SOME ASPECTS OF THE ROCK BURSTS IN THE KIRKLAND LAKE GOLD MINES AT KIRKLAND LAKE ONTARIO CANADA

A THESIS

SUBMITTED

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THE PROFESSIONAL DEGREE OF

GEOLOGICAL ENGINEER

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ILLUSTRATIONS

INTRODUCTION

For the past two years the writer has had the opportunity to study the effects of rock bursts in the Lake Shore Mine, Kirkland Lake, Ontario, and to gather information on rock bursts in the adjoining mines to east and west.

Since the prevention of rock bursts is closely related to mining methods, the practical side of the investigation has received considerable attention.

The problem of rock bursts is recognized by mining men to be rather complex. This is largely due to the many variable factors with which we must deal. There are no two mines in the world with conditions exactly parallel from which we may draw definite conclusions, unless they are adjoining.

Rock bursts are due directly or indirectly to the weight of the rock masses, the suddenness and violence of the failure of pillars depending on the character of the rock, and the presence of concentrated stresses. The fact that rock bursts have increased in severity with increased depth, especially in the deep mines of India, Africa and Michigan, is proof that depth and consequently pressure are the main causes. Also it is found that the effect of pressure upon a locality is as the relation of worked out areas is to the solid areas.

The first rock burst to occur in the Lake Shore Mine was in 1801 East drift (box hole pillar) August 8th 1931 at 9.30 P.M. Since then crush bursts have occurred from the 1400 down to the 2800 levels. Strain bursts have occurred in the shaft down to the 4450 pocket.

ACKNOWLEDGEMENTS

To the general manager of the Lake Shore Mines E. W. Todd, the writer is indebted for the privilege of making the investigation.

To W. T. Robson, Chief Geologist, J. Conlin E. Martin Underground Superintendents, for information and co-operation in the work.

To J. Adamson Chief Mine Engineer, for the opportunity to study in detail longitudinal and composite plans of the mine.

PURPOSES OF THE INVESTIGATION

1. To find the locus of the rock bursts and gather any information as to their relation to fault planes and pillars.

2. To obtain a close check on pressure movements in the mine.

3. From the character of the rocks to determine the most likely places that rock bursts may occur.

4. To test the use of the geophone in determining ground movements. Also to ascertain whether this instrument could be used with electrical amplifiers to give warning of impending rock bursts to the miners.

5. The collection of literature on the subject of rock bursts and the various methods of stoping and supporting the ground in order to minimize or eliminate the effect of these bursts.

6. From the accumulated information and from the facts presented to make suggestions for protective measures to be taken when possible.

CLASSIFICATION OF ROCK BURSTS

The Witwatersrand Rock Burst Committee have classified rock bursts into the following headings:

(a) Spitting where a small piece of rock flies out from the solid.

(b) "Sudden flaking" where a slab scales off without pre-existing fracture.

(c) "Sudden fracturing" where a crack forms or opens in the rock.

(d) A rock burst accompanied by movement of the walls of a working place and a shock or tremor.

The categories (a) (b) and (c) may be classified under the common cause known as "strain bursts" and (d) as "crush" or "pressure bursts."

It is recognized that these terms are not strictly accurate, but are more satisfactory than the terms "air blasts and quakes."

Strain bursts are due to the strained condition of the rock affected. They may be caused by former compression of rock owing to the depth below the surface, to geologic movement, change in the mineral composition of the rock; or recent action such as cooling in water or air, blasting in the vicinity or pressure brought on the rock by subsidence of the hanging wall of the working place.

Crush bursts are due to the failure of the rock to support excessive pressure and are accompanied by movement of the walls of the working place. The pressure is due to the weight of superincumbent strata supported by the pillar or remnant affected.

Practically all the rock bursts in the Lake Shore Mine where any damage has occurred, belong to the type known as crush bursts.

GENERAL GEOLOGY AND STRUCTURE

The rocks occurring in the area surrounding Kirkland Lake are all pre-Cambrian in age. The oldest and most extensive formation is the Keewatin, which consists of highly metamorphosed lavas and diabase, and minor quantities of iron formation and volcanic tuffs. At Kirkland Lake the productive veins are associated with rocks younger than the Keewatin. These rocks, consisting mainly of

Timiskamian sediments and intrusive masses of syenitic types, occur in the form of a comparatively narrow syncline in the Keewatin basement.

The synclinal structure, which is marked by sedimentary formations and represents a line of weakness in the earth's crust, extends from the Matachewan area for 75 miles to the Quebec boundary and then a farther distance of 125 miles.

CLASSIFICATION

In the following tables the rocks and superficial deposits are classified according to relative ages, the oldest at the bottom.

LEGEND FOR THE KIRKLAND LAKE AREA

Quaternary Glacial and recent	Sand, gravel, swamp
Pre-Cambrian	Diabase dikes Lamprophyre dikes Syenite porphyry Red Syenite
Algoman	Basic syenite and lamprophyre Serpentine Horneblende and biotite granite and gneiss, syenite, granite, porphyry, pegmatite, horneblendite.

Timiskamian	Volcanic tuff Volcanic flows - trachyte and basalt. Conglomerate and greywacke Rusty carbonate
Keewatin	Pillow lava, altered diabase, green schists, rusty carbonate iron formation and tuff.

INTRUSIVE ROCKS OF THE KIRKLAND LAKE AREA

The first phase of the igneous invasion is represented by a very basic syenite which resembles certain lamprophyres in structure and composition. This rock is followed by a more acid syenite of relatively high potash content, which is in turn cut by a syenite porphyry rich in soda.

Field relationships indicate a close bond between the lamprophyric and red syenite types. The latter is invariably found associated with large masses of the former, no instance being known of red syenite intruding the sediments away from the basic type.

LAMPROPHYRE AND BASIC SYENITE

The texture is rather coarse compared with that the other intrusive rocks. The rock consists essentially of augite and alkali feldspars.

The very dark basic type shows in many cases a gradual transition to a light-colored phase with a small amount of augite and an increased amount of feldspar, thus grading into a normal syenite. The common term for this rock underground is syenite while the darker type is called lamprophyre.

When the basic syenite is adjacent to later intrusives it becomes reddish in color. The rock also develops a less basic aspect along vein walls or where cut by fractures along which gases and solutions have circulated and caused alteration. The first step in alteration is the change of pyroxene and biotite to chlorite and carbonates. The felspars are next attacked and altered to sericite and replaced by carbonates.

SYENITE PORPHYRY

The youngest member of the syenite series is a porphyritic type in which the phenocrysts are mainly albite feldspar and an occasional othoclase crystal. The rock varies from grey to red depending on the extent of alteration. The slightly altered porphry on the lower levels is grey and in some cases quite dark owing to the presence of ferromagnesian minerals, principally biotite. There is not much quartz along the ore zone, especially on the upper levels. Apatite, magnetite and ilmenite are the common accessories; chlorite and sericite are the chief alteration products.

The secondary calcite which fills the interstices of the rock mass appears to play an important role in the problem of rock bursts. See discussion under Character of Rocks on page 17 .

DIABASE

This rock is typically diabasic in texture, is fine grained on the margins and coarse toward the middle of the dike. Interstitial quartz, and alteration of the plagioclase and augite to epidote and chlorite may be seen. Magnetite, ilmenite and apatite are the common accessories.

LAMPROPHYRE DIKES

Dikes of mica lamprophyre are seen cutting the granite and syenite masses exposed to the south of the Timiskamian belt.

DIABASE DIKES

There are three important dikes of diabase in the Kirkland Lake camp extending in a northerly direction. One of these dikes on the Lake Shore property is near the boundary of the Teck-Hughes Mines. The width of the dike averages 45 feet, the dip is 85 degrees west and general strike is North 15 degrees West.

STRUCTURE

The series of more important geological events leading up to and following the formation of the ore bodies may be summarized as follows: Pressure associated with the invasion of a batholith of Algoman granite caused the folding of the Timiskamian series and the

Keewatin on a general east-west line and thus produced the synclinal structure of Kirkland Lake; along lines of weakness developed roughly parallel to the folds, differentiates from the deep seated granite magma consisting of syenite types, porphyry and diabase were injected; release from continued pressure, which was applied from the southwest to northwest, produced a series of overthrust faults extending in an approximately easterly direction; deep seated mineral solutions began to circulate through some of the fractures formed and in the case of the "Main Break" at Kirkland Lake, faulting and mineral deposition continued contemporaneously over a considerable period of time, which appear to post-date the end of the period of ore deposition; finally erosion, extending over an immense length of time and still proceeding, removed the upper parts of the folds and changed a region once mountainous into one of low relief.

INTRUSION OF SYENITE ROCKS

There are two principal zones along which igneous rocks come up in considerable volume in the Temiskamian series. Both are in the north limb of the syncline.

MINERALIZED FAULTED ZONES

There was no doubt faulting during the injection of the intrusive rocks. The faults of most economic interest are those which were formed after the rocks solidified, since along some of these breaks ore-bearing veins occur. The "Main Break of Kirkland Lake is one of a number of parallel faults.

"THE MAIN BREAK"

The veins of Kirkland Lake are simply bodies of secondary minerals filling fractures in and partly replacing the country rock along a faulted zone which has been styled the main break of the area. The principal faults follow a remarkably straight line, striking about N. 65 E. Apparent changes in the strike of the veins are mostly due to offsets and caused by a system of north-south faults that displace the veins.

THE NORTH VEIN FAULT

This is the vein on which all the rock bursts have occurred in the Lake Shore Mine. Detailed mapping of the surface brings out much information in regard to the movement on this great fault. On the Teck-Hughes property its presence is plainly shown by the occurrence of conglomerate on the north side of the veins and igneous rock on the south. That this is not an ordinary contact between sediments and intrusives is clear from the fact that the contact cuts across the strike of the porphyry dikes, a condition that can be accounted for only by faulting. See figure page 16.

CROSS FAULTS

The first known displacement occurs at the Lake Shore dike; surface mapping shows plainly a displacement of 20 feet to the south on the east side. At a

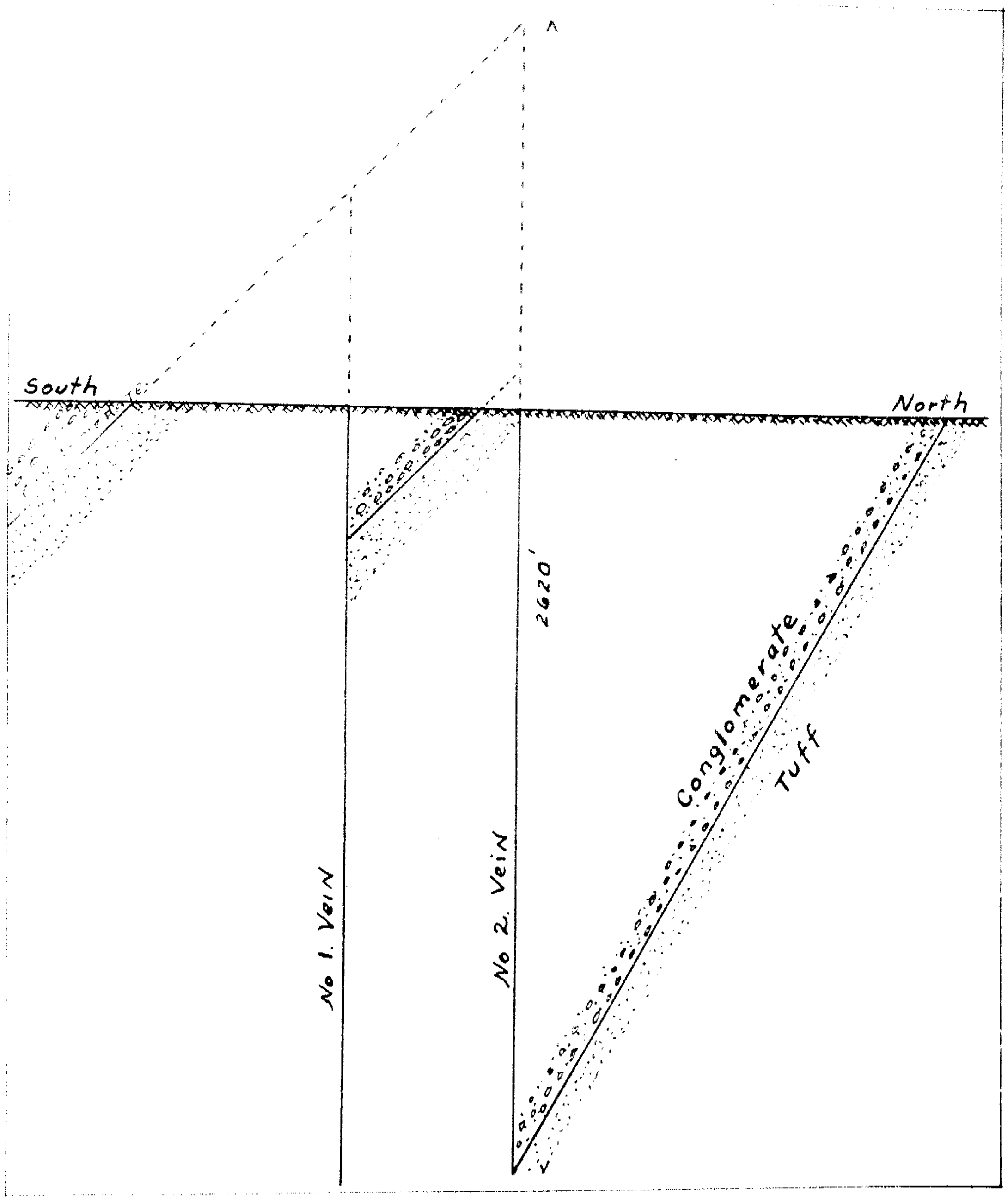
...int 180 feet east of the Lake Shore dike the southern conglomerate tuff contact is plainly moved to the north on the east side for a distance of 80 feet.

