The Operation of the Cominco Potash Mine with Special Consideration of some Principles of Applied Rock Mechanics for Strata Control

Fritz F. Prugger

Cominco Ltd., Potash Operations, Vanscoy, Saskatchewan, Canada SOI 3JO

ABSTRACT

After the start of production at the Cominco mine, in January 1969, it soon became apparent that the ground behavior there was quite different from that in other potash mines in Saskatchewan.

Early roof failure could not be prevented by artificial ground support. To continue the operation, access drifts were excavated in waste material up to a stable roof bed. The causes of roof failure were analyzed and the ground's quick reaction to high stresses was taken advantage of to create stable main entries utilizing stress relief creep.

The original room and pillar design was replaced by panel and pillar mining with elongated, narrow yield pillars between long rooms where the roof of a completed room is allowed to cave, thereby protecting the next room. The square pillars of the room and pillar design were changed to long support pillars between adjacent panels.

The removal of ore from the continuous miners by conventional truck haulage evolved to a more efficient system of continuous extensible conveyor haulage adapted to meet the particular ground conditions in this mine.

INTRODUCTION

Cominco is one of the world's largest producers of zinc and lead, with active mines in many countries around the globe. It also produces gold, silver and other metals. In the 1930's the manufacture of nitrogen and phosphate began, to be complemented in 1969 by the addition of potash from Saskatchewan. When Cominco's mine near Saskatoon went into production in 1969, seven other mines were already operating in the province, with two more to follow shortly.

The potash of Saskatchewan is found in a belt 150 km wide and stretching for 600 km across the central part of the province, from the Manitoba border in the east to Alberta in the west. It occurs in the Prairie Evaporite Formation deposited in the Elk Point Basin of Middle Devonian Age. The lower half of the Prairie Evaporite consists of massive halite and anhydrite with some dolomite. In the upper 60 m the formation contains potash beds, with halite, clay and shale. It is overlain by the argillaceous shales of the Second Red Beds. The Evaporite Formation ranges in thickness from 80 m to more than 200 m.

Goudie and Holter describe three potash mineral zones which in ascending order are the "Esterhazy Member", the "Belle Plain Member" and the "Patience Lake Member". Three mines in the Southwestern region of the province mine potash from the "Esterhazy Member" at a depth of 950 m. One operation, in the South central part of Saskatchewan, uses the solution mining technique, dissolving the ore of the Belle Plain Member at a depth of 1,720 m. Six mines in Northwestern Saskatchewan mine the Patience Lake Member at depths between 975 m and 1,115 m. The Lanigan Mine exploits the lower seam called "D Zone" while the other five mines in the Saskatoon area mine the upper "B Zone."

In the Southeastern area there is a cover of 25–30 m of salt and about 8 m of shale between the water-bearing Dawson Bay Formation and the potash below. In the Northwest area the cover between the mine openings and the Dawson

Bay Formation consists of 12–18 m of salt and 4 m of shale. This thin protective cover is the main reason for the low extraction rate of about 35%. Most mines are, however, testing the possibility of increasing the extraction rate.

GEOLOGY

At the Cominco Mine the Prairie Evaporite Formation varies in thickness from 80 m to 185 m. In some areas the carbonate rocks of the Winnipegosis Formation protrude as reefs, causing a thinning of the evaporites. Mining is done close to the top of the evaporites in the B-Zone. There is an average cover of only 14 m of salt and 4 m of argillaceous shale of the Second Red Beds to the limestones and dolomites of the Dawson Bay Formation which in some areas of the mine contain water. Besides the Winnipegosis and Dawson Bay formations, there exist six additional water-bearing formations at the mine.

Because of the regional dip, the Cominco Mine at a depth of 1,070 m to 1,115 m is the deepest potash mine in Saskatchewan. The mineable seam is 3 m to 4 m thick and dips slightly to the southwest. The stratigraphy is very uniform throughout large areas with the exception of local disturbances caused by collapsed structures or leached zones. The actual high grade ore zone consists of a sylvinite seam designated "B-5". Three clay seams above this zone form a very unstable roof and must be removed in the process of mining. This lowers the ore grade and increases the insoluble content (Fig. 1).

The mine roof is composed of a bed of halite 0.75 m to 1 m thick, followed by a 0.15 m layer of gray and red shale locally called B-2 shale, which is in turn overlain by a halite section 1.5 m thick containing inclusions of shale laminae. Overlaying this is a layer of clayish shale, 0.50 m thick, called B-1. Above the B-1 is the B-0 bed which consists of halite and lacks clay partings. This is followed by 6 m of halite and the 4 m thick shale of the Second Red Bed Formation which forms the base of the limestones and dolomites.

For a safe mine opening the most important features of the stratigraphy to consider are the B-4 clay partings, the B-3 salt beam and the B-0 salt beam.

The B-4 clay partings have a twofold effect on the safety of a mine opening. Separation and roof fall occur if this section is not cut out along the base of the B-3 salt. Due to the weakness of the clay, these layers move rapidly into the mine opening, creating wall cusps. The original cutting profile of the mining machine which provided for a rounded-off corner was therefore altered to allow for a right angle corner.

The salt beam of the B-3 is not strong enough to withstand the horizontal pressure. It buckles and fails, caving up to the base of the B-0 bed. Again the effect of the B-2 and B-1 shale is apparent. The time it takes for a failure of the immediate mining roof to occur depends on the thickness of the B-3 salt, crystal size, clay intrusions, width of the mining opening, extraction rate, effect of neighboring openings and "cutting high" with the mining machine. In virgin ground, it may take anywhere from 1 month to 6 months for an opening 5.5 m wide to fail, whereas in high stress areas a single pass opening of 5.5 m may fail after only a few days. Unless it is protected by another opening, the B-3 salt beam invariably fails, causing the collapse of the next 3 m of ground.

The B-0 salt forms a strong and dependable salt beam which has not shown any tendency to crack or separate; it does, therefore, form a stable roof.

HISTORY

Production started in January of 1969 and the mine design was originally based on the conventional room and pillar system with rooms 8–9 m wide and with square pillars measuring 70 m × 70 m (Fig. 2). Although the extraction rate was only 25% and the B-3 salt in this area is 1.10 m thick, the roof failed in all entries within 2–5 months. Attempts to support the roof with wooden posts, hydraulic props, wood cribbings and roof bolts were not successful. A reduction of the opening width from 8 m to 5.5 m delayed roof failure but did not solve the problem. In order to continue the operation, travelways and conveyor galleries were blasted up to the B-0 salt. Some drifts were excavated with the continuous borer, cutting commencing along the base of the B-0 salt. These drifts were cut 6.25 m high in three stages. Though the roof has been in excellent condition for the past 9 years, the walls continue to loosen due to continuous pillar expansion. Because of the necessity to remove this loose material, the drifts developed along the B-0 have been widened from their original width of 5.5 m to 8.0 m and more.

With the roof of important entries secured, the continued operation of the mine was guaranteed. However, the major disadvantages of stabilizing the roof by extracting material to the B-0 bed are the additional cost of excavating and handling 3 m of waste material and the increased maintenance work to remove wall slabs. Therefore, it was essential to discover the reasons for the roof failure and to find simpler and less costly means of developing safe main entry systems and an efficient method of panel mining.

At a depth of ± 1,100 m, stresses are more or less hydrostatic at 246 kp/cm^2. Opening of a room under these stress conditions results in an immediate stress-relief creep of the adjacent rock into the room. Vertical stresses are transferred into the abutments close to the opening, resulting in a high peak of stress distribution. As the walls immediately adjacent to the opening creep into it and yield, the high stresses move away from the opening. As the stress peak migrates away from the opening, the stress gradient is reduced.

