EEG-25

OCCURRENCE OF GASES IN THE SALADO FORMATION

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FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the proposed Federal radioactive Waste Isolation Pilot Plant (WIPP) near Carlsbad, in order to protect the public health and safety and ensure that there is minimal environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department -- the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP.

Analyses are conducted of available data concerning the proposed site, the design of the repository, its planned operation, and its long-term stability. These analyses include assessments of reports issued by the U.S. Department of Energy (DOE) and its contractors, other Federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP.

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INTRODUCTION

The impetus for this study was provided by a recent series of incidents at the Kerr-McGee mine near Carlsbad, New Mexico. On December 13, 1983, a miner operating a continuous mining machine apparently hit a pocket of trapped, pressurized gas. The sudden release of pressure from this gas pocket caused the gas to expand. This resulted in dislodging of rock and debris and loose fixtures on the mining machine. According to a preliminary investigation by MSHA, "The operator of the continuous miner was apparently killed as a result of being struck by a light fixture which had been torn loose from the continuous miner and hurled back into the victim's face." (See Appendix A, p. 34.) Two more incidents, fortunately non-fatal, within a 5 week period in the same mine have resulted in a concern about the possibility of the occurrence of such blowouts in the WIPP excavations. The blowouts occurred 9 miles north of the center of the WIPP site in a geological strata which is 660 ft above the excavations for the WIPP repository.

U. S. Mine Safety and Health Administration (MSHA) and N. M. Inspector of Mines Department are investigating the Kerr-McGee blowouts. Officials of the Kerr-McGee mine are conducting their own investigations with the help of consultants of the causes of these occurrences and to make the mining operations safer. This study (EEG-25) uses the reported encounters of gas in the potash mines as well as the studies related to the WIPP project as valuable information to reach some tentative conclusions about the possibility of such a hazard existing at the WIPP excavations. The conclusions of this study do not relate specifically to the safety conditions at any given mine and make no judgements about incidents in the mines.

Factual information provided by the officials of the Kerr-McGee mine, N. M. Inspector of Mines and U. S. Mine Safety and Health Administration (MSHA), is gratefully acknowledged.

GEOLOGY OF THE SALADO FORMATION

The WIPP site and all the potash mines in the vicinity are situated in the Delaware Basin in Southeastern New Mexico. The Salado Formation is a part of about 10,000 ft of sediments deposited under marine conditions in this basin during the Permian period (>225 million years ago). Initially deposition in the basin was bounded by the Capitan Reef. By late Permian, the basin had filled and the saline water spilled over to the north and east covering a large area now known as the Permian Basin. Evaporation at the surface of this shallow sea under arid conditions resulted in the precipitation of salts, mainly halite which accumulated over a period of time. The formation resulting from this process is called the Salado.

The Salado Formation varies in thickness but at the WIPP site and the potash mines, it is about 2000 ft thick. The Salado consists mainly of Halite (NaCl) and other salts including polyhalite [$k_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$], glauberite ($Na_2SO_4 \cdot CaSO_4$), sylvite (KCl), Kainite ($KCl \cdot MgSO_4 \cdot 3H_2O$) Carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$), Langbeinite [$K_2Mg_2(SO_4)_3$] and kieserite ($MgSO_4 \cdot H_2O$) as well as layers of clastic rocks and anhydrite. Beds locally rich in potassium minerals, primarily sylvite, carnallite and langbeinite, are mined from the McNutt Potash Zone located in the middle part of the Salado Formation. Other than the presence of potassium and magnesium rich minerals, the McNutt zone is similar in all other aspects to the rest of the Salado.

Using the remarkable continuity of individual beds in the Salado, the U. S. Geological Survey (Jones, 1960, 1973) has developed a system of identifing the stratigraphic location within the formation by designating 43 individual seams of anhydrite and polyhalite as numbered "marker beds." The first continuously identifiable bed of polyhalite, 120 feet below the top of Salado (at the WIPP site), is designated MB 101. The lowest marker bed (MB 144) consists of a bed of anhydrite in the lower part of the formation, 336 feet above the base of Salado at the WIPP site center. The proposed repository for WIPP is located between M.B. 138 and M.B. 139 in the lower part of Salado (Fig. 1).