The next fault to the east is known in the Lake Shore Mine as No. 2 fault. It shifts the No. 2 vein to the north on the east side about 40 feet on all levels. It is not clear whether the movement died out between the two veins or whether it crossed both, causing apparent horizontal displacement of the south-dipping No. 2 vein and not the vertical No. 1 vein. The structure as seen underground suggests that the fault is a minor one, the ore shoots continuing on both sides of it without much disturbance.

Between this fault and the No. 1 shaft on the Lake Shore Mine there is another small fault known as No. 1 fault which shows on all levels and affects both veins. The horizontal displacement is about 30 feet.

The next fault is very important. The two main veins of the Lake Shore Mine are displaced along the plane of the fault so that they pass through the Wright-Hargreaves property.

The horizontal movement amounts to 600 feet. The average dip of the fault is about 65 degrees east which is the opposite direction from most faults belonging to this system. Slickensides appear to be nearly horizontal, there being no great extent of vertical throw with the movements.



[illegible] section 250 feet west of No. I shaft at right angles to the veins [illegible] probable vertical components of the north and south faults, based [illegible] of conglomerate and tuff, as found on surface and underground
Scale 400 feet to the inch.

PHYSICAL CHARACTER OF THE INTRUSIVE ROCKS

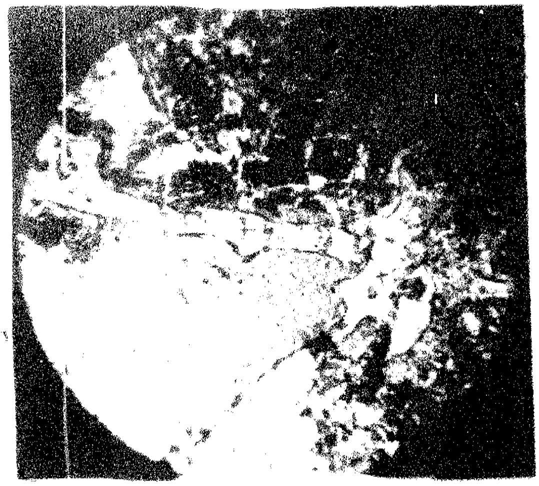
It has been found in the Lake Shore Mine that the physical character of the rocks is of prime importance in the consideration of rock bursts. The classification may be based on hardness, brittleness or friability, on one hand and softness and plasticity on the other. Some of the most severe rock bursts have occurred in the syenite porphyry on the east side of the mine. This rock is brittle and friable--no doubt the friability comes from the fact that the rock is cemented with calcite, a very friable mineral. The writer has made several thin sections of the rock taken from different parts of the mine where rock bursts have occurred in the syenite porphyry. These sections under the microscope usually show many small calcite stringers. See photographs on page 20.

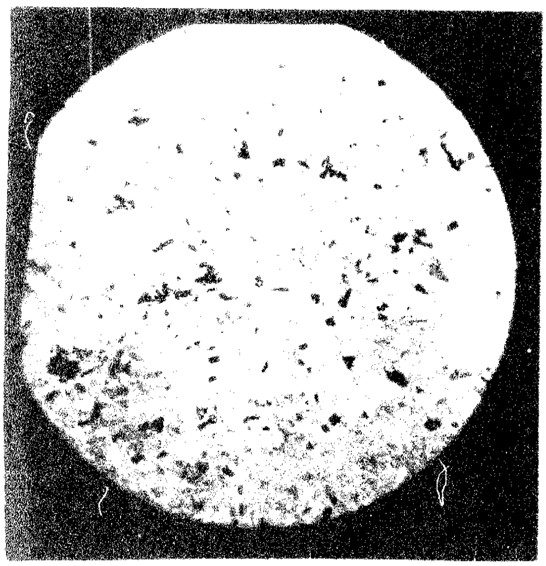
This class of rock is capable of sustaining considerable weight without deformation; but when the limit of its crushing or shearing strength is reached a rock burst [illegible]. The writer has found by testing the rock under [illegible] pressure, that the basic syenite, most of which [illegible] of the shaft, has a greater crushing and shearing [illegible] than the syenite porphyry. The shearing strength of the syenite ran from 1700 to 3900 pounds per square inch on several samples of drill core. The shearing strength of the porphyry ran from 1500 to 2900 pounds per square inch. Several rock bursts have occurred at the contact of the syenite and the porphyry. There seems to be a weakness along the contact of these two rocks. However this is only a supposition and nothing definite has been proved up to date.

Where mud seams are found the rock usually yields without disruption. Photograph on page 50 shows the floor pillar heaving along a mud seam on the hanging wall side. In the wide sections this ground becomes "heavy" and danger of caving occurs when the sills are being removed.

The direction of the planes of fracture in the rock are important in predicting a rock burst-- especially where a strain burst occurs. But in crush or pressure bursts brought about by stoping conditions the fractures do not play such an important role. In this case the pressure is great enough to rupture the rock regardless of the direction of the major planes of fracture.

When the plane of fracture is parallel or normal to the plane of the vein the maximum danger exists. In the former case we have bursts in the walls of the drift or stope; while in the latter the bursts occur in the floor pillar or stope backs. Photographs on page 22 shows planes of fracture that are normal to the vein. Pressure exerted from the back of the drift or walls will cause slabs to burst from the back of the drift with a loud report. Photograph on page 23 shows fracturing approximately parallel to the dip of the vein. The photograph on page 24 shows fractures crossing the vein at various angles other than 90 degrees. The danger of rock bursts has been found under these conditions to be at a minimum.



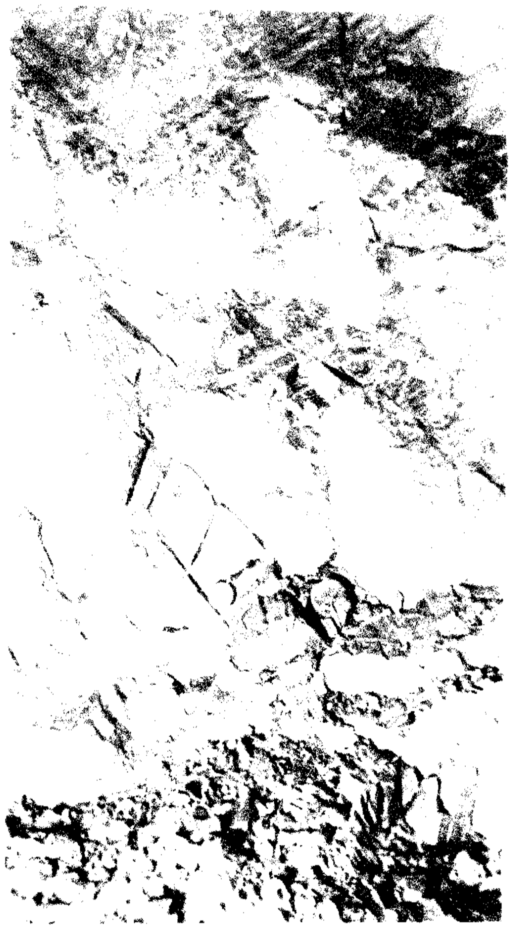


Basic Syenite

Syenite

37496

Stringer Structure



Cross- Fractures

Cross- Fractures

MINING METHODS AT THE LAKE SHORE MINE

In the early history of the mine shrinkage methods were in general use. Breasts were carried from 6 to 8 feet high and about 40 feet apart. Pillars were left in places to support the walls. There was no systematic backfilling until July 1930 when stopes 1670 and 1613 were the first cut-and-fill stopes. Since July 1930 sand filling has been employed extensively in the Lake Shore Mines.

The square-set system of mining was adopted in certain wide stopes where the ground was heavy, about the same time that sand filling commenced. The stope backs were flat or horizontal. Now the tendency on account of rock bursts is to use steep rills.

The Teck-Hughes Mine on the west does not use sand filling. Their stopes next to the Lake Shore are open. It is believed that this condition has helped to increase the pressure along the boundary stopes. Also Teck-Hughes active mining levels are several hundred feet below the level of those of the Lake Shore Mines.

[illegible] IN ROCK BURST AREAS

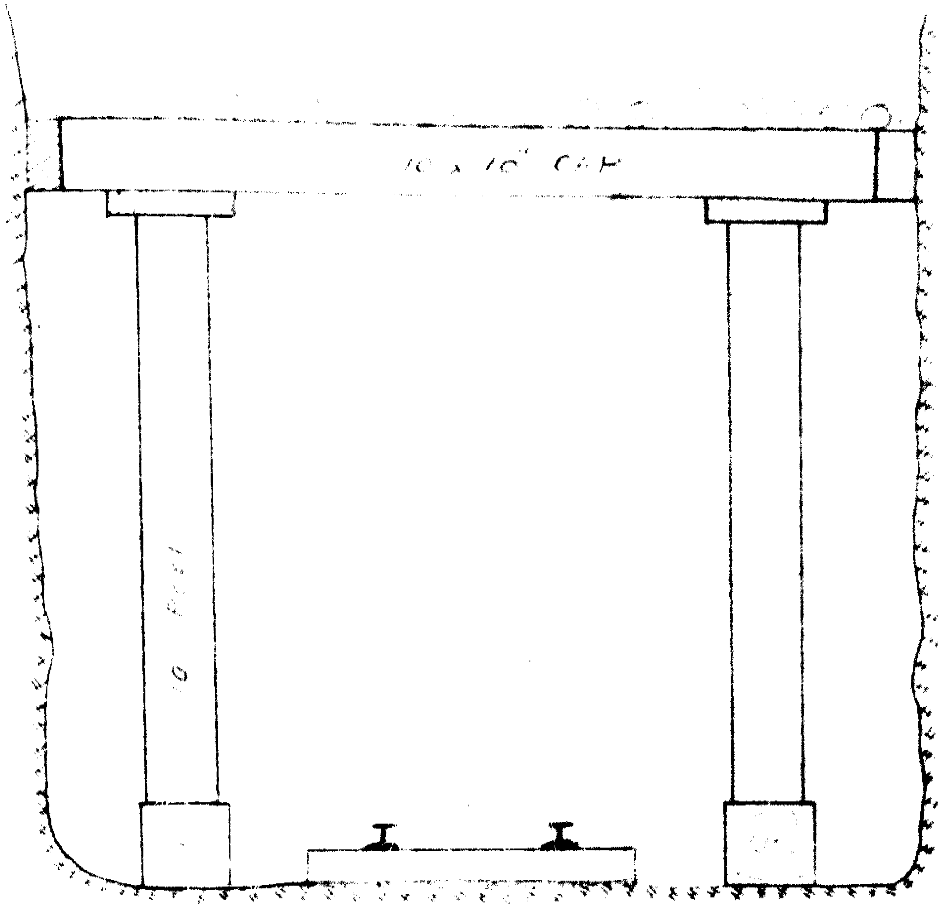
[illegible] problems in rock burst areas [illegible] (sand or waste rock) from [illegible] rock burst has occurred in [illegible] the backfill comes into the drift [illegible] cases to use spiling to open the [illegible] in progress the amount of ore [illegible] curtailed.

