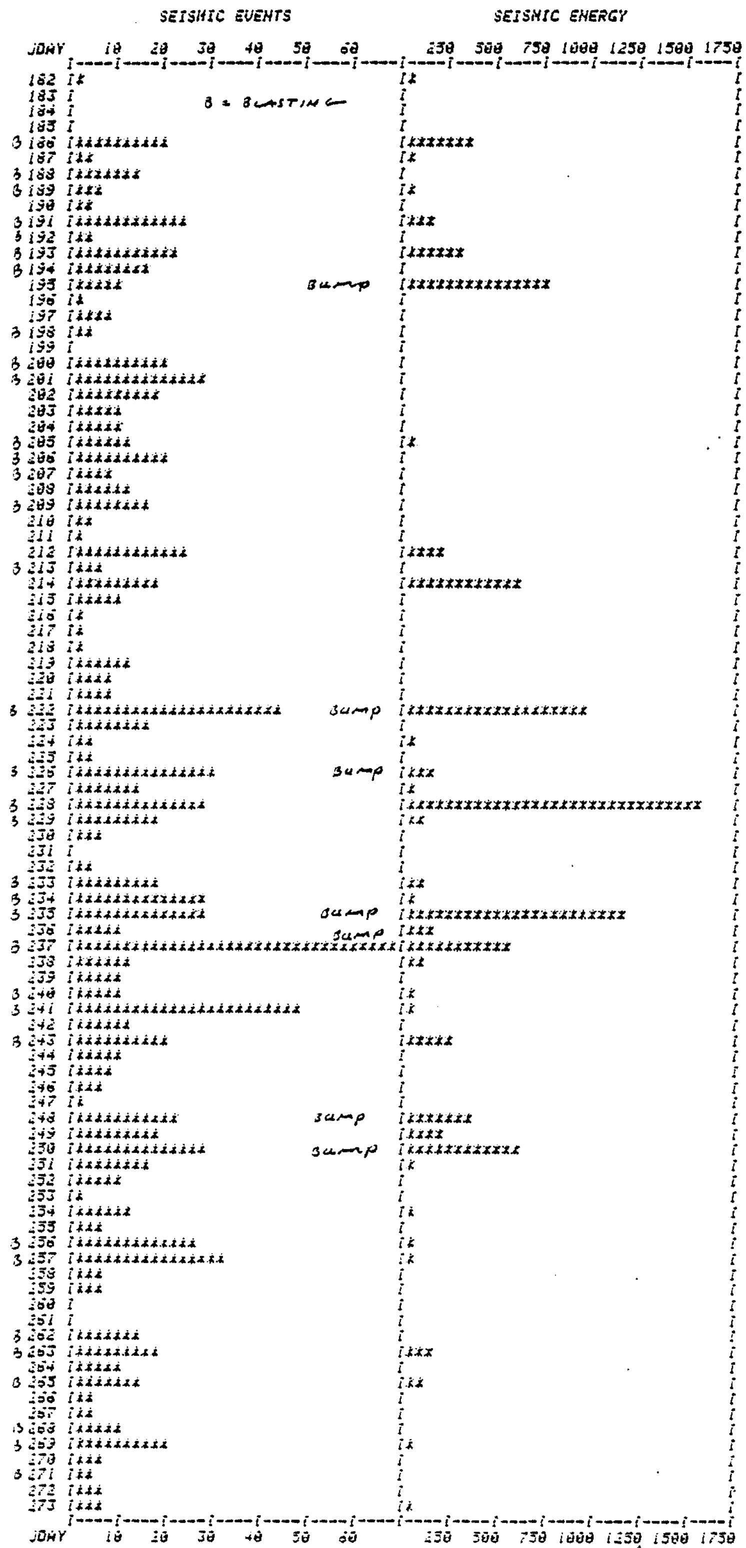


Figure 6-15 Daily Sum of Seismic Activity, 10 Stope, 7700 Level, Star Mine, Third Quarter 1978