Thousands of feet of drill cores and geophysical logs of boreholes in the northern Delaware Basin have been closely examined and correlated in connection with the site selection and characterization for the WIPP project. This study

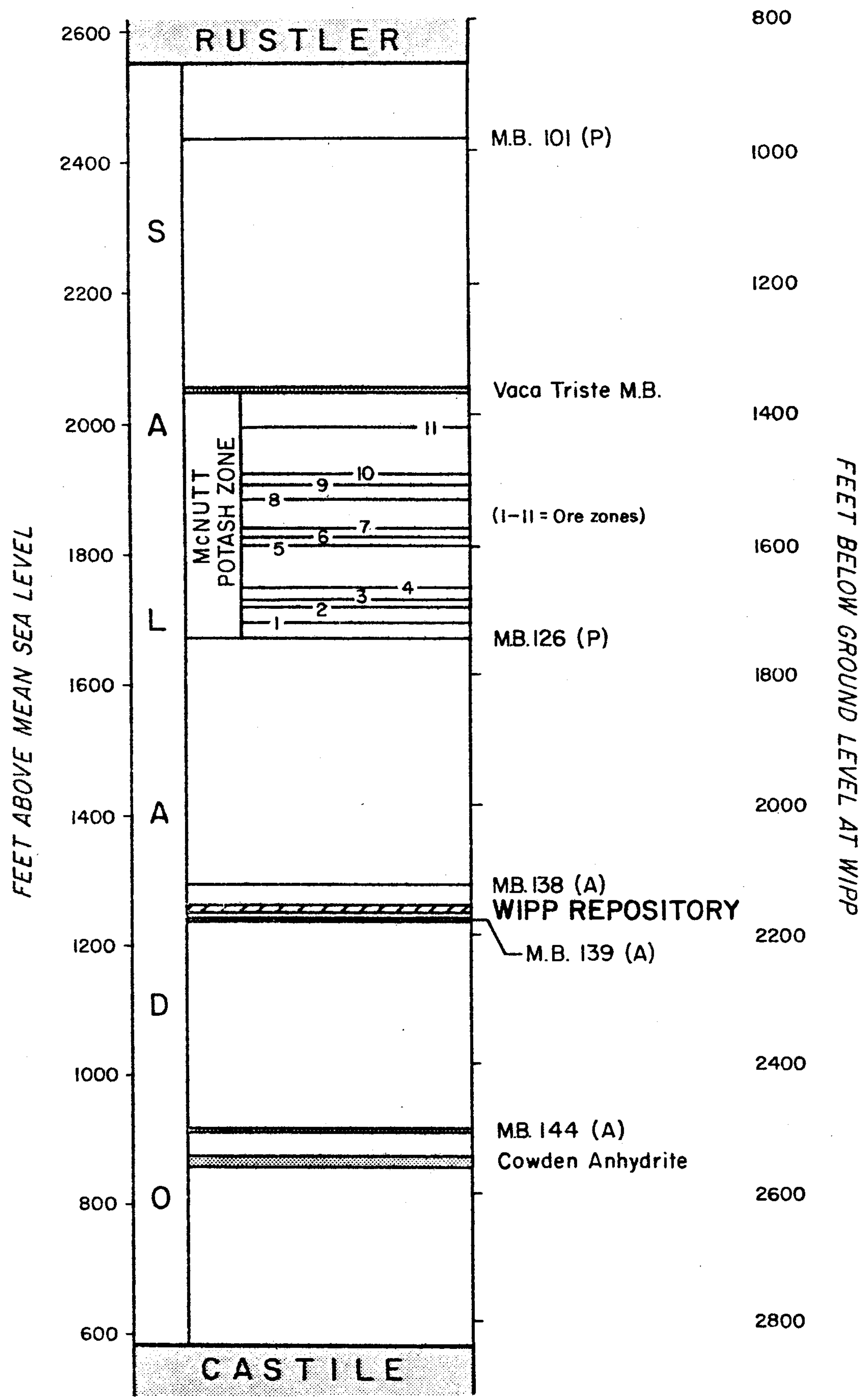

Figure 1. Details of the stratigraphy of the Salado Formation showing the locations of the marker beds, ore zones and the WIPP repository. P = Polyhalite, A = Anhydrite

has shown that the deposition of the Salado Formation followed a cyclic pattern (Powers, et al, 1978). Each cycle consists of a layer of clay at the base followed by anhydrite or polyhalite and halite. The halite becomes more argillaceous as one proceeds upward. The cycle is finally capped by claystone and another cycle commences. This sequence is repeated several times as one studies the formation from the bottom to the top. The clay layers are thought to result from dissolution of clayey halite by inflowing sea water and thus each cycle probably represents a fresh influx of sea water in the evaporating pan. The beds of anhydrite ($CaSO_4$) and thick deposits of halite (NaCl) represent long periods of evaporation from a progressively concentrated sea water under very arid conditions. Rock salt constitutes about 85-90 percent of the Salado Formation.