[illegible] floor pillar there is [illegible] posts. There is a component [illegible] breaks the cap in [illegible] burst and slabs of rock [illegible] It has been found advisable in [illegible] of 4 to 6 inches [illegible] the caps from [illegible] the lower levels a hollow [illegible] pressure from the walls, [illegible] occurs.

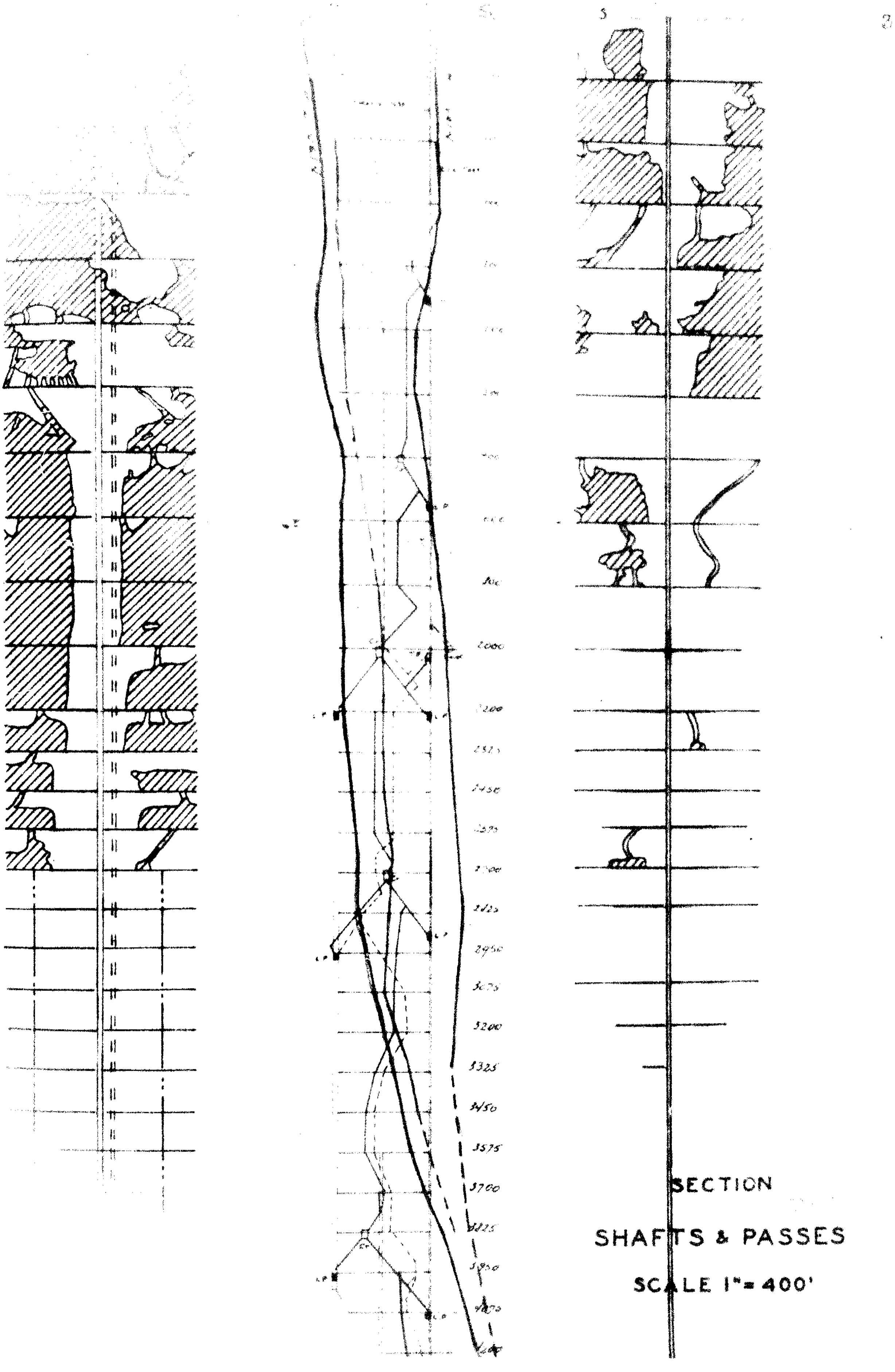
[illegible] a batter on the [illegible] The batter of the [illegible] floor leaves during a rock burst the post is at the edge of the rock dome. The post in this manner escapes to a large extent the upward thrust as the rock under it is thin enough to crush and break. A vertical post would be closer to the top of the rock dome and therefore receive considerably more thrust. Also when a vertical post is used the cap is close to the wall and in many cases tight against the wall. When a rock burst does occur this post is invariably knocked out, whereas if it had been a foot or more from the wall it would have escaped this initial thrust. A good example of the aforementioned conditions was noted in 13-1 East drift. See photograph on page 29 figure 1. Post A was placed with a batter and with an elbow which had a clearance of six inches from the rock at each end. When the rock burst occurred, this drift-set was left undamaged. Post B was set up without a batter, and with a cap which was wedged tightly between the walls of the drift. When the rock burst occurred this drift-set was shattered as shown in the picture.

Another method is to place 12 x 12 B. C. fir stringers on the posts. These stringers act as booms and support posts in the drift as the sill is being removed. See [illegible] made [illegible]. These stru[illegible] [illegible] been [illegible], however in rock [illegible] [illegible] pillar [illegible] [illegible] drawn up [illegible]. In some sections of the shaft cribs are built [illegible] structures. See cut 30 .

Fig.



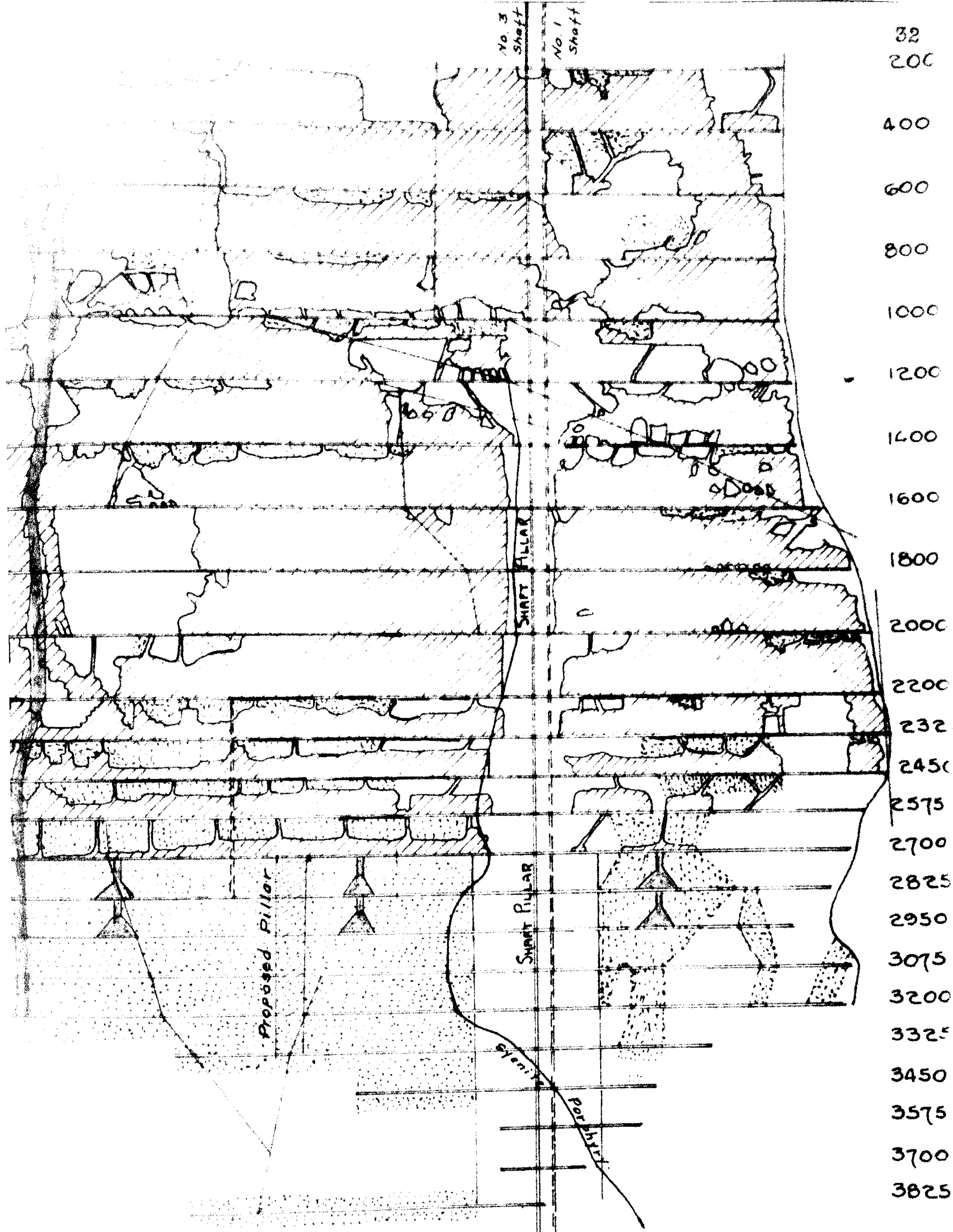
Longitudinal Stringer



SECTION

SHAFTS & PASSES

SCALE 1" = 400'



...RL SECTION
... VEIN
... MINES LTD.
Sept 14-34

STOPPED AREA
ORE
FAULTS
DIABASE DYKE
ROCKBURSTS
PROPOSED RILLS

DESCRIPTION OF A ROCK BURST

2401 West Sec. 2 July 12 6.30 A. M. 1935
Floor fill and stope backs.

A rock burst of medium intensity occurred on the above date in 2401 west stope. The locus of the burst appears to have been around No. 2 raise from the 2501 west stope. The stope was in the shape of a bottle neck and not over 5 feet wide at one point 20 feet west of No. 2 raise. The damage was as follows:

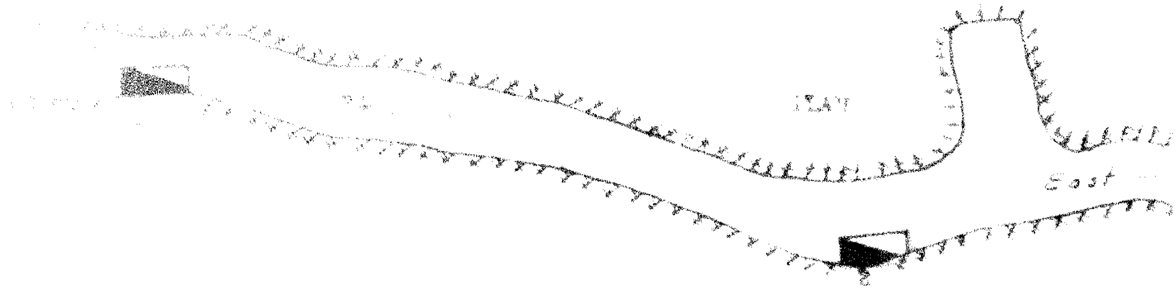
<u>2401 W. drift Sec. 2</u>

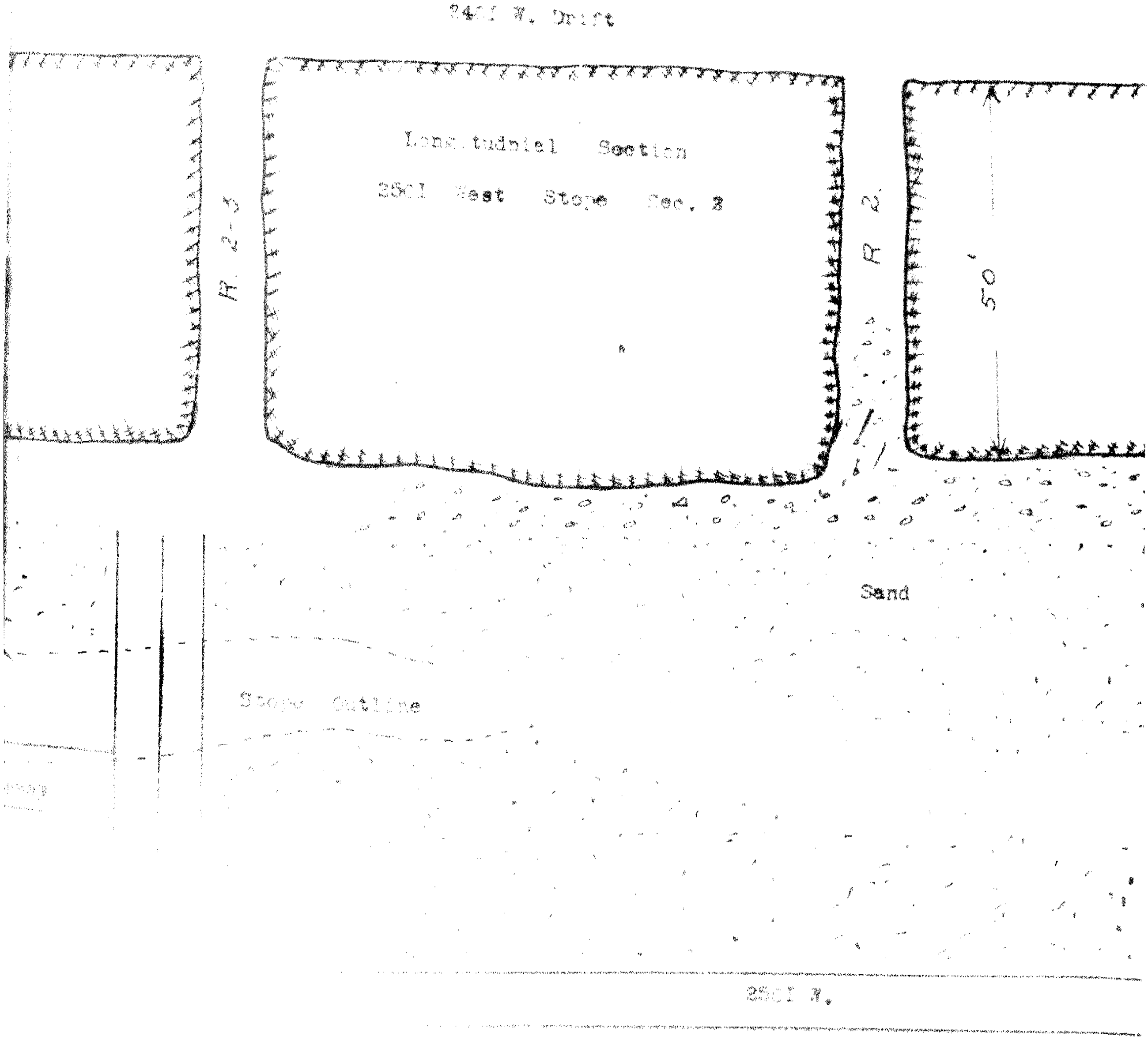
The track was heaved at No. 2 raise and the footwall shattered. No. 2 raise walls were badly shattered and the timber in the raise damaged.

<u>2501 W. stope Sec. 2</u>

The stope walls were shattered at 2--3 raise and at a point 30 feet east of 2--3 raise the square sets were down. The damage extends over beyond No. 2 raise. Figure shows the narrow condition of stope on page [illegible]. Photograph on page [illegible] shows the fractured condition of the foot-wall. The area marked in red is the rock burst zone.

2 July 12, 4.3 A M





Scale 1" : 20'

Shows shattered condition of the foot-wall after the stope had been cleared of loose rock from the walls. Photograph taken in the narrow section of drift just east of No. 2 raise.

DESCRIPTION OF A ROCK BURST (Stope Pillar)

On October 28th 1934, at 2. 7 A.M., a heavy rock burst occurred in a stope pillar in section 4 of the 2301 E. drift. See figure page 79.

The rock burst occurred from 10 to 15 minutes after the cut was blasted in 2-- raise from the 2401 E. drift. The vibration set up from this blasting no doubt was strong enough to bring about the burst.

The locus of the burst was in a waste pillar above the 2301 E. drift between the east end of section 3 stope and No. 5 raise to the 2201 E. drift. The floor pillar appears to have received no damage since the track did not heave in 2301 east drift.

<u>The following is a summary of the extent of the damage:</u>

<u>2401 E. Drift Sec. 3</u>

Two caps were split in the drift near No. 4 manway and the timber also shows signs of pressure.

<u>2401 E. Stope Backs.</u>

In the 2401 E. stope section 3 the square sets were smashed for a distance of 2[illegible] feet beginning 20 feet east of No. 3 raise.

2301 E. Drift

The damaged area begins at No. 4 manway section 3 which was crushed allowing the backfill to come into the drift. The drift has caved for a distance of 45 feet to the east. There was a stope pillar directly above the damaged area and apparently this was the locus of the burst.

2201 E. Drift Sec. 4

In section 4 between chutes 3 and 5, a distance of 70 feet, considerable rock was thrown from the south wall on to the track.

2001 E. Sills

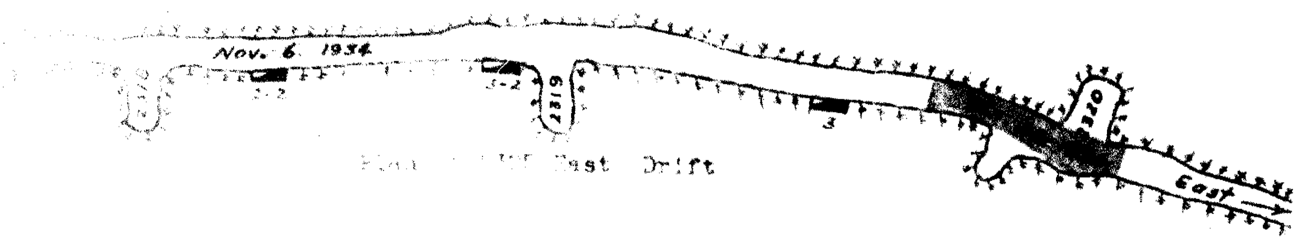
Two men workin in the gangway near No. 10 raise reported a heavy shock, and loose rock fell from the north wall. The vibration also opened up several fissures causing large slabs of rock to break loose on the footwall and ride on the timber.

The indications leading up to the rock burst of October 28th 1934 are as follows:

About October 12th the 2301 E, drift started to show considerable pressure--especially at a point where 2--2 raise would hole from the 2401 east stope. The drift caps started to break and the track heaved more than 3 inches on the south side. The sounds heard in the geophone indicated that a strong pressure movement was in progress.

A burst was expected when 2--2 raise broke through into the 2301 E. drift and so precaution was taken to remove all men from the area. However as the cut was blasted of the last round in 2--2 raise a rock burst occurred 190 feet to the east in a stope pillar above the 2301 E. drift.

The only warning given by the stope pillar was an almost imperceptible spalling of rock from the back of the drift just east of No. 5 raise to the 2301 E. drift. At a point directly under the pillar the 2301 E. drift was timbered and lagged overhead. If spalling occurred here it would not be noticed.



[illegible] East Drift

1

Rockburst Nov. 6 1934

2325 East Drift Sec. 3

2

Rockburst Nov. 6 1934

In gangway bottom of 2--2 raise

3

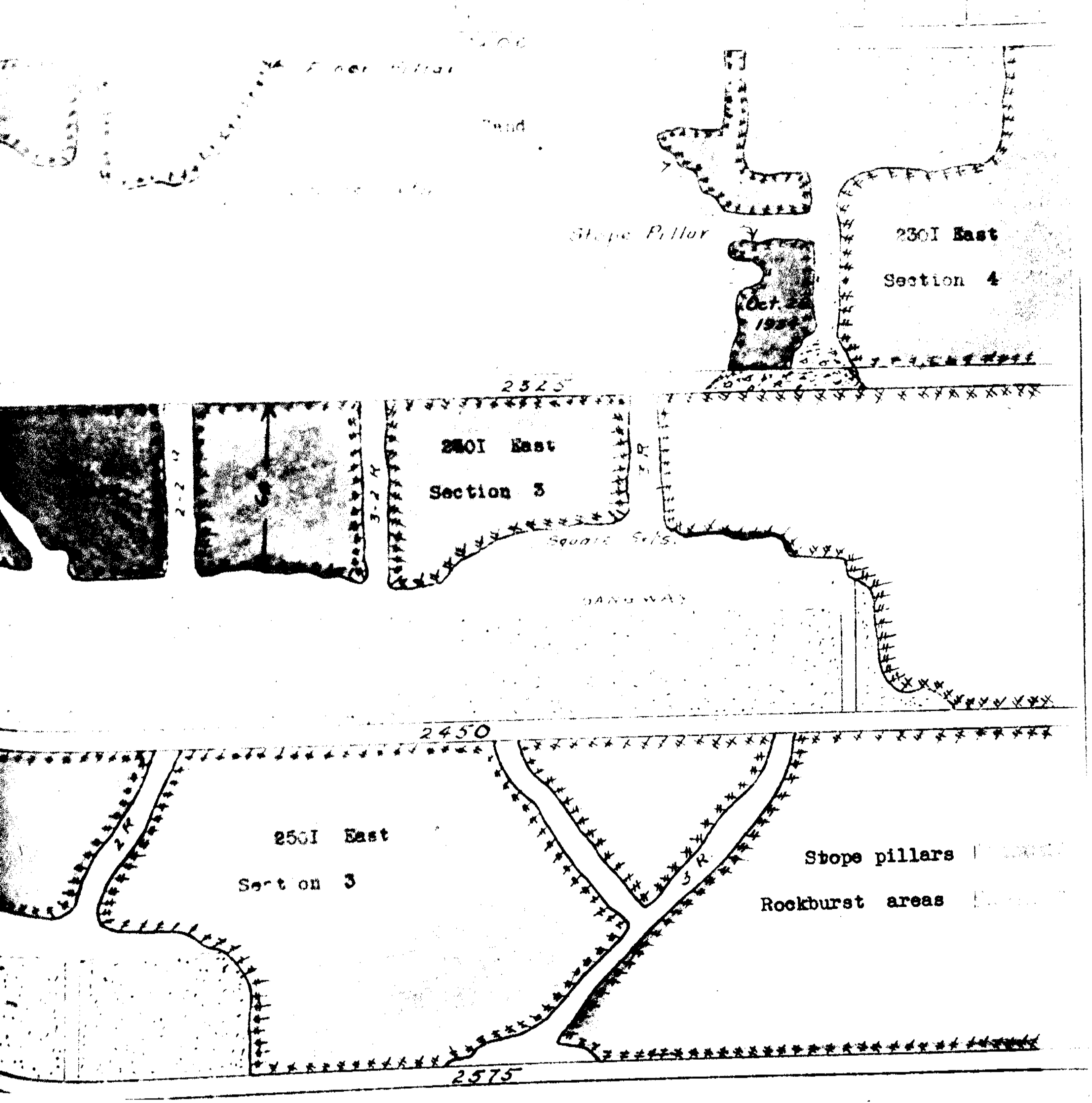
[illegible] 1934

[illegible]

4

Rockburst Oct 28, 1934

Looking west at 2320 X- Cut


Stope Pillar
2301 East
Section 4
Oct. 1934
2325
2401 East
Section 3
Square Sets
Gangway
2450
2501 East
Section 3
Stope pillars
Rockburst areas
2575

DESCRIPTION OF A ROCK BURST (Floor Pillar)

On November 6th 1934 at 2.30 A.M. a small rock burst occurred which was followed immediately by a heavy one. See figure page 40. The miners had just blasted 3 breasts in the 2401 E. stope section 2. The vibration from these rounds was strong enough to bring on the burst.

The locus of the rock burst appears to have been in the floor pillar at a point 20 feet to the east of 2--2 raise from the 2401 E. stope. Here the track is heaved about 4 feet bringing loose rock from the floor pillar into the drift. The drift at this point is nearly closed from broken timber and loose rock from the walls and floor of the drift.

The following is a summary of the extent of the damage:

In the 2301 E. drift sections 2 and 5 the damaged area begins 20 feet west of No. 2 raise from the 2401 E. stope and extends to the east for a distance of 180 feet. For the first 70 feet of this distance to the 2318 cross-cut the drift has about 2 feet of loose rock thrown from the walls on to the track. In this area there are ten caps broken. Then from the 2318 cross-cut to the 2--2 raise the track has been heaved and thrown out of place. Then from ten feet east of 2--2 raise to 20 feet west of 3--2 raise a distance of 40 feet, the drift is nearly closed with loose rock from the floor pillar and walls. There is no back fill in this drift.