Horizontal stresses are transferred in a similar fashion to

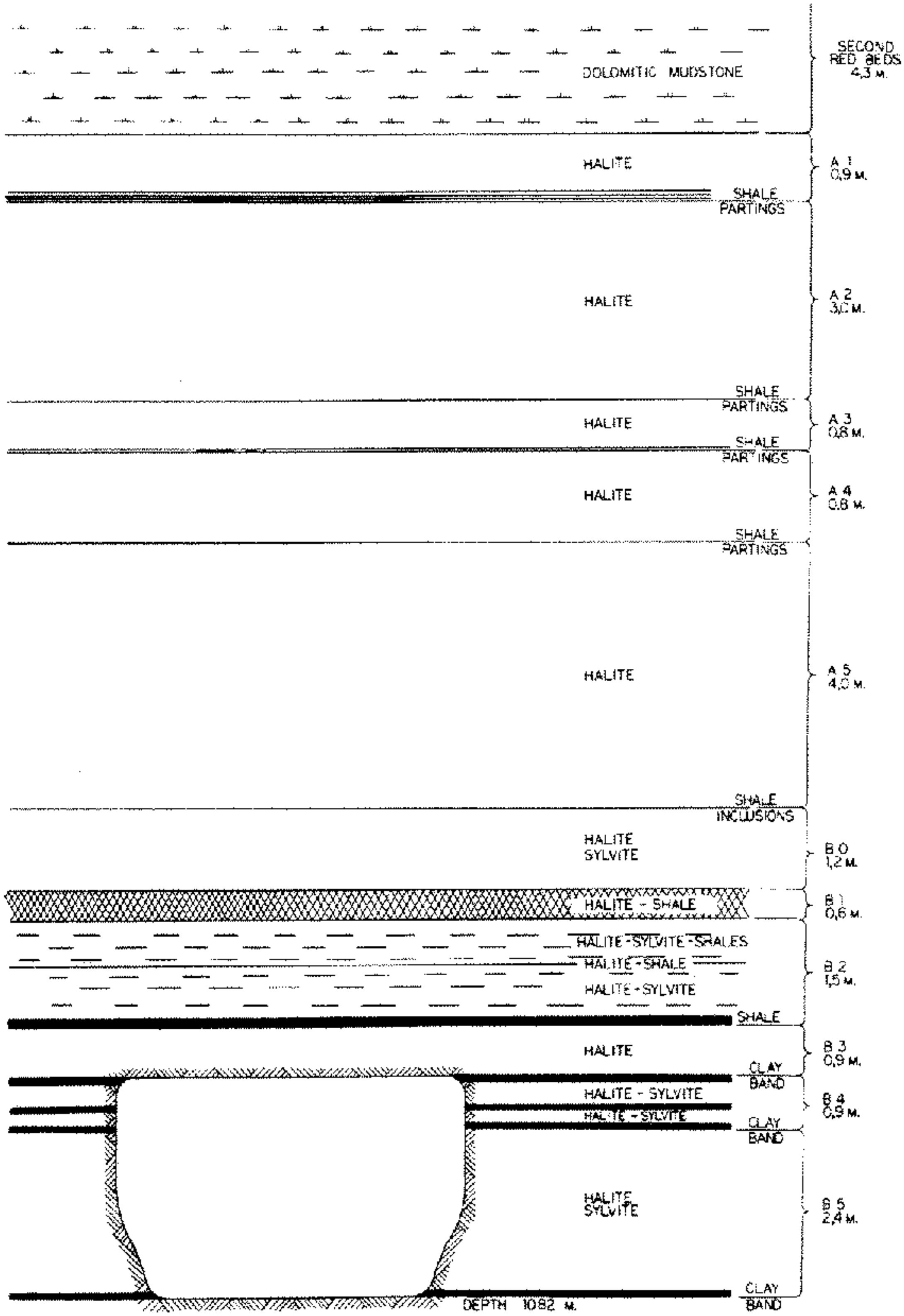

Figure 1. Stratigraphic location of mining zone.

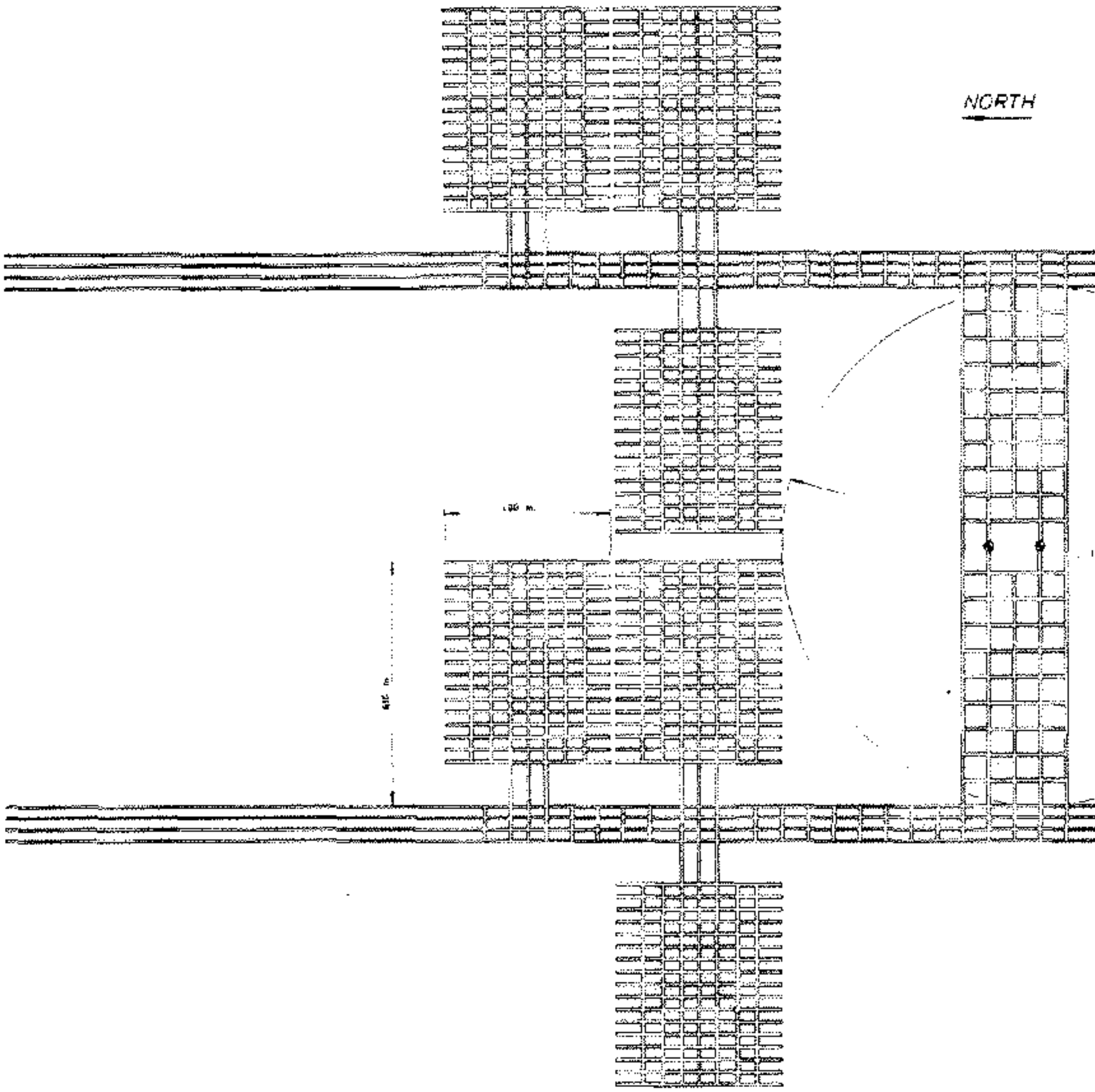

Figure 2. Original plan of room and pillar mining.

the beds immediately above and below the opening. The clay beds act as planes of weakness and because of their low shear strength, speed up the process of roof failure and floor heave. After the B-3 salt bed has failed the stress concentration moves deeper into the roof, causing the successive layers to fail until the solid B-0 salt bed is reached. This bed is strong enough to withstand the side pressure and no more failure occurs.