Jones (1973) has provided a detailed study of the lithology of the Salado formation. According to him, the entire Salado Formation basically consists of alternating thick seams of rock salt and thinner seams of anhydrite and polyhalite. In this manner, the McNutt potash zone is very similar to the upper and the lower Salado. The potassic minerals at best comprise only 3 to 5 percent of the McNutt zone in the most potassium-rich sections of the northern Delaware Basin.

Figure 1 shows the details of the Salado stratigraphy as observed in borehole ERDA-9 at the center of the WIPP site. Locations of several important marker beds, the 11 ore zones within the McNutt potash member and the WIPP repository horizon are shown.

PHYSICAL CHARACTERISTICS OF GAS OCCURRENCE

Existence of gas pockets is a common feature of the evaporite deposits. In the potash mines of the Delaware Basin minor "poofs" of gas outburst is a common phenomenon. Several large blowouts have been reported from the potash mines, some of which have resulted in fatalities. Table 1 summarizes the reported incidents of gas blowouts in the potash mines near WIPP during the past 10 years. The incidents have been reported from (1) Kerr-McGee mine located 9 miles north of WIPP, (2) Duvall-Nash Draw mine located five miles west of WIPP and (3) Eddy mine of the National Potash Co., located 17 miles northwest of WIPP. Figure 2 shows the locations of these mines and the WIPP site. The following is a description of the reported incidents in the three mines.

Kerr-McGee Potash Mine - 1983, 84

The approximate boundary of the Kerr-McGee Chemical Corporation mine is shown in Figure 2. The author visited the mine on February 1, 1984.

The first of the three most recent reported incidents in this mine occurred on December 13, 1983 at 4:27 a.m. The mine level is in ore zone #10 (see Fig. 1) approximately 1600 ft below the ground level. The incident occurred in Area 169 in the southern part of the mine (Fig. 2). Figure 3 shows the exact location of the blowout.

A continuous mining machine was being used to cut the 6 ft high and 27 ft wide room. The mining was heading south when a gas outburst occurred in the upper right side of the indented working face. An estimated 8 tons of ore was dislodged out as a result of the outburst. Figure 4 is a photograph of the 9 ft long, 5 ft high and 2.5 ft deep cavity formed as a result of this outburst. Large boulders, weighing up to 500 lbs. were ejected up to 60 feet from the mine face. The operator of the continuous miner was killed and a shuttle car operator who was standing near his machine behind the continuous miner was injured by flying rock pieces. The blowout left an open fracture 1/4" to 1/2" wide, oriented S58°E. This fracture can be seen across the 27 ft wide room along the back (ceiling) and 2 ft down from the back in the eastern wall of Room 1 (Figures 5 and 6). Air samples from the open fissure

Table 1. Reported Major Pressurized Gas Encounters in the Potash Mines Near the WIPP Site