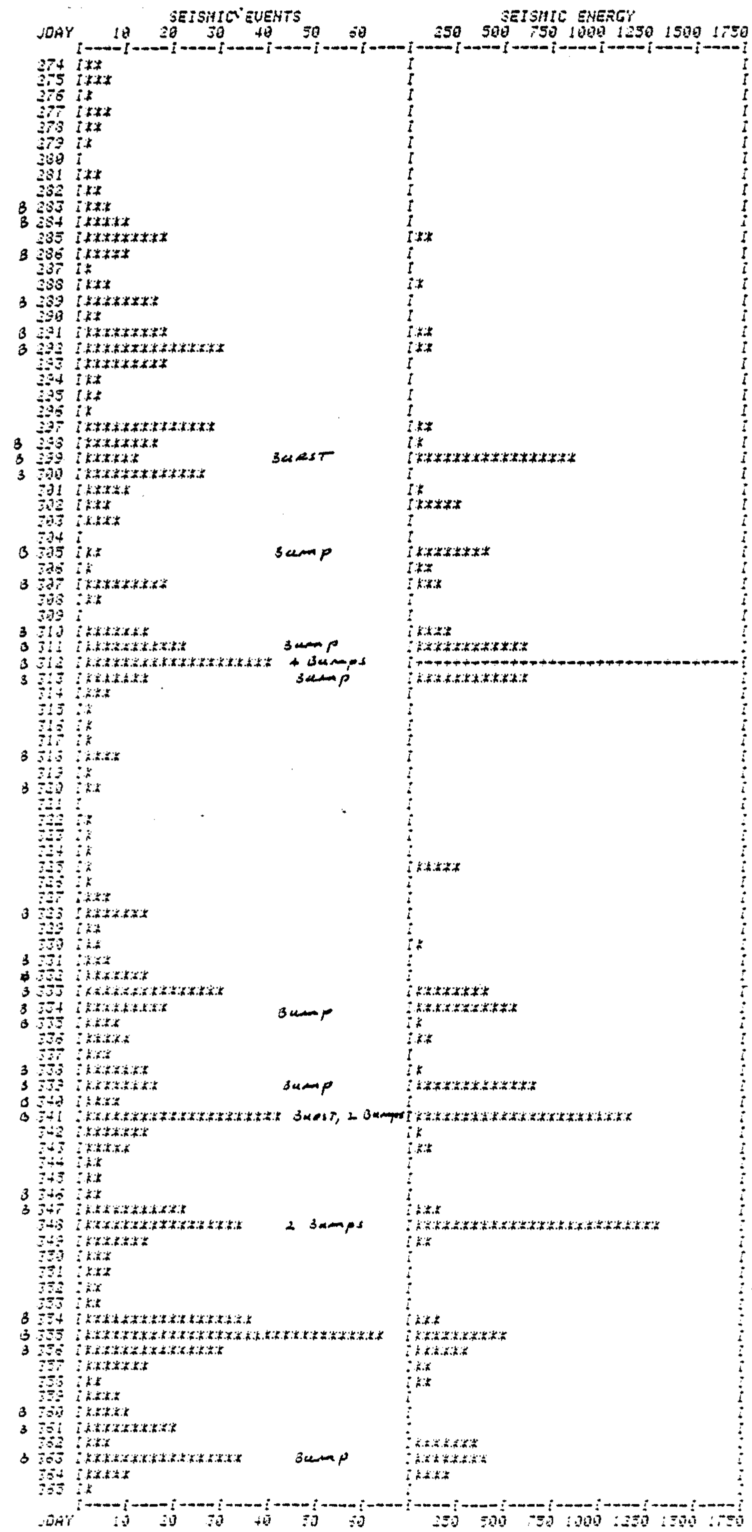


Figure 6-16 Daily Sum of Seismic Activity, 10 Stope, 7700 Level, Star Mine, Fourth Quarter 1978

An interesting feature during the mining of 7 stope was the occurrence of a small rock burst resulting from longhole destress drilling. It was not anticipated that the drilling of a 4 inch diameter longhole into a highly stressed area would disturb the stress field sufficiently to result in bumping and bursting around the end of the borehole. While it is common to having popping and cracking accompanying the drilling of a highly stressed face, the occurrence of bursting resulting only from drilling has never previously been documented. Some longhole face destressing was used in 7 stope to allow mining through popping ground--mostly in waste zones.

SECTION 7

CONCLUSIONS

The concept of rock preconditioning to improve rock-burst control was shown to be valid based on the results of a field demonstration carried out on the 7700 level of the Hecla Mining Company's Star mine. Mining through the preconditioned zone was characterized by greatly reduced rates of released seismic energy and no bumping or rock bursting occurred.

The occurrence of rock bursting accompanying the mining above the preconditioned zone points out the need for rock preconditioning to be carried out on an entire stope block basis to be maximally effective. Because preconditioning, like destressing, results in stress transfer away from an advancing mining face, care must be used in planning and sequencing preconditioning to insure that the stress transfer process is done smoothly and does not itself create problems.

The change in the bursting pattern at the Star from first floor and sill pillar bursting to a more random bursting ahead of an advancing stope face not only points out the need for stope block preconditioning, but also indicates that, like in South Africa, at greater depths increased bursting ahead of a stope face will occur despite the mining geometry. That is, at greater depths or higher stresses bursting ahead of a face will occur for either overhand or underhand mining.

The increased incidence of bursting in the 7700 level 7 stope area, associated with the lower grade or waste zone, points out the need for more and better geologic information about a stope block. This would not only be helpful with respect to the location of raises and stope partitioning, but could result in more effective stope preconditioning and better rock-burst control.

The variability of rock bursting from level to level and from stope to stope make it difficult to extrapolate past burst and microseismic data for purposes of rock-burst prediction. This feature also points to the fact that stope preconditioning to prevent or minimize the occurrence of rock bursting should be a more effective means of rock-burst control than trying to detect, delineate and evaluate the stability of already existing high stress or potential rock-burst zones.

The bursting and seismic data obtained from the mining, both in and beyond the preconditioned zone, on the 7700 level of the Star will be very useful in evaluating the planned stope block destressing experiment on the 7900 level.

SECTION 8

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