No. 2 raise from the 2401 E. drift

The raise has caved and the square sets were knocked out at the bottom of the raise.

2--2 raise from the 2401 E. stope

The square sets were knocked out and buried with loose muck from the sides of the raise. The stringers were still in place at the top of the raise on the 2301 E. drift.

3--2 raise from the 2401 E. stope

Several lining boards were knocked off the sand chute and it was blocked with loose muck. The north wall down at the gangway burst and partly closed the chute.

Section 3 west rill

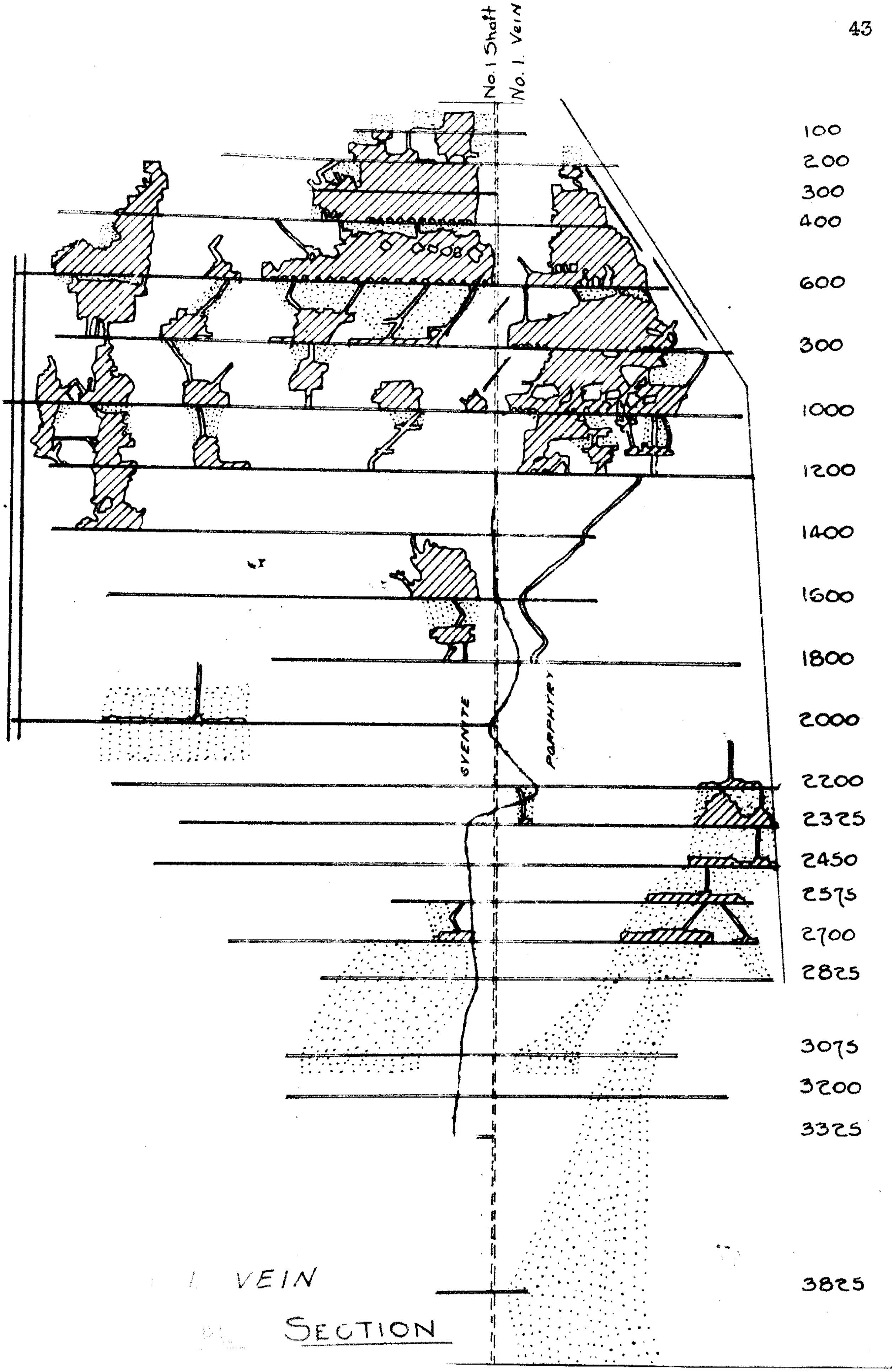
A small cave occurred at the foot of the rill and the back and walls were shattered.

Gangway in stope

The gangway is partly closed between 3--2 raise and a point directly under where 2 raise holes on the 2301 E. drift. The rock burst shoved the north wall out into the gangway, and almost blocked it.

2401 E. Section 2 stope

It was not possible to get into the stope. However from all evidence gathered it is assumed that the square sets in the stope are down.


No. 1 Shaft
No. 1. Vein
100
200
300
400
600
300
1000
1200
1400
1600
1800
2000
2200
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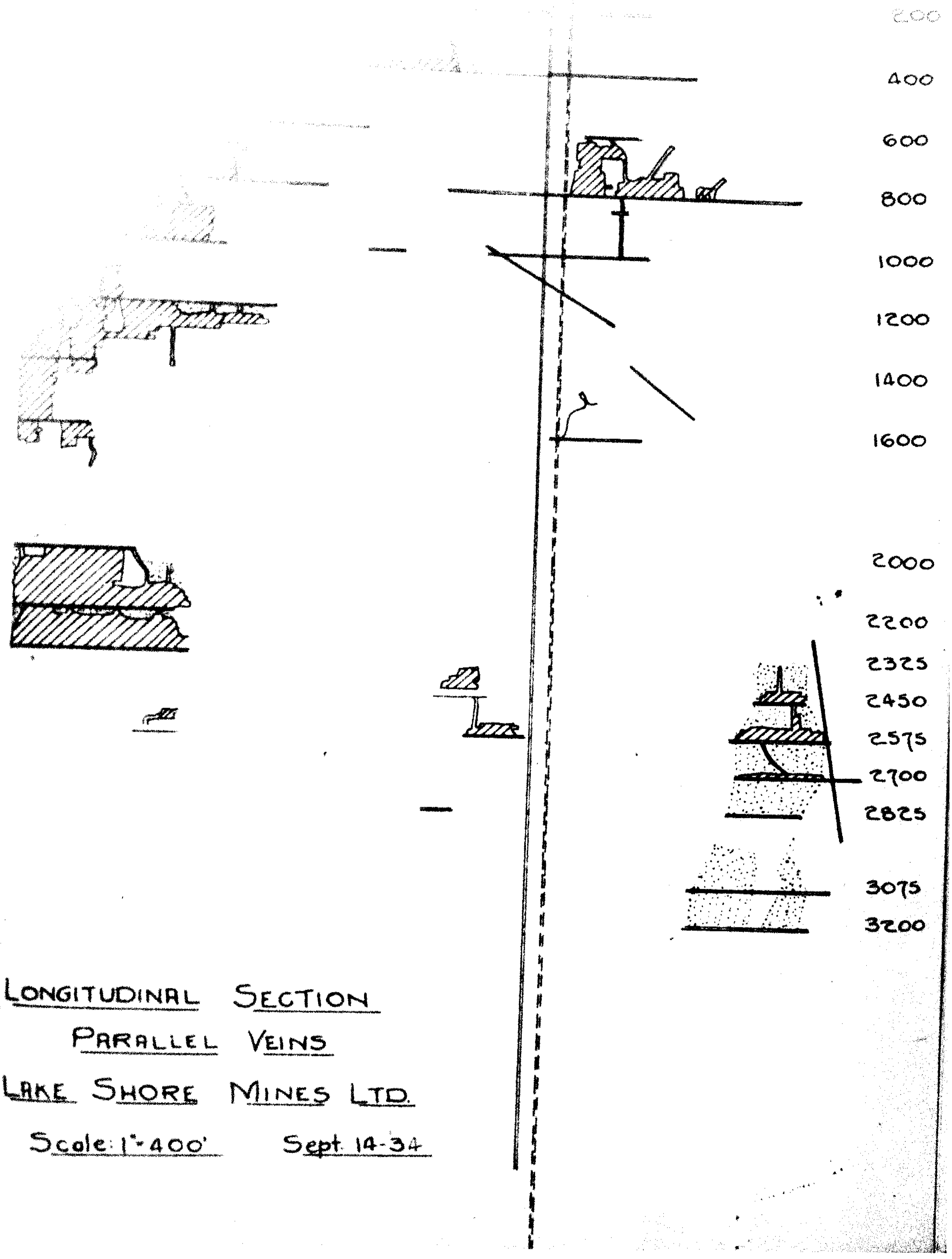
2450
2575
2700
2825
3075
3200
3325
3825
SYENITE
PORPHYRY
VEIN
SECTION



Longitudinal Section
Parallel Veins
Lake Shore Mines Ltd.