Date	Mine	Location	Brief Description
Jan. 23, 1984	Kerr-McGee	10th ore zone, Area 169, Room 5 (N-S).	The mining machine moved back about 2 ft as a result of the blast. About 2 tons of debris was produced. Near vertical open fracture trending 110° Figs. 2 and 3. No fatality. Minor injuries.
Dec. 19, 1983	Kerr-McGee	10th ore zone, in a N-S tending room in Area 160.	Blowout was associated with a vertical fracture trending 125°. Fig. 2.
Dec. 13, 1983	Kerr-McGee	10th ore zone, Area 169, Room 1.	The mining machine was found 25 ft away from the face where blowout occurred. Estimated 15 tons of ore was dislodged. A cavity about 60 ft^3 in volume was formed. Vertical fracture trending 122°. One fatality. Figs. 2 and 3. MSHA report dated 1/16/84 (App. A).
March 1976(?)	Duvall Nash Draw	Sylvite level (10th ore zone?)	MESA (Precursor of MSHA) Report dated 4/7/76 (App. B). Roof fall (48'x32'x5'), 180 tons of material, caused by trapped gases above the roof. One fatality due to suffocation.
Nov. 27, 1974	Eddy Mine Nt'l Potash Co.	North Pillar Section	State Inspector of Mines report dated 11/27/74 (App. C). Roof fall with strong sudden air-blast. One serious injury and seven lost-time injuries.
Dec. 16, 1973 to Feb. 24, 1974	Eddy Mine Nt'l Potash Co.	North Section	State Inspector of Mines reports dated 4/18/74, 2/25/74, & 12/20/73, (App. C). Release of trapped gases with a floor break on 12/16/73. One sample from a floor bleeder contained 12% oxygen and 16% methane. On 2/24/74, an area of bottom approx. 230 ft x 230 ft fell 30 to 40 ft down after release of gas. A section of roof, 6 to 8 ft thick also fell near the center of the area of floor fall.