MAIN ENTRY SYSTEMS

Starting in July of 1969, two separate three-entry relief systems were excavated to test the feasibility of developing stable openings for main entry systems without the expense incurred by going to the B-0 salt bed. A "three entry relief system" consists of two relief drifts and one protected or relieved room. The relief drifts are cut about 15 m apart and allowed to fail. The protected room is then cut between the relief drifts, leaving two small yield pillars. The caved relief drifts isolate the roof beds of the protected room from horizontal stresses which are transferred to more competent beds. The yield pillars allow these competent beds to expand and creep and thus protect the roof in the center drift from caving. The first three-entry systems providing access to the mine were cut in the fall of 1969. The roof of all these entries is still in excellent condition.

A variety of combinations of rooms, size of openings, size of yield pillars and overall span were tested. A continuous analysis of in situ deformation and closure measurements have led to the development of a number of entry systems based on stress relief creep to suit specific operational requirements (Fig. 3).

The systems most extensively used are the "four-entry relief system" for the development of main entry systems and the "five-entry relief system" for section entries. The four-entry system has an overall span of 41 m and provides two protected entries, one for conveyor way and the other

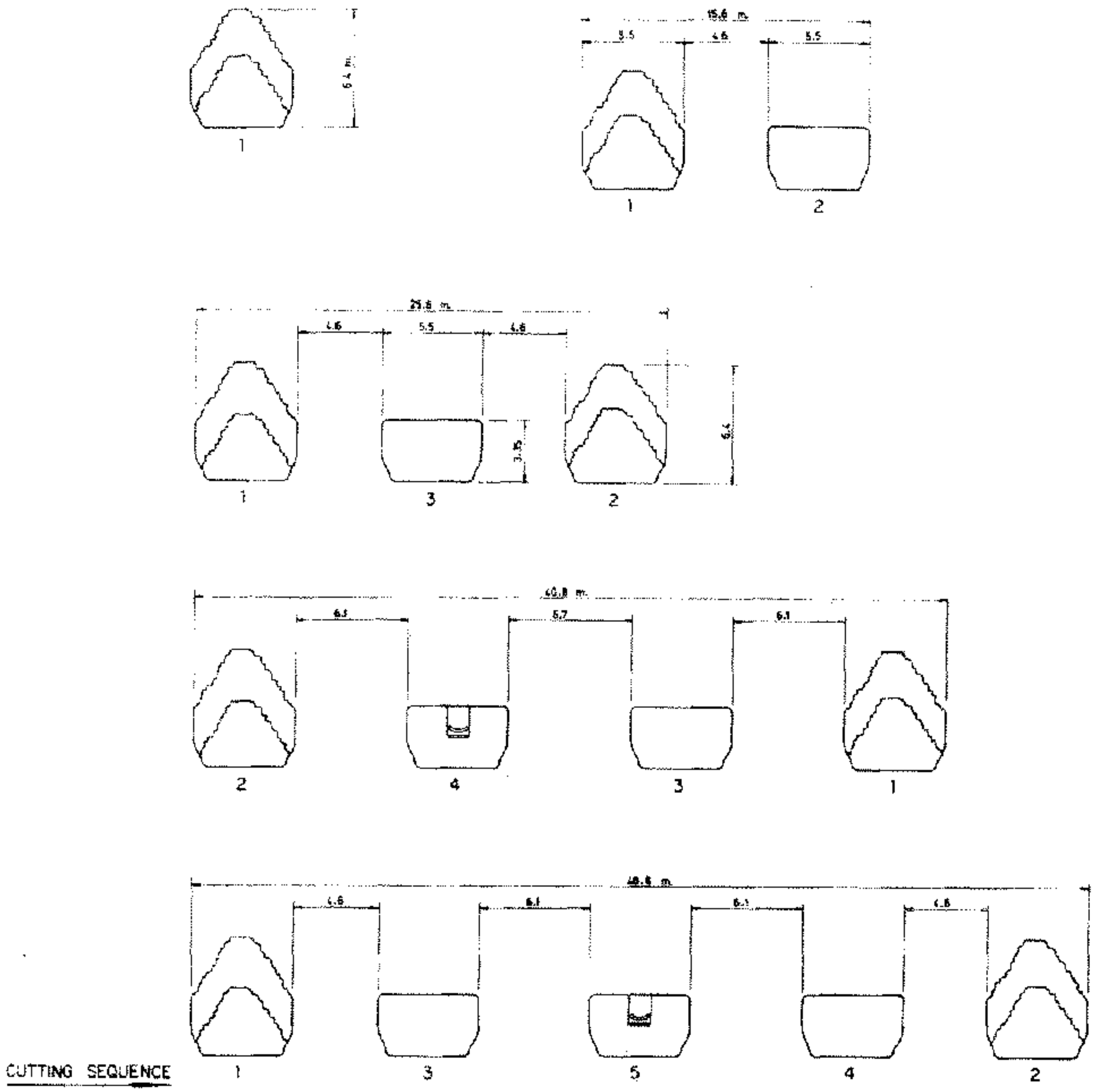

Figure 3. Typical stress relieved systems.

for travel and fresh air supply. The five-entry system has an overall span of 49 m and provides three protected entries. The center entry is used for the conveyor installation with a travelway on either side to provide access and fresh air to mining panels without crossing the conveyor.

Since 1973 all main entry systems have been cut by the Marietta Miner with extensible conveyor haulage. All drifts are single passes and have a width of 5.5 m and a height of 3.35 m. Depending on the general mine layout the length of the drifts varies from 1,200 m to 1,500 m. Three factors are important for the stability of main entry systems based on stress relief creep:

1. The overall span of the system should be between 35 m and 50 m, because wide spans greatly increase the loads which must be supported by the yield pillars and abutments.
2. The size of the yield pillars should be between 6.50 m and 9.0 m. Pillars smaller than 6.50 m will yield under relatively low vertical stresses and do not provide long-term support. They react well in low extraction areas, but are too weak to withstand the effects of loading from adjacent mining, causing excessive room closure. Pillars larger than 9 m are too strong to yield sufficiently to protect the immediate roof beds. A compromise between allowable roof separation and long-term pillar stability must therefore be reached.

3. The elapsed time between cutting the two relief drifts and the protected room is from four months to over a year. It is important to allow the relief drifts to cave and give the stresses enough time to transfer to deeper and competent beds before the protected rooms are cut.

While the roofs of protected entries of all relief systems are excellent, pillar expansion and floor heave create a continuous maintenance problem in main entries.

PANEL AND PILLAR MINING

In panel and pillar mining each of the three Marietta Miners works in a separate section of approximately 1,200 m by 1,200 m. As a rule there are seven panels in a section. Panels generally consist of five rooms and four narrow yield pillars. When mining activities in a room are completed, the room is allowed to fail. The pillar between neighboring panels is ± 50 m wide (Fig. 4).