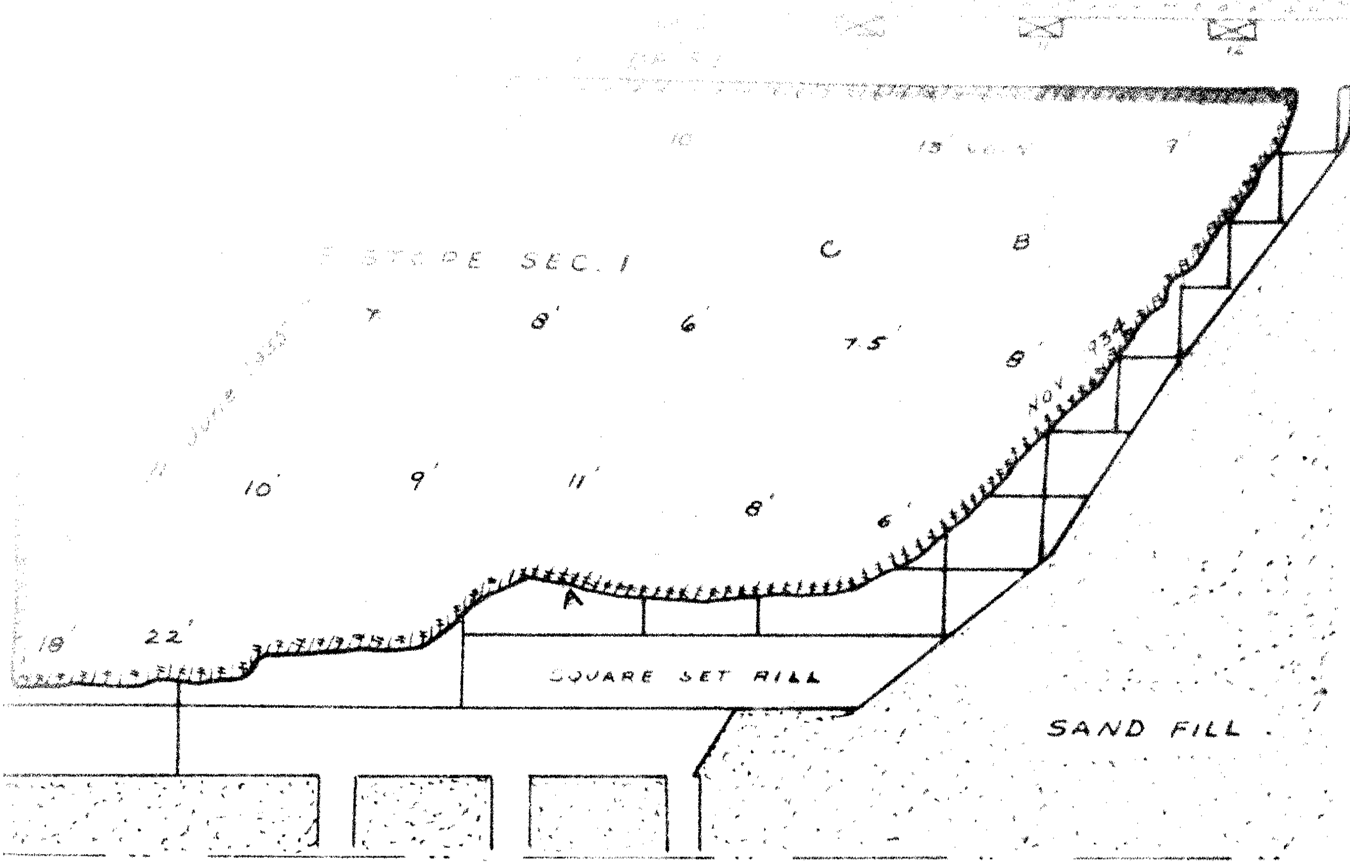
Scale: 1" = 400'   Sept. 14-34

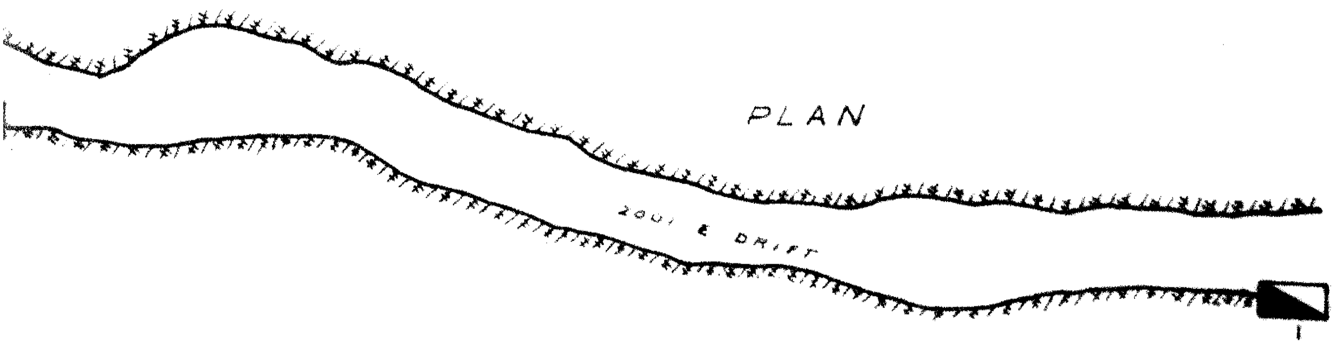
[illegible] OF A REMNANT

A remnant is a block of ground which has dimensions of 150 feet or less on the strike and [illegible] 150 feet or less on the dip.

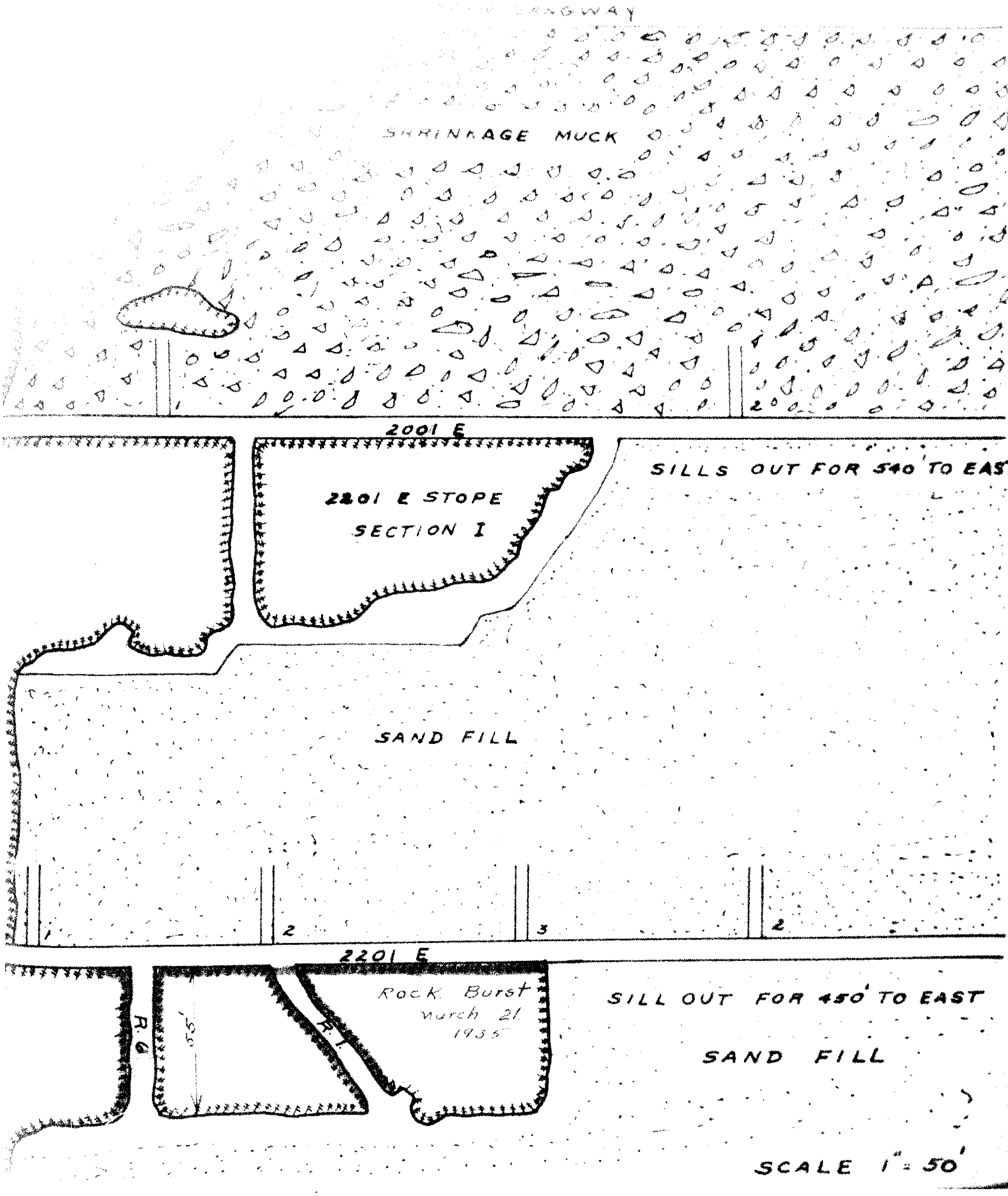
For a period of 8 months a close check was kept on the pressure movements of a remnant in 2201 E. stope section 1. Figure 1 page47 shows this remnant on a scale of 1" = 20'; while figure 2 page48 is on a smaller scale and shows the area surrounding the remnant.

When the first cut on the rill was brought up to a point B about 20 feet from the 2001 east drift the track started to heave at an alarming rate along the distance marked in red on the figure page47. See photographs also on page 49. It was thought that a rock burst was imminent. The same indications of pressure occurred when the second cut reached a point C on the figure marked in yellow. It was decided to avoid flat backs on the rill as far as possible. The remnant was made more into the shape of an isosceles triangle with a steep rill making an angle of approximately 55 degrees with the drift. Since this procedure has been adopted it is believed that the remnant will be removed without a [illegible] below the one under observation [illegible] stope burst violently on March 2[illegible]. [illegible] # 48 . This rock burst occurred at 10 [illegible] in the morning when a bulkhead was blasted out of [illegible] raise. Mining had been stopped on this remnant for over a year and the stope was being put into condition to resume operations. The drift on the 2200 level was badly damaged and closed from # 6 raise for a distance of 125 feet to the east.


STOPE SEC. 1
C
B
7
8'
6'
7.5'
8'
10'
9'
11'
8'
6'
19'
22'
A
SQUARE SET FILL
SAND FILL


PLAN
2001 E DRIFT
1

SCALE 1" = 20'



DRAGWAY
SHRINKAGE MUCK
2001 E
SILLS OUT FOR 540 TO EAST
2201 E STOPE
SECTION I
SAND FILL
2201 E
Rock Burst
March 21
1935
R. 6
R. 7
55'
SILL OUT FOR 450' TO EAST
SAND FILL
SCALE 1" = 50'

200' east drift heaving mostly on
the hanging wall side.

[illegible] the [illegible] wall side

[illegible] be relieved

[illegible] INFORMATION

[illegible] of the rock bursts for over a period of [illegible] shows that they occur in groups or series. [illegible] they build up in strength or magnitude to a maximum every two and a half months. From this maximum point the rock bursts diminish and fade out with a period of quiescence before the next series begins. It has not been possible to predict from these cycles the time at which a rock burst might occur. With the decrease in severity and occurrence of the rock bursts in the latter part of 1935 these cycles are becoming longer.

The greatest number of rock bursts have occurred directly after blasting. This is for the day shift 3 P.M. and the night shift 3 A.M. But some bursts have occurred between shifts. The rock bursts have occurred in all months of the year. However the greatest number have occurred in the months of October and March. From August 8, 1931 to the end of 1935, one hundred and three rock bursts have been recorded.

Considerable noise accompanies a rock burst. In some cases there has been a grating and grinding sound and in others a noise like that produced when a round ted and all the holes explode at once. The shocks and tremors are more severe on the surface. The waves build up in intensity and after reaching a maximum fade out. Severe shocks have been felt in Swastika a distance of 6 miles from Kirkland Lake. Very often the tremor is accompanied with a noise like a clap of thunder. Houses whose foundations are on solid rock receive a much greater shock than those on sand, gravel or clay.

The rush of air accompanying a rock burst is small. At the most, men's hats have been blown off and their carbide lights extinguished. Rock bursts have sometimes been incorrectly called "air blasts"

Air blasts properly so called, have occurred in the caving system of mining when a stope would fail to cave for a certain period of time and the muck continued to be removed from below. Then a large block of ground would fall into a partly empty stope and cause a violent rush of air down the chutes and into the drift.

The energy liberated in a rock burst has not been accurately measured; in fact it has not been possible, so far, to make anything but a very rough estimate of its magnitude. However Mr. P. J. Crowle in his "Notes on ements and Methods of Support in Deep Mining" estimated from seismograph records one moderately heavy burst and has given the energy liberated to be in the order of 15,000,000 foot tons.

The geophone was used in several cases to determine pressure movements in advance. With the aid of this instrument sounds made by rock under abnormal strain could be detected for some time before they were audible to the unaided ear.

The writer is still experimenting on an electrical geophone with amplifiers to give warning of impending rock bursts.

Sag meters consisting of an upright beam and pointer arranged so as to measure the increased pressure were once under consideration. These sag meters are used in the South African Mines; but as conditions in the Lake Shore Mines are different from those in the African Mines it was decided that these sag meters would not be practical. In the mines of South Africa the veins are flat and narrow; while in the Lake Shore Mine the veins are wide and almost vertical. There was also the psychological effect on the miners to be considered. A sketch on page 56 shows one these sag meters.