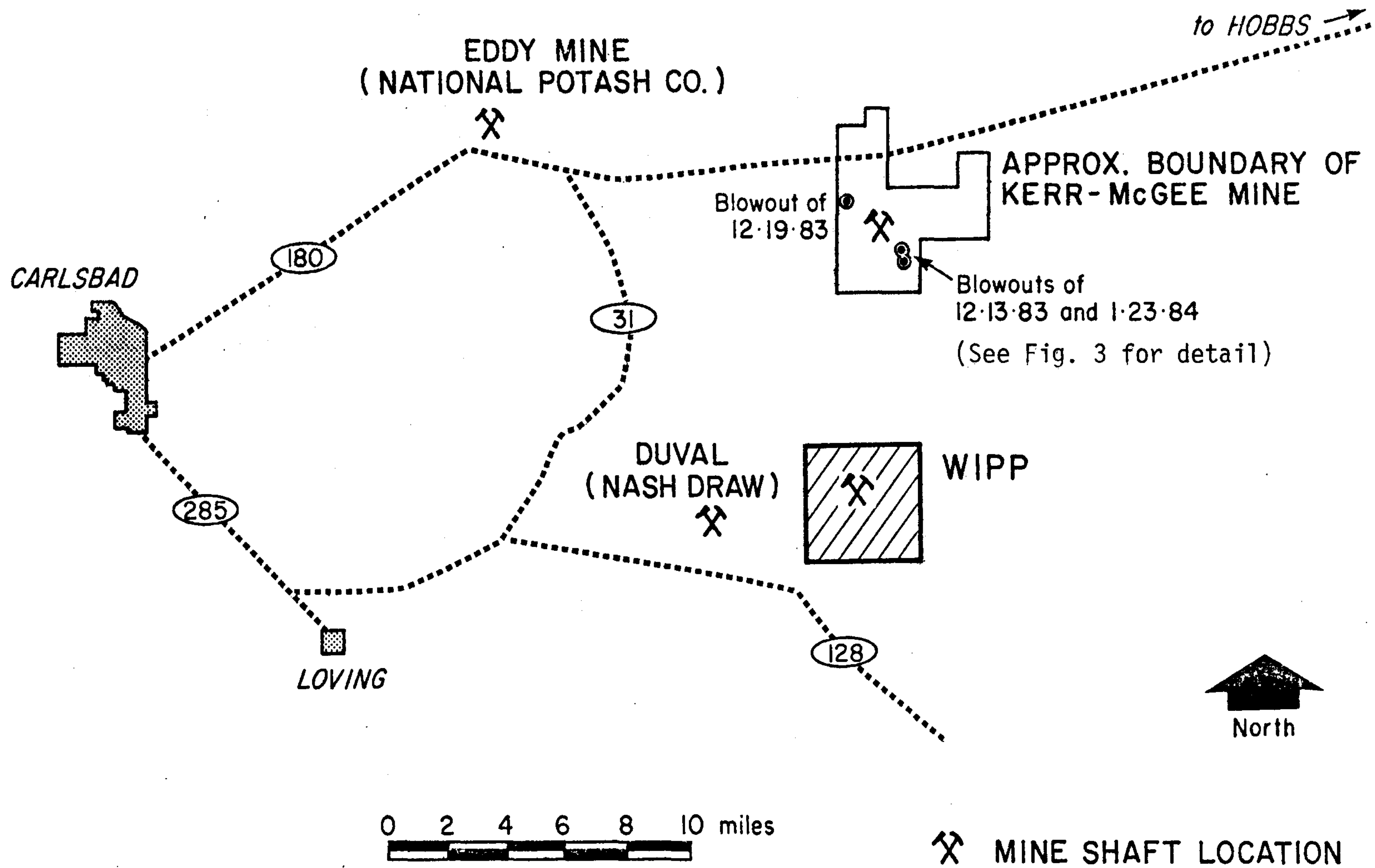

Figure 2. Location of the WIPP site and potash mines where gas blowouts have been documented.

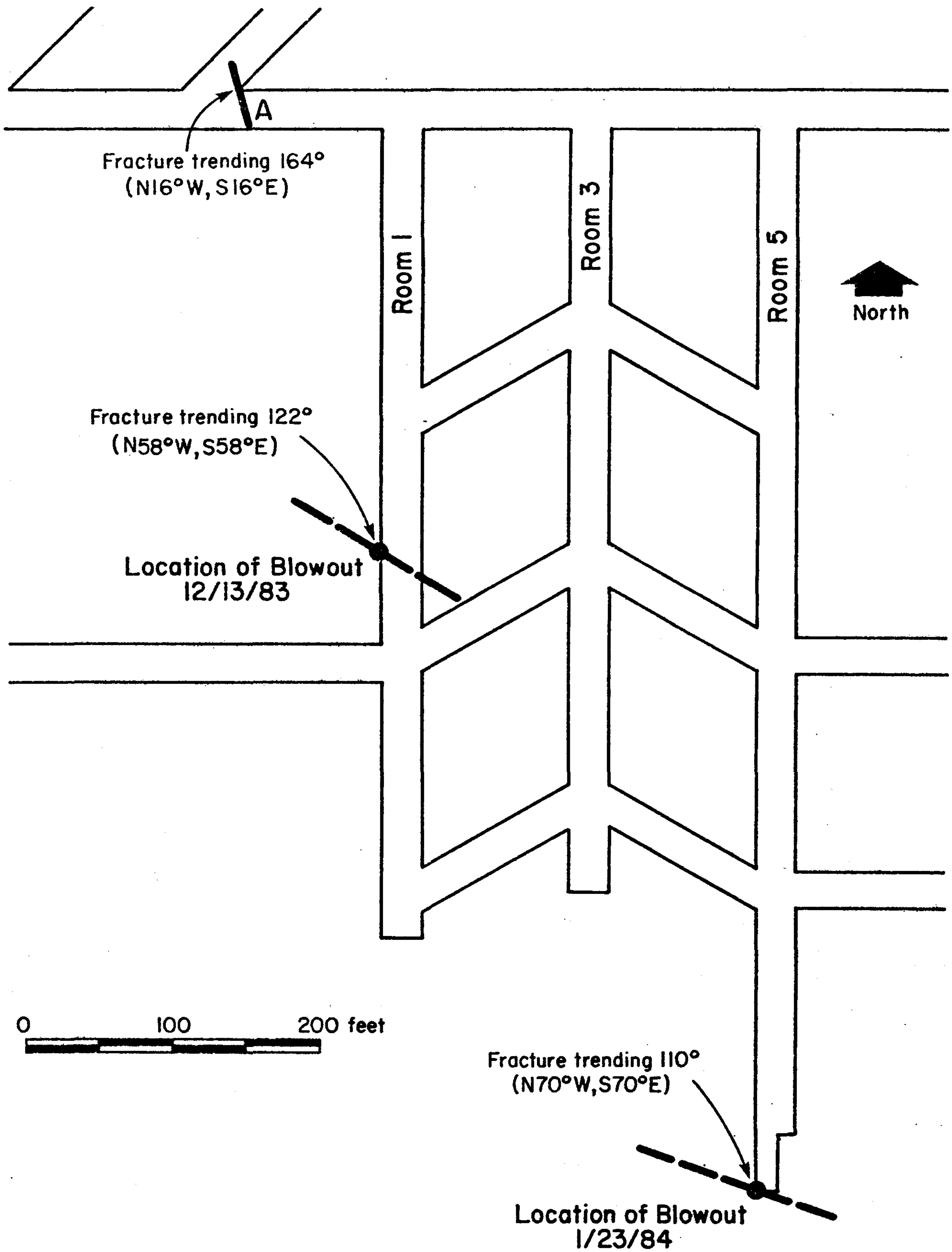

Figure 3. Detailed layout of Area 169 at the Kerr-McGee mine where the gas blowouts of 12•13•1983 and 1•23•1984 occurred. The orientation of fractures is shown. The fracture at A resulted from a previous blowout. (See Fig. 2 for location within the mine)