Until now each section has been accessible through a four-entry system. The two protected entries serve as travel and conveyor ways and for fresh and return air. Originally a 120 m wide barrier pillar was created to protect the section entry system. From the section entry a four-entry and a two-entry relief system were utilized for access, conveyorway and ventilation for a mining panel. However, it was soon found that the load from mined-out panels affected the section-entry system. The barrier pillars have since been eliminated and the panels are now cut directly off the sec-

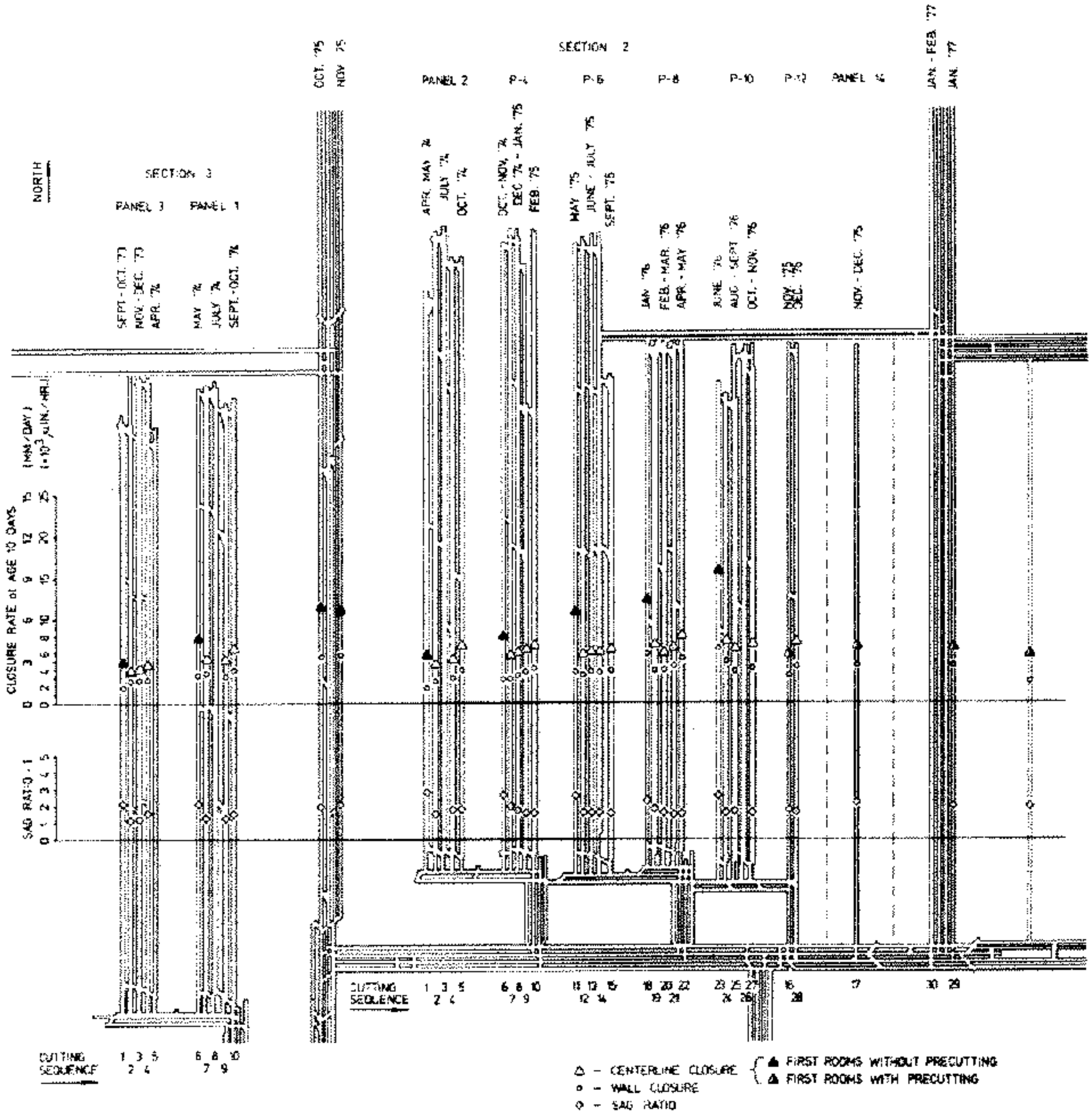

Figure 4. Panel and pillar mining. Total closure rates in Block 1, Section 2 and 3.

tion entries. Without the barrier pillar, the section-entry system stands up well for the duration of mining activity which is about 3 to 4 years.

Due to the machine configuration, mining is done from the left to the right. Rooms 1,200 m in length are excavated with continuous borers and extensible conveyors at an average advance rate of 110 m per day for first pass and 180 m per day for second pass. Because unprotected openings fail rapidly, first rooms are always cut as single passes 5.5 m wide and 3.35 m high and the mining equipment is retreated when the room has been completed to 1,200 m. Stress relief creep causes the redistribution of loads and as the rock yields and the stress peak moves away from the opening, the stress gradient is reduced.

Separated by a small pillar 6–8.5 m wide, a second room can now be excavated in the stress relieved zone. At this point caving has usually taken place in the first room and the roof beds of the second room are now protected on one side from horizontal stresses. On completion of the first pass in the second room, the mining machine is turned around and in retreat cuts a second pass, widening the room to 9.75 m. Soon after its completion, roof beds in the wider room begin separating and failing.

A third, fourth and fifth room is cut similarly in double pass. Thus, a completed panel consists of five rooms separated by small yield pillars with a width of 6–8.5 m. Separating the panels are support pillars 45–60 m wide. Room stability is judged by visual observation and by evaluating vertical closure rates. Development of cracks is an indication of roof failure. Since the rooms are widened in retreat it is possible to shorten conveyors if necessary and to remove any equipment from areas that may fail. This happens frequently in the fourth and fifth rooms of a panel. Continuous observation of roof conditions is essential to ensure a safe operation.

Vertical closure is measured in the center of the room and also close to the wall. The ratio of the closure rates along the center-line as compared to those along the wall is called "sag ratio" and indicates the degree of bending in the immediate roof beds. Because of the rapid advance of the mining machines, all closure and sag ratios are compared at a room age of ten days. Based on creep measurements the stress development over a mining area can be seen in Table 1 and Figure 4.

The first room of the first panel in a production area closes and fails following creep curves typical of openings in virgin ground, with rates of 3.04 mm per day and 1.35 mm per day respectively, along the center-line and wall. In the second room the center-line rate drops by 18% whereas the pillar rate increases by 27%, indicating the formation of a yielding pillar. In the third, fourth and fifth rooms, closure rates increase progressively with panel width, and in the fifth room center-line rates are frequently higher than corresponding rates in the first room. However, the sag ratio is much lower in the fifth room, showing that it is still protected by the caving of previous rooms.

Closure rates in the first rooms of the second and subsequent panels show a marked increase over the rates in the first rooms of the first panel. They follow an almost straight line, indicating the transfer of stresses further into the ground as the width of the mining area increases. The center-line closure rate in the first room of panel 10, for example, shows an increase of 179% over the comparable rate in Panel 2. These increased loads create additional problems as they lead to accelerated wall slabbing and premature roof failure.

To effectively eliminate the problems associated with cutting in high stress areas, precutting of all first rooms was introduced and since May of 1975 most first rooms in a mining section have been precut in virgin ground.

Figure 5 shows the stress development in section 2, which is located 2,000 m from the mining area discussed above. Here the B-3 salt bed is generally thinner and roof failure occurs sooner. Because abutment loads are transferred over large distances, it has not been possible to complete all first rooms to their planned length. However, all semiprotected rooms have been completed as planned, although it has been necessary to shorten conveyors frequently on second pass due to roof failure.

In order to provide a rock mechanics measuring station in

TABLE 1

Vertical Closure Rates at Age 10 Days in MM/Day Block 1, Section 2

	Room 1		Room 2		Room 3		Room 4		Room 5	
Panel	CL	W	CL	W	CL	W	CL	W	CL	W
2	3.53	1.28	2.86	1.79	—	—	3.41	2.01	4.26	2.47
4	4.87	1.76	3.53	1.88	3.71	2.19	3.96	2.43	4.26	2.62
6	6.76	2.56	3.65	2.19	3.77	2.43	3.77	2.37	3.90	2.43
8	7.68	3.65	4.26	2.43	3.65	2.56	4.02	2.74	4.87	3.35
10	9.87	3.96	4.63	3.04	3.96	2.37	—	—	4.14	2.56
12	3.65	2.07	4.38	2.68	—	—	—	—	—	—
14	4.02	1.82	—	—	—	—	—	—	—	—
16-4	—	—	—	—	—	—	4.02	2.19	—	—
18	3.53	1.64	—	—	—	—	—	—	—	—