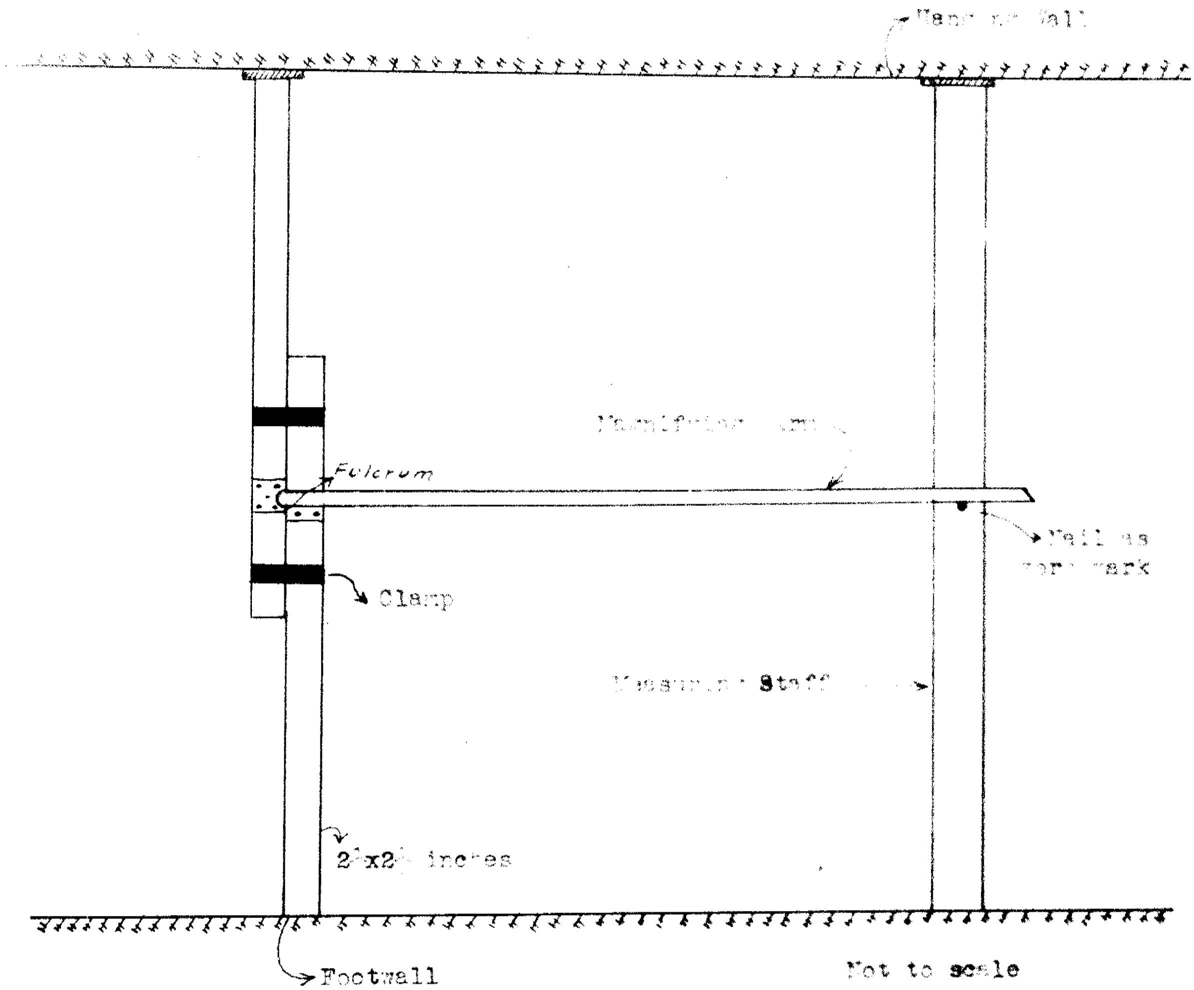
...nts by Daubree, Leith and others we ...der pressure shears at approximately ... If we represent A-B as a cross-section of ...ft in figure on page 59 we can understand how the ...ck is thrust upward from the floor pillar when a rock ...urst occurs as shown in photograph on page 60 . The only difference between these figures and the actual conditions of a drift is that the rock in the drift has only one way to break--hence there is no down shear unless the pillar is thin.

If we take a narrow section of the drift--say a section 7 feet wide, where most of the rock bursts have occurred--and analyze the force diagram it will be seen that the ability of the floor pillar to resist shear is directly proportional to its width. Rock before it ruptures or reaches its elastic limit arrives at a certain degree of curvature as indicated on the dotted line in figure on page 5 9. Also in a wide section there is more tendency for the small fractures to bring on crushing, and less likelihood of shearing and bursting.

At lower levels when the pressure becomes excessive the narrow sections could be mined early in the scheme of extraction and a semi-rigid fill of lean concrete used.

[illegible]t has been made to make a thorough study [illegible] faulting in the Kirkland Lake district to find [illegible] what effect it may have on the rock bursts. Over a period of two years measurements were made on certain faults underground and in two cases movements were noted.

SAG- Meter



[illegible] ROCK PRESSU E ON FLOOR PILLARS

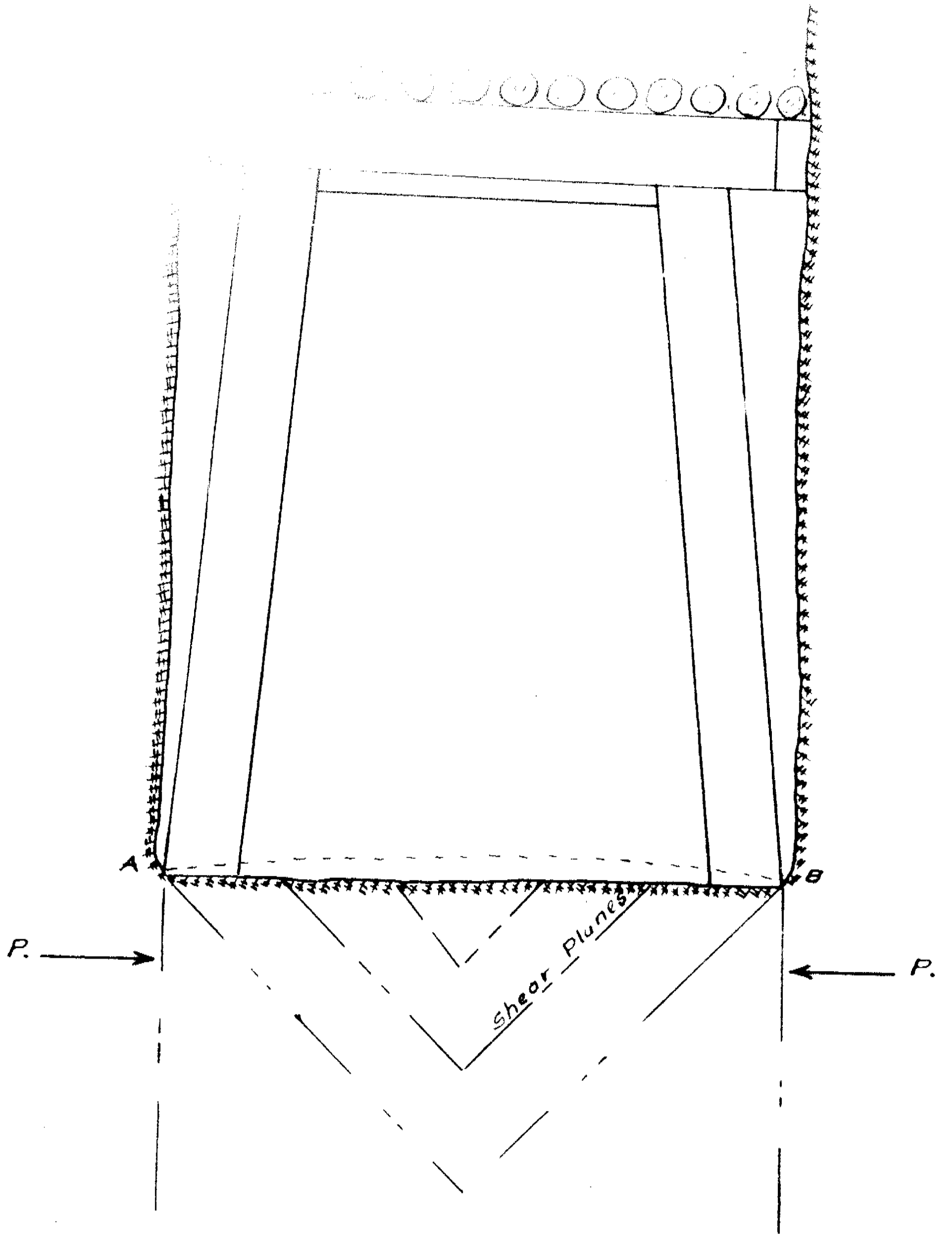
[illegible]e rock bursts occurring in the floor pillars in [illegible] Lake Shore Mine have been in the narrower sections [illegible] the drift, usually where the drift is about 7 feet wide. There has been one exception to this rule: on May 30, 1935 on the 24[illegible]1 west drift section 5 a floor-pillar 25 feet wide burst. This drift had been silled and cribbed and in reality the pressure was confined as it would be in a narrow drift. Also the locus of the burst was in a stope pillar below the area. In other words the narrow sections have been found to be weak points and danger zones.

In mines where rock burst are a serious problem it is conceded that the best practice is to mine away from the weak points. Therefore these narrow sections should be mined as early as possible. However we know from experience that raises and rills must be placed at certain fixed intervals and they do not always correspond with the narrow sections of the ore.

If we analyse the rock stresses it will be seen that the narrow sections are the ones most likely to have rock bursts, while in the wide sections there is more danger of caving.

[illegible]lysis of the figures it can be seen [illegible] de section--say 14 feet--will stand twice the [illegible]re that a narrow section 7 feet wide can bear before it bursts.

At the present time the ground that is heaving is all in the narrow sections of the drift--these sections are the weak points and danger zones for rock bursts.



Cross- section of drift showing the shear planes in floor pillar

Scale I inch equal 2 feet

Shows the [illegible] effect of the drift after a rock burst

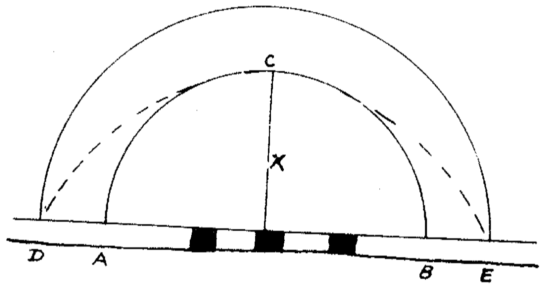
in the floor pillar

DOMING

The idea of doming was first introduced by Rziha in 1881 and was subsequently greatly developed by Fayol.

The word dome is used as the name for the surface which separates the solid rock from the semi-loose rock in the walls on either side of a stoped-out lode. The shape of the dome is highly important, but unfortunately not accessible in most cases to measure. The only available evidence for deducing the shape is that derived from cracks in cross-cuts or passages. In isotropic rock these sections must be arcs of circles. However the writer has found that they are more likely to be flatter than semi-circles. The coalescence of domes is thought to be one of the important causes of rock bursts. See drawings on page 62 for further details.

Restricted Dome Span D-C-E



Natural Dome Span A--B

In the above sketch A-B represents a stoped portion of the vein which has been supported by a compressible method. The dome ABC has formed and developed sufficient expansion to attain the ultimate compression on the supporting medium.

Additional stoping produces additional stress, but for doming to continue into the walls additional volume for the broken rock is now required within the dome. Along the line X the maximum compression has already been attained, unless the supports fail or the walls shear between supports.

If neither of these conditions result from the stress. the penetration of the dome into the walls must cease, and subsequent stoping results in the development of a flat dome with the supporting medium acting as an abutment.

[illegible] ROCK BURSTS

[illegible]es where rock bursts have occurred in [illegible] mine a disturbance was noted for varying [illegible] of time. Sometimes they have been noticeable only [illegible] hours before the burst; sometimes the period of disturbance lasted for several days, and occasionally it has been prolonged for two or three weeks.

The signs of a disturbance consisted of sounds, such as crackling accompanied by spitting and flaking of small fragments from the walls. The track heaved in the drift, and the timbers showed that abnormal pressure was being exerted on them. However these indications do not always mean that a rock burst will occur. In several places the floor pillar has heaved the track up six inches or more, but no burst has occurred. It has been found that the character of the rock plays an important role in a case of this kind. Where the rock is a brittle feldspar porphyry with small calcite stringers running through it, there is great danger of a rock burst; but when we have a mud seam running parallel with the vein, an adjustment takes place on the hanging wall side of the vein; thus pressure is relieved and a burst averted.

In certain sections of the mine, notably on the east side, the syenite porphyry has many calcite stringers. Since calcite is very friable it is believed that the crackling and snapping preceding a burst may be due to the presence of this mineral.