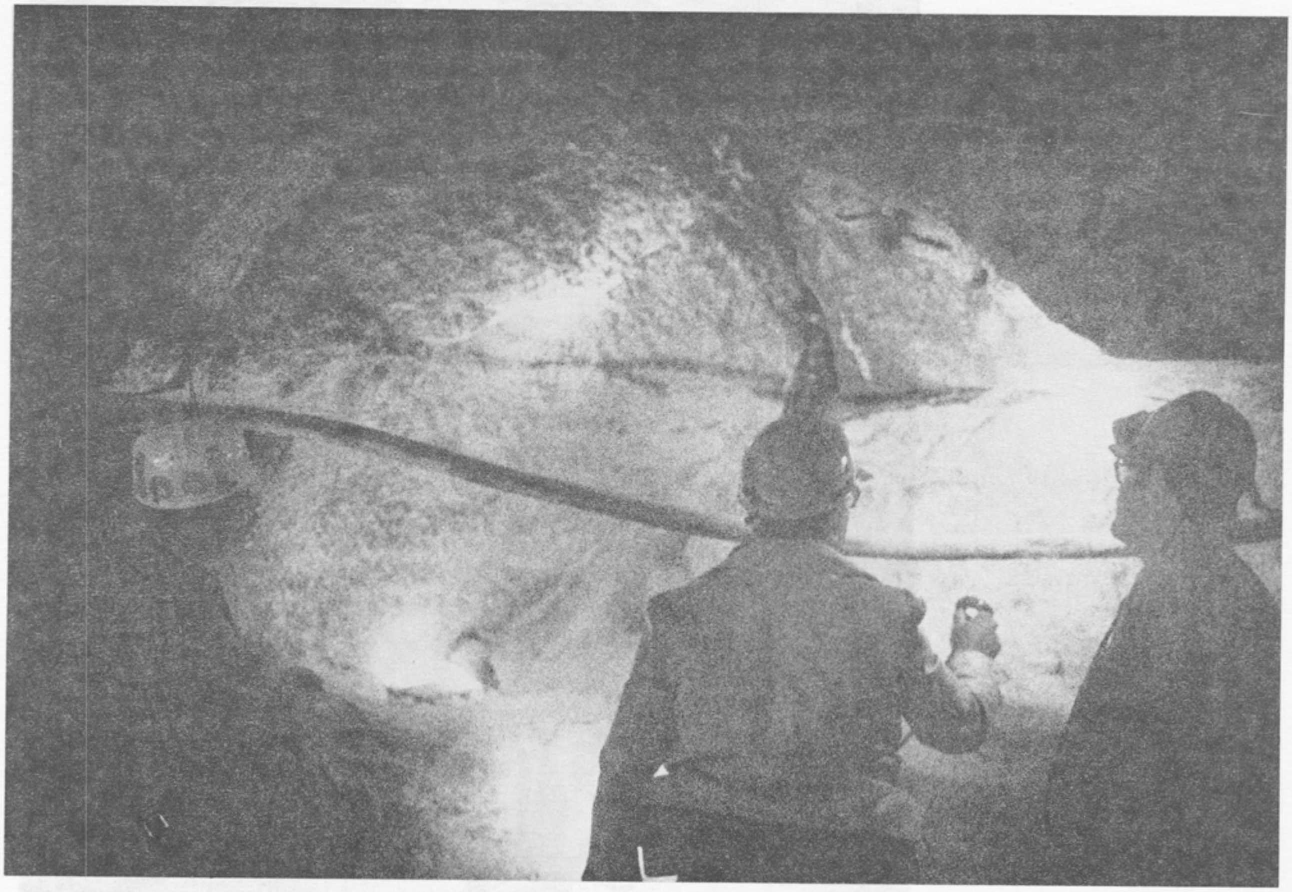

Figure 4. The location of 12·13·1983 blowout showing the cavity (9ft x 5ft x 2.5ft) formed and the vertical fracture trending 122° in Room 1, Area 169, Kerr-McGee mine (See Fig. 3 for location).