Refer to Figure No. 4
CL = Centerline Closure W = Wall Closure

TABLE 2

Vertical Closure Rates at Age 10 Days in MM/Day Block 1, Section 3

	Room 1		Room 2		Room 3		Room 4		Room 5	
Panel	CL	W	CL	W	CL	W	CL	W	CL	W
3	3.16	1.43	2.68	1.91	2.74	1.95	3.04	1.82	—	—
1	4.87	2.19	3.16	2.25	—	—	3.22	2.25	4.08	2.55
1103	7.19	3.50	—	—	—	—	—	—	—	—
1100	7.00	3.53	—	—	—	—	—	—	—	—

Refer to Figure No. 4
CL = Centerline Closure W = Wall Closure

TABLE 3

Vertical Closure Rates at Age 10 Days in MM/Day Block 3, Section 2

	Room 1		Room 2		Room 3		Room 4		Room 5		Room 6	
Panel	CL	W	CL	W	CL	W	CL	W	CL	W	CL	W
14	2.43	1.33	2.31	1.58	—	—	2.74	1.64	2.15	1.39	—	—
12	4.41	1.61	3.16	1.76	3.16	1.79	3.41	2.07	3.41	2.25	—	—
10	7.09	2.26	3.41	2.07	—	—	3.89	2.83	4.26	2.37	2.07	1.30
8	5.78	2.31	4.26	2.31	2.61	1.70	2.49	2.07	12.78	3.47	—	—
6	5.72	1.94	5.17	2.98	3.16	2.07	3.16	1.94	3.65	2.19	—	—
4	10.35	3.65	4.26	2.43	—	—	3.22	2.16	4.56	3.34	—	—
2	7.91	3.95	4.56	2.43	—	—	6.09	2.22	3.65	2.19	—	—

Refer to Figure No. 4
CL = Centerline Closure W = Wall Closure

the center of this mining section, an attempt was made to excavate panel No. 8 in the fashion described for main entry systems, with rooms 1 and 5 being cut as relief entries and 2, 3 and 4 forming protected entries. This cutting sequence explains the very high closure rates and premature failure of room 5 in panel 8.

In some of the other panels interruption of the normal cutting sequence was caused by changes in production requirements and by vacation shutdowns. The high closure rates in the first rooms of panels 6, 4 and 2 are partially due to a high stress concentration caused by the previously mined panels and partially by additional floor heave because of the thinness of the potash seam in this area.

By November, 1977 all five-room panels in this section had been completed. An analysis of all rock mechanics data collected in the area showed that additional rooms could be cut in the pillars between the mined out panels, if located in the stress relieved zone immediately adjacent to older panels. Because of conveyor availability and elapsed time considerations, the first sixth room was cut in panel 10. As expected the closure rate (of 2.07 mm per day at 10 days) was extremely low and wall and roof conditions were excellent. However, shortly after cutting had started, minute amounts of brine seepage occurred throughout the room causing great concern until an analysis of the solution showed it to have a high content of $MgCl_2$ and its presence could be explained as caused by metamorphosis. As there has never been a trace of moisture encountered in this section during the four years of mining, it can be concluded that the high pressure concentration in the support pillar has forced residual brine to migrate to the areas of low stress near room 5.

The cutting of additional rooms in the pillars between mined-out panels is now in progress. The stress development in the support pillar between two panels is shown in Figure 6. The steep stress gradient formed immediately after completion of room 5 flattens in a period of two years as shown, and makes it possible to excavate Room 6 in relaxed ground.

EQUIPMENT DEVELOPMENT

The original selection of mining equipment was done with room-and-pillar mining in mind, employing continuous miners, gathering-arm loaders and haulage trucks. The three 911A Marietta Borers were complemented with three 968 Goodman gathering-arm loaders, four diesel-driven Wagner Teletrams (18 t capacity), four battery-operated Jeffrey Ramcars (22 t capacity), three N.M.S. feeder breakers and a number of panel and main line conveyors.

The severe ground conditions did not only lead to a change from the conventional room-and-pillar mining system to one which takes advantage of stress relief creep in both main entry systems and in panel mining as already described, but also necessitated major modifications on the continuous borers and significant changes in the method of ore haulage.

On the miner the top cutting bar was extended to allow a

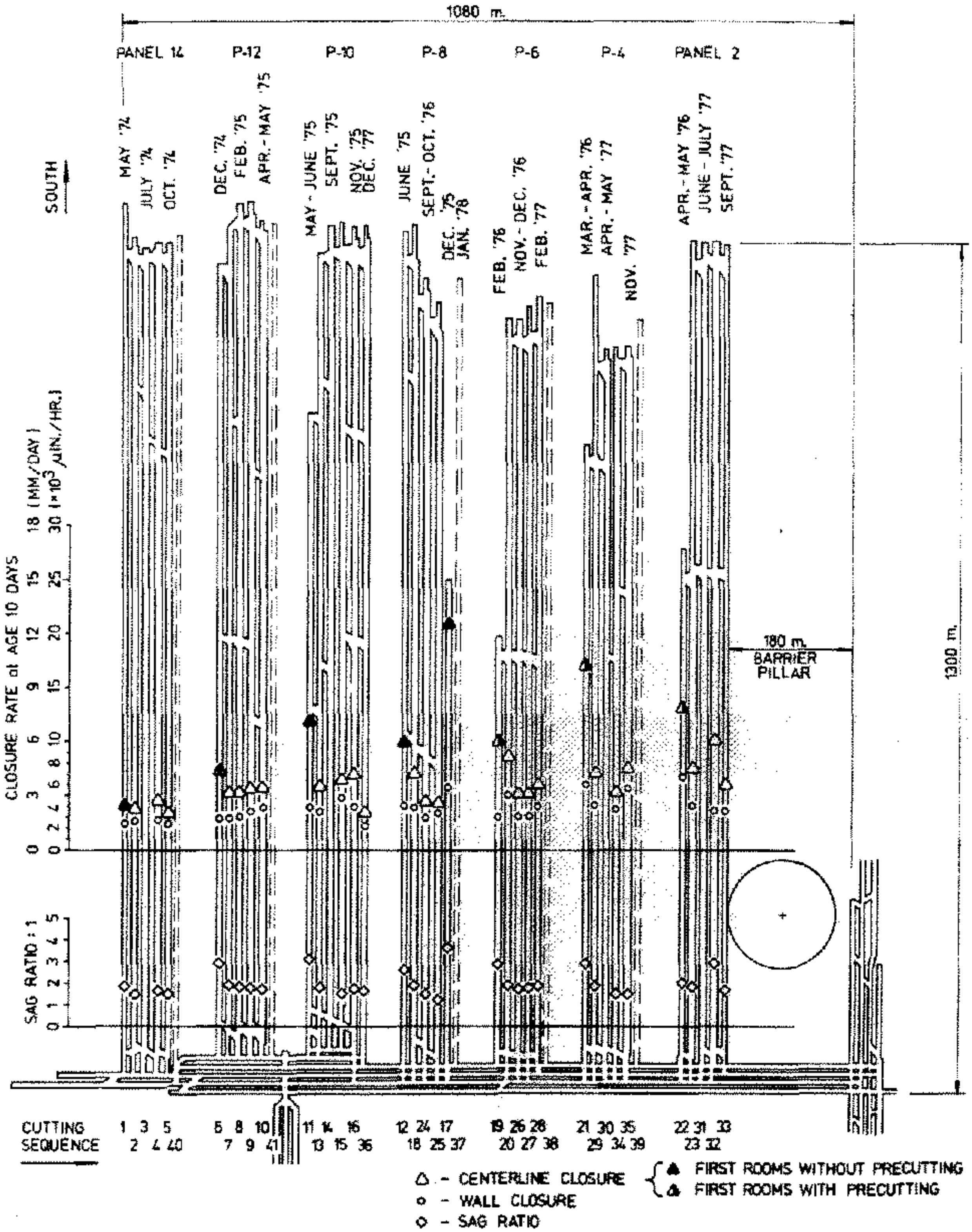

Figure 5. Panel and Pillar mining. Total closure rates in Block 3, Section 2.