[illegible] AGAINST PRESSURE BURSTS

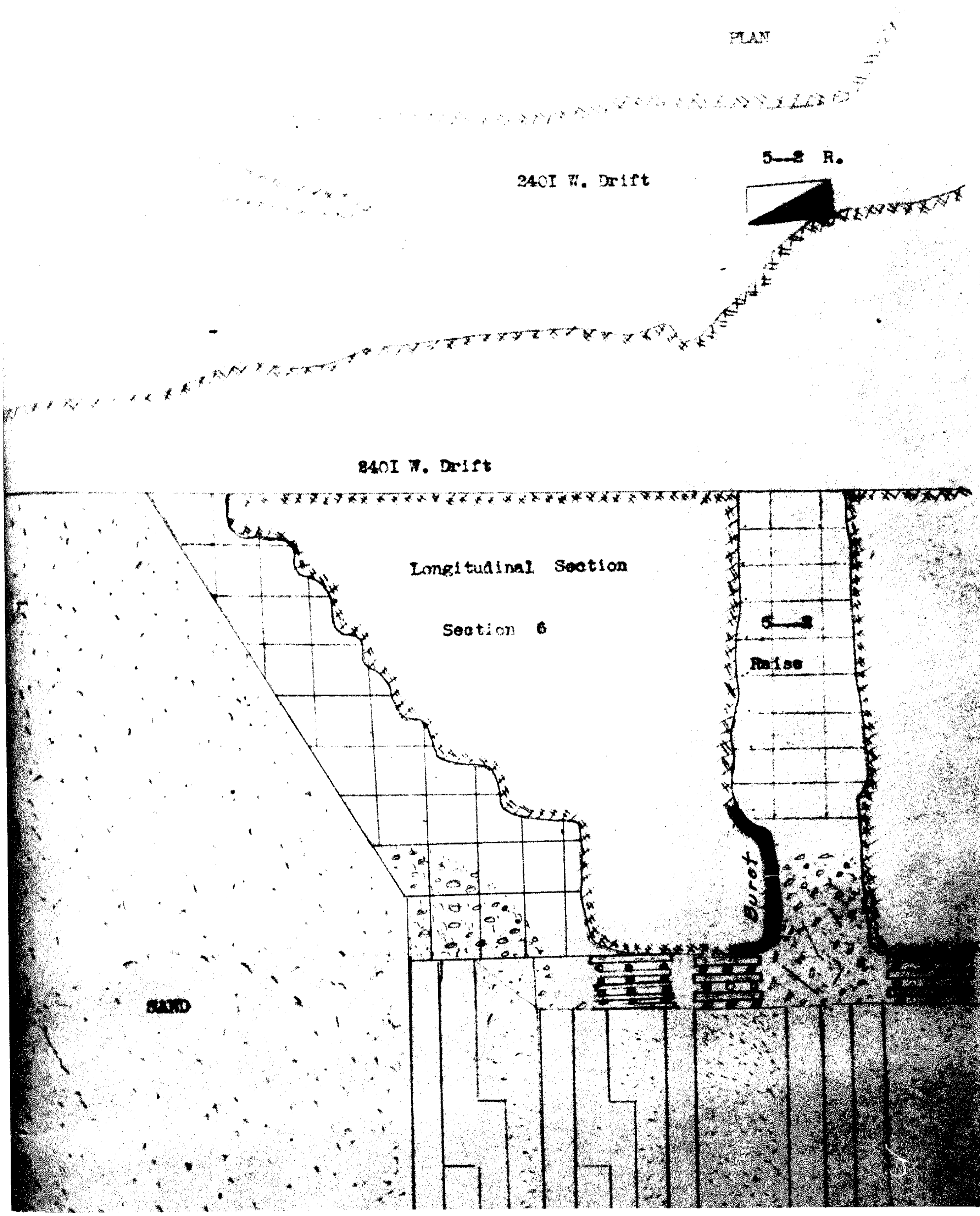
[illegible] is done except at the end of a shift [illegible] is left between [illegible] and wall, specially when drifts are re-timbered. Special cushion blocks are now being used with 4 inch hollow space in each block.

3. The mill holes (chutes) are kept full of ore. This helps to prevent their collapse during a rock burst.
4. The number of persons employed, especially in remnants is limited.
5. The number of remnants worked at one time within a given area is limited.
6. It is most essential to have a full and heavy blast on every blasting shift; for when that period of stability or instability prior to failure is reached, it is essential to bring about that failure as speedily as possible after all persons have left the working face and before they re-enter it.
7. Pillars should be large enough to prevent fracturing in the vicinity of shafts. Remove small waste pillars in stopes.

[illegible] tice is to eliminate rectangular pillars.

[illegible] being replaced by rills.

[illegible] tions should be avoided. Sketch on page 66 shows where rock burst occurred on September 6, 193[illegible] in a projection on a stope face.


PLAN
5—2 R.
240I W. Drift
240I W. Drift
Longitudinal Section
Section 6
5—2
Raise
Burst
SAND

[illegible] NO. 2 [illegible] APRIL [illegible] I933

		S		P	S	
[illegible]	[illegible]	0	200 E.	I232	0	used I50 feet
[illegible] W.	I509	I59I	400 E.	52I	II55	
[illegible] W.	2I0	2734	600 E.	II47	432	
[illegible] W.	302	2723	800 E.	808	753	
I000 W.	I04I	2045	I000 E.	397	II28	
I200 W.	I326	20I4	I200 E.	I084	498	
I400 W.	934	2490	I400 E.	594	I084	
I600 W.	974	2426	I600 E.	397	I29I	
I800 W.	II68	2I66	I800 E.	388	I442	
2000 W.	I940	I436	2200 E.	955	II74	
2325 W.	II50	I050	2325 E.	893	6I4	
2450 W.	II52	908	2450 E.	805	500	
2575 W.	I265	882	2575 E.	I000	330	
2700 W.	I476	694	2700 E.	III7	I85	
Total	I7978	25368		II788	I2I93	

Pillar to 2700 on the west side of mine equals 4I.[illegible] percent
Pillar to 2700 on the east side of mine equals [illegible].I "
Pillar to 2700 on the east and west side equals 44.[illegible] "

PERCENTAGE OF PILLAR LEFT TO STOPPED AREA NO. 2 VEIN JAN. I I935

	P	S		P	S	
200 W.	2380	0	200 E.	I232	0	used I50 feet
400 W.	I509	I59I	400 E.	49I	II85	
600 W.	II0	2834	600 E.	655	924	
800 W.	229	2796	800 E.	808	753	
I000 W.	900	2I86	I000 E.	379	II46	
I200 W.	I300	2040	I200 E.	376	706	
I400 W.	894	2530	I400 E.	580	I098	
I600 W.	934	2466	I600 E.	397	I29I	
I800 W.	II58	2I76	I800 E.	290	I540	
2000 W.	I087	2273	2000 E.	I99	I858	
2200 W.	775	260I	2200 E.	297	I832	
2325 W.	508	I692	2325 E.	555	952	
2450 W.	526	I534	2450 E.	587	7I8	
2700 W.	I33I	839	2700 E.	I097	205	
Total	I4520	28826		94II	I4570	

Pillar to 2700 on the west side of mine equals 33.5 percent
Pillar to 2700 on the east side of mine equals 39.2 "
Pillar to 2700 on the east and west side equals 35.5 "

RECOMMENDATIONS FOR THE CONTROL OF ROCK BURSTS

"While nature is primarily responsible for the condition of unstable equilibrium, the immediate agent is man, who interferes with forces beyond his control." However it is now believed possible to control in part the occurrence of rock bursts by employing mining methods particularly adapted to that end.

Economy of operation is the controlling factor, and all proposals advanced must be subject to the acid test of costs.

The control or diminution in effect of rock bursts is probably the most desirable end sought, rather than prevention. Considering the damage resulting from the rock bursts in the Lake Shore Mine the maximum intensity was reached in 1934. During the latter part of 1935 only small bumps have occurred with practically no damage or injury to the miners. This does not mean that the situation is completely under control, since there are waste pillars left in the mine that may yet burst with serious results. Increased stoping continues to throw more weight on these pillars, and unless the stope pillar is already crushed a rock burst may eventually occur, when the rupture point [illegible] also applies to the pillars that have been [illegible] within 30 or 40 feet of the level above. See [illegible] page [illegible] which show a stope and floor pillar.

We may eliminate or minimize rock burst by using the following means:

Rigid Support.

This is usually done by leaving pillars of waste or ore. Rigid support must be adequate for the purpose of keeping the individual domes isolated. When extraction passes beyond that point there is always danger of serious bursting, due to pillar failure and the resulting merging of domes. The pillars in the Lake Shore Mine did not start to fail until about 60 percent of the ore was extracted down to the 2700 level. The present practice is to remove any small waste pillar in the stope to prevent bursting at a later date.

Compressible Support

It is reasonable to suppose that the support permitting the least sag will be the most effective. However the most effective supporting method is not always adaptable to the conditions in a particular mine.

The method of support in a mine depends, among other things, upon the stoping method. With underhand stoping close support is limited to the unit type, such as stulls,

...ls, sandows and rock filled cribs. With ... back stoping, in addition to the unit type of ..., there is the choice of mass practice, as represented by the various filling methods.

In the Lake Shore Mine, especially on the north vein, the practice is to square-set and fill with sand. The sand helps to support the walls, and in the case of a rock burst, it appears to deaden and arrest the vibrations set up in the affected area. Sand for support would be much more effective if flushed into the stopes with water. Cribs are built with spruce logs in wide stopes, and drifts. The Lake Shore veins vary in width from 7 feet up to 40 feet and in some places they reach a width of 65 feet. It has been found that these cribs are very effective in the stopes when a rock burst occurs, since they prevent the backs from coming down and, completely closing the stope. On the lower levels where the veins start to flatten out a more rigid support will be required to prevent rapid subsidence of the hanging wall; rock cribs or packwalls may serve the purpose.

Sequence of Stoping

Stoping away from a major weakness in a systematic manner would be advantageous. The weakness might be a a fault, joint, or large calcite slip. A systematic removal of ground would also eliminate many of the irregular doming tendencies due to the failure or removal of pillars.

are removed systematically the dome would be given every opportunity to grow and expand as a single unit.

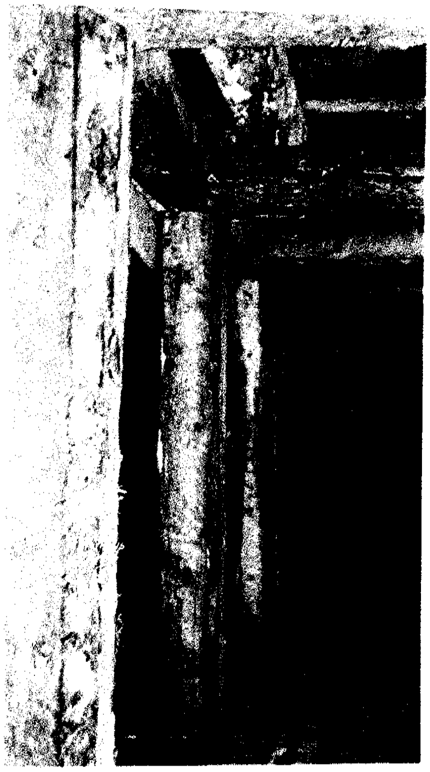
When the dome grows gradually, there is a steady and uniform application of weight upon the supports, and this is a very desirable condition.

Mining Methods

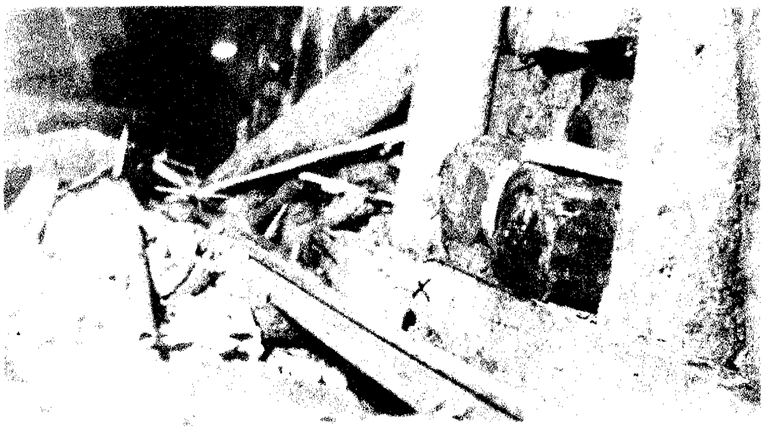
In changing from flat-back to rill stoping an important advance was made in the control of both pressure and strain bursts. Strain bursts will however continue and probably increase with depth since they are inherent in the rock itself. Small strain bursts still occur even on rills when fifteen feet or more of the rill becomes flat or horizontal. This feature requires close supervision, especially when the rock is a brittle feldspar porphyry with small calcite or quartz stringers. Rills have eliminated the work of mucking, tramming of fill, and the building of chutes and have thereby reduced the cost of mining by about 30 percent. A remnant in the shape of a rectangle, when it reaches the level above, has been found much more likely to fail under pressure than one in the shape of a triangle.

It has been proposed to leave a 100 foot pillar about half way between # 3 shaft and the Teck-Hughes boundary.

[illegible] distance between the shaft pillar and the [illegible] wall as a beam, the maximum bending moment or [illegible] in the stope walls would fall midway between supports. Since the shaft pillar or parting wall has not burst it is believed that this pillar will be strong enough to resist failure and give considerable support to the west end of the mine.



Square set stope



[illegible] west secti[illegible] shows [illegible]
[illegible]
[illegible] breaking

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