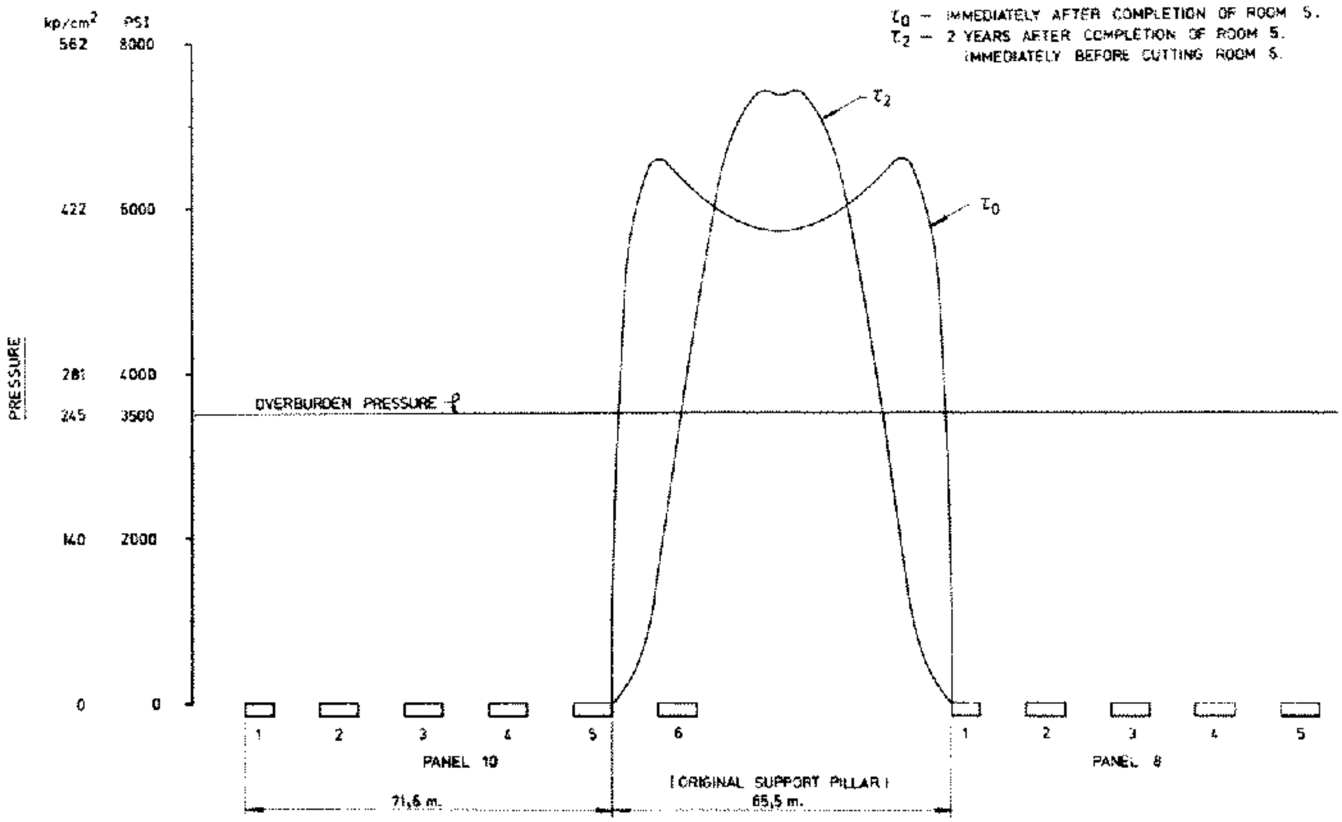

Figure 6. Stress distribution in a support pillar between two panels.

change from the original round cutting profile to a right angle corner configuration, which reduced slabbing from the B-4 section.

To meet high tonnage requirements in a relatively narrow heading, an extensible conveyor system was developed. The hardware components had to be light weight, strong and suitable for quick extension or retreat. The system had to withstand floor heaves, yet be floor mounted. It had to be practical for use in single passes as well as for cutting second passes in retreat when teamed with the bridge conveyor breaker.

The extensible conveyors now operating are primarily of Cominco design, incorporating manufactured components whenever they were suitable and readily available.

A distance of 65 m is required to set up a boring machine with continuous extensible conveyor haulage. The equipment consists of a continuous miner, a bridge breaker, an idler discharge skid, a belt cluster and the conveyor drive. This distance is cut with the miner and the ore is removed by truck haulage (Fig. 7, 8).

The cutting is done with the Marietta 911A continuous miner, which was manufactured by the National Mine Service Company of Pittsburg, Pa., USA. It is a self-propelled, continuous two-rotor boring machine, weighing 175 t, electrically operated at 4160 volts and a total installed power of 900 KW for two 375 KW cutting motors and one 150 KW motor which drives the hydraulic pumps. The two rotors are equipped with both tungsten carbide cutting bits and core breakers for penetration; a continuous trim chain cuts a smooth roof and floor to create an opening 5.5 m wide and 3.35 m high.

The continuous borer pulls a bridge conveyor-breaker and an idler discharge skid, both designed and built at the minesite. From the boring machine the ore is discharged into the bridge breaker where large lumps are reduced for easier conveyor handling. The bridge conveyor-breaker weighs 15 t and has two 4160 Volt, 60 KW motors for the crusher and chain conveyor.

The idler discharge skid houses the tail pulley of the extensible conveyor and provides storage room for sufficient conveyor idler stands for a 30 m extension. The idler stands are spaced 2.50 m apart and are pulled off the discharge skid by connecting side rails as the mining unit moves ahead in first pass. Thus, the mining unit can advance for 30 m of continuous cutting.

The continuous miner, the bridge conveyor and the idler skid form one unit which advances at an average rate of 20 cm per minute in first pass. A laser beam provides guidance to keep the mining unit on a straight line. A curtain wall is installed from a stand on the idler discharge skid to separate the exhaust from the fresh air flow.

In preparation for second pass, slashes are cut at the end

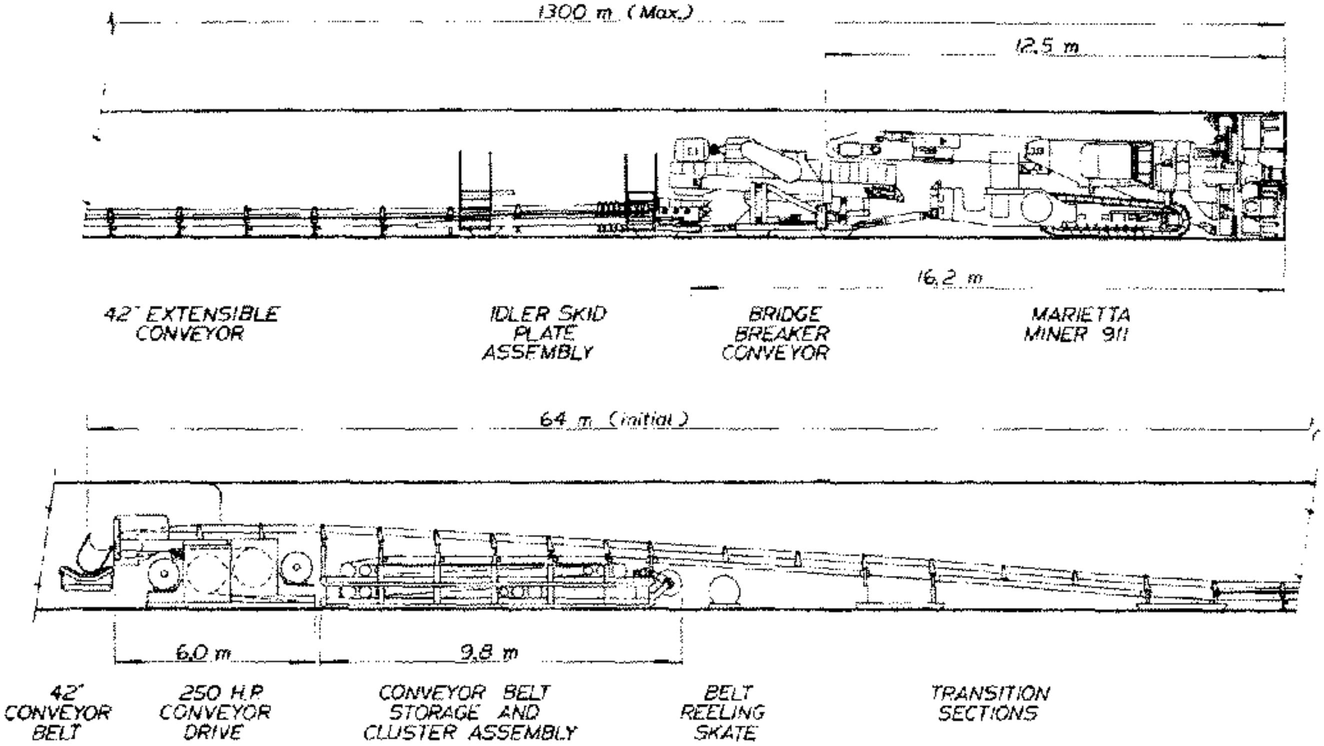

Figure 7. Marietta mining unit.

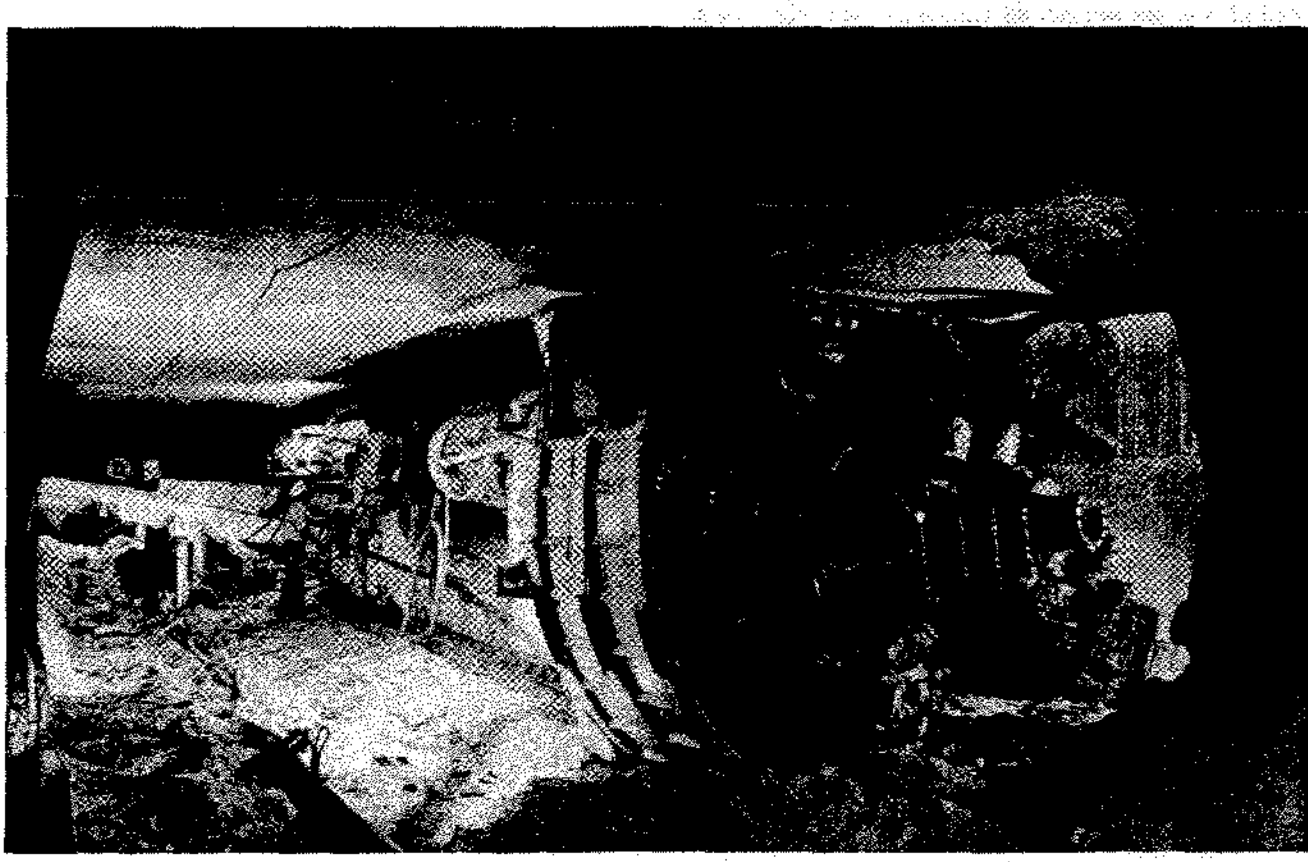

Figure 8. Marietta 911A in second pass.

of the first pass to increase the width of the room sufficiently to allow the boring machine to turn around. The tail pulley is anchored and the bridge conveyor breaker is used as a cross conveyor to move the ore from the miner to the extensible conveyor which, for the duration of second pass cutting, is used as a stationary conveyor.

At the outby end is a belt storage cluster which can hold 60 m of 1,070 mm wide belting. Proper belt tension is maintained with hydraulic cylinders. After every 30 m advance of the mining unit, another 60 m reel of belting is added into the cluster. A double drum conveyor drive equipped with two 100 KW, 550 Volt motors provides power for the extensible conveyor.

MATERIALS HANDLING

Because of the high rate of floor heave, all permanent facilities for materials handling such as conveyor drives, take-ups, intermediate structures and tail pulleys, as well as crushers, are suspended from the roof.

Presently, permanent conveyor installations consist of 5,000 m of main entry conveyors 1,220 mm wide and 9,500 m of section entry conveyors 1,070 mm wide. Including the extensible conveyors, there are presently 6,000 m of 1,070 mm wide floor mounted temporary conveyors in use. All permanent conveyors operate at a belt speed of 3 m per second; all temporary conveyors run at 2.3 m per second.

From the mining face the ore is transported over the extensible belt to a 1,070 mm wide section conveyor and then onto the 1,220 mm wide block and main conveyor to a storage bin which has a capacity of 4,000 t. From there it moves over a reclaim conveyor system, through a crusher to a 450 t surge bin, down to the measuring pockets in the shaft and is finally hoisted to the surface in 22 t skips. The entire ore handling system is automatically interlocked and can be controlled from surface. To avoid transfer points, main conveyors are operated in long flights. The longest conveyor is 3,200 m long and operates as one continuous conveyor with one 200 KW drive at the front, a 100 KW auxiliary drive at 1,050 m and a second auxiliary drive of 200 KW at 2,150 m.

GROUND MAINTENANCE

The exploitation of stress relief creep in main entry systems provides stable roofs in the protected entries. However, pillar expansion can reduce protected openings of 5.5 m to 4.0 m in four years, and floors heave at a much greater rate. To maintain travelways and conveyor entries of sufficient size, a continuous program of wall and floor trimming is in progress, employing 2 Heliminers, 1 Alpine Miner and 2 chain cutters.

The 120 HR Heliminers are drum cutters with a horizontal cutting drum 93 cm in diameter and 3.90 m long. It weighs 60 t and is equipped with two 225 KW, 4,160 Volt motors. The Alpine AM50 Miner weighs 20 t and has a total electrical capacity of 190 KW at 550 Volts.

The chain cutters are used to remove wall slabs and cut slots in the roof. Slotting the roof allows for creep which extends roof life in unprotected and semi-protected areas.

Drilling and blasting is now limited to those relief drift intersections where the opening must be extended to the B-0 section. Wooden cribbings and roof bolts are sometimes installed to provide temporary roof support.

OVERALL PRODUCTION PLAN

Due to double pass cutting and a higher extraction rate, panel mining is more efficient and has a 35% higher output than development mining. Development mining is therefore stressed more in times of low ore demand.

Since October 1975, one Marietta mining unit, and since November 1976 two units, have been employed in the development of main entry systems (development mining) while the third unit was engaged in panel mining. Thus, three new mining sections have been prepared to provide areas sufficient for the next 4 to 8 years' panel mining requirements (Fig. 9).

The first rooms of all panels in the new mining sections are being precut before actual panel mining starts. As the B-3 salt bed in these new areas is more favorable, most first rooms can be precut as double pass rooms.

Each Marietta unit mines its own section; however, two will utilize the same section conveyor in the center room of a 5-entry system. After the completion of all first rooms, the cutting sequence will be in retreat from the end of the section. In order to do this, one miner will be changed to a "left-hand machine" to facilitate cutting from right to left.

Frequently, the uniformity of the ore body is interrupted by disturbances caused by collapsed structures. It is not possible to penetrate these disturbances with the big and heavy Marietta miner. Therefore, whenever a disturbance is encountered in a main entry system, the boring machine is pulled out and the system is completed with the more flexible Heliminer.

A continuous haulage system consisting of 6 mobile bridge conveyors has been developed for ore removal from the Heliminers. Whenever ore requirements are high, one or both Heliminers can be employed in ore production to assist the three Marietta production units.

Using this flexible system our mine can produce a total of 2.5 million t of ore per year with the present mining equipment.

CONCLUSION

The additional depth of about 75 m more than in most other potash mines in Saskatchewan and some differences in the thickness and composition of the shale and halite beds of

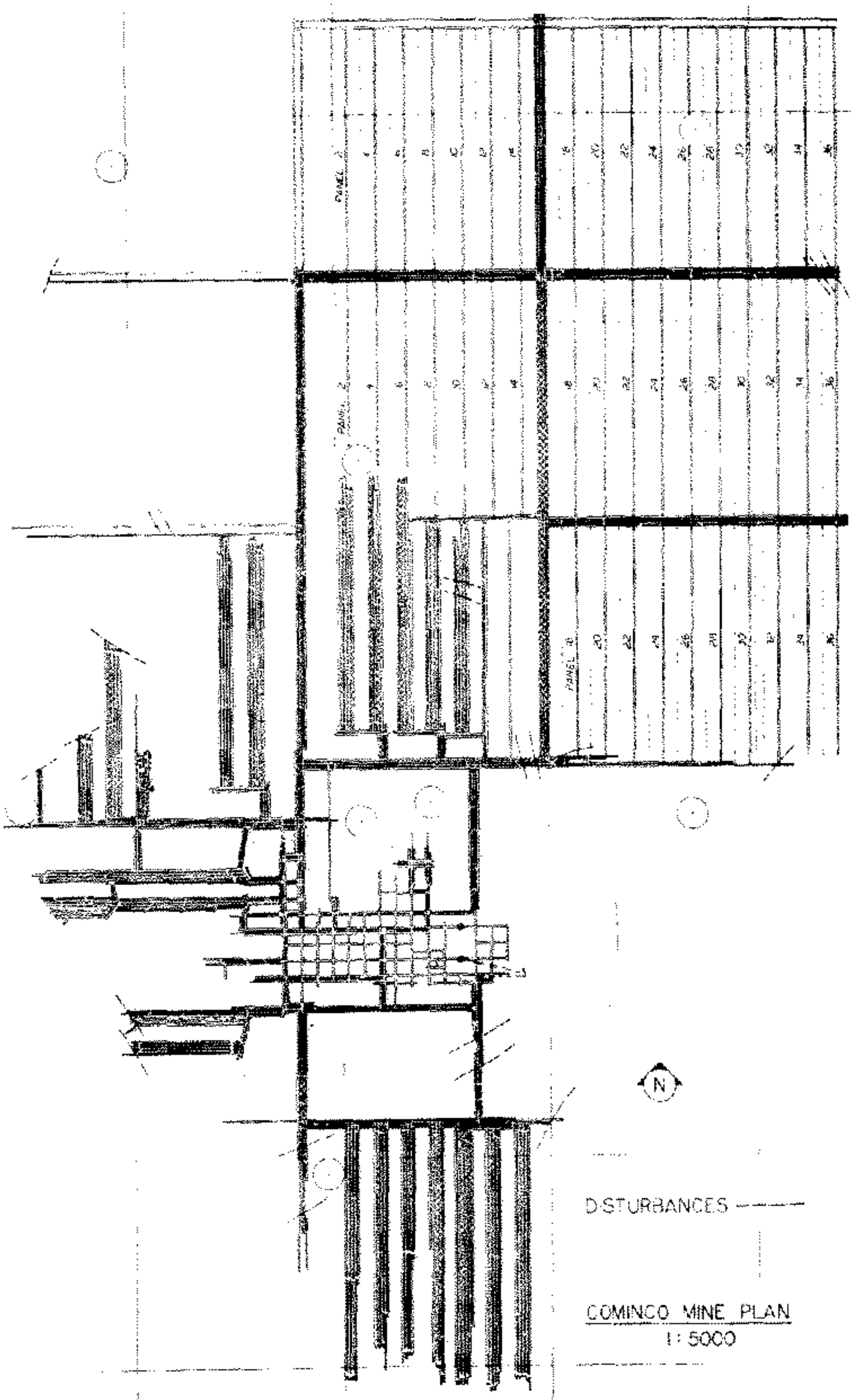

Figure 9. Cominico mine plan.

the immediate roof formations in the Cominco mine, cause quicker reaction of the ground with consequent early roof failures.

It has been possible to take advantage of the specific ground behavior to ensure safe openings for main entries as well as to develop an efficient method of panel and pillar mining.

In main entries, the necessity to live with single pass rooms creates frequent non-productive periods whenever mining equipment has to be retreated after the completion of a room. Furthermore, it is difficult to plan machine cutting in such a way as to allow sufficient time for the relief drifts to cave before the protected entries are excavated.

In panel and pillar mining it is very important to complete a room in the shortest time possible. Generally, the rapid advance of a maximum 75 m in first pass and 125 m in second pass during an 8-hour shift, with the continuous miner and the extensible conveyor system, accommodate this requirement very well. Lengthy delays require the installation of wooden cribbings for temporary support and may cause the loss of the room.

The continuous, vigilant observation of the roof conditions, as well as careful planning and co-ordination of the process of setting up and cutting with the three Marietta production units, is the key to a safe and efficient operation.

To help ensure mine safety, we have an ongoing seismic program to indicate variations in the thickness of the Prairie Evaporite formation and irregularities of the formations below and above, and which also suggests the possible existence of disturbances in the ore bed.

Constant observation and evaluation of ground behavior and ground reaction is the most important aspect of our overall mine planning and also of the day-to-day operation of the mine. A rock mechanics program based on the measurement of convergence in mine openings, pillar expansion, pillar stress and surface subsidence is the means by which this is achieved, and is also the guideline by which the maximum safe extraction rate is determined.

DISCUSSION

Comment by Dr. Shosei Serata, Serata Geomechanics, Inc., USA.

I would like to make the following comments as the person responsible for introducing the Stress Control Methods to the Cominco Mine:

1. **Applicability to other mines.** The Stress Control Methods should be applicable to other underground mines; not only to salt and potash mines, but also to hard rock mines.
2. **Method of application.** The same mine layout and cross-sectional dimensions of the Cominco Mine may be successfully applied to other salt and potash mines provided that the Cominco's cross-sectional designs are adjusted in proportion to each individual mining height. This means that application of the Methods to another mine with a mining height twice as large requires an increase of the pillar and room dimensions by a factor of 2.
3. **Modification.** In order to adapt the Stress Control Method most successfully to a wide variation of underground conditions, more than ten different types of design layout have been developed and field tested. The modification is based on adjusting the following fundamental design factors of room width, pillar width, pattern arrangement, and time delay in cutting sequence.