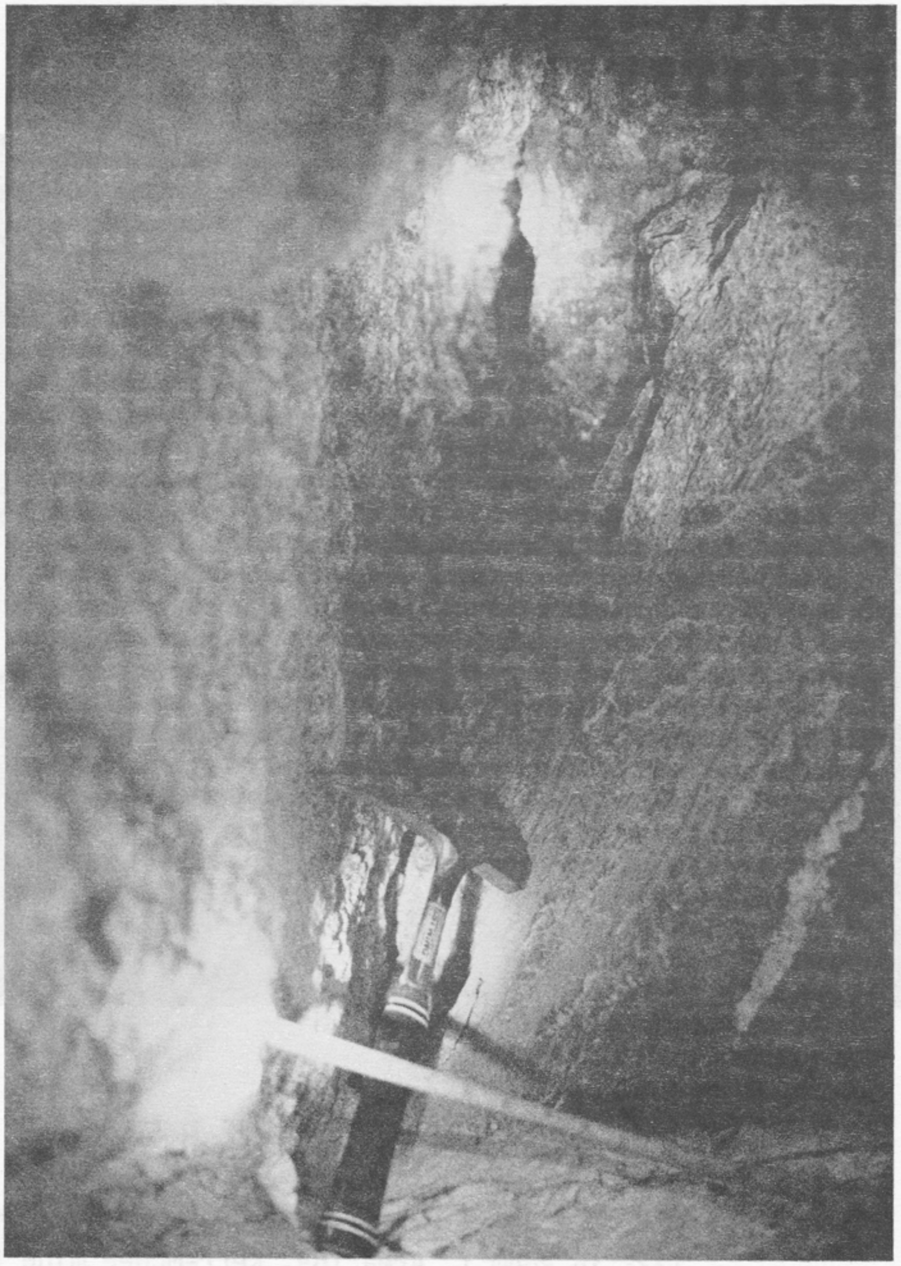

Figure 5. Close up of the fractures at the location of 12•13•1983 gas blowout in area 169 of the Kerr-McGee mine (See Fig. 3 for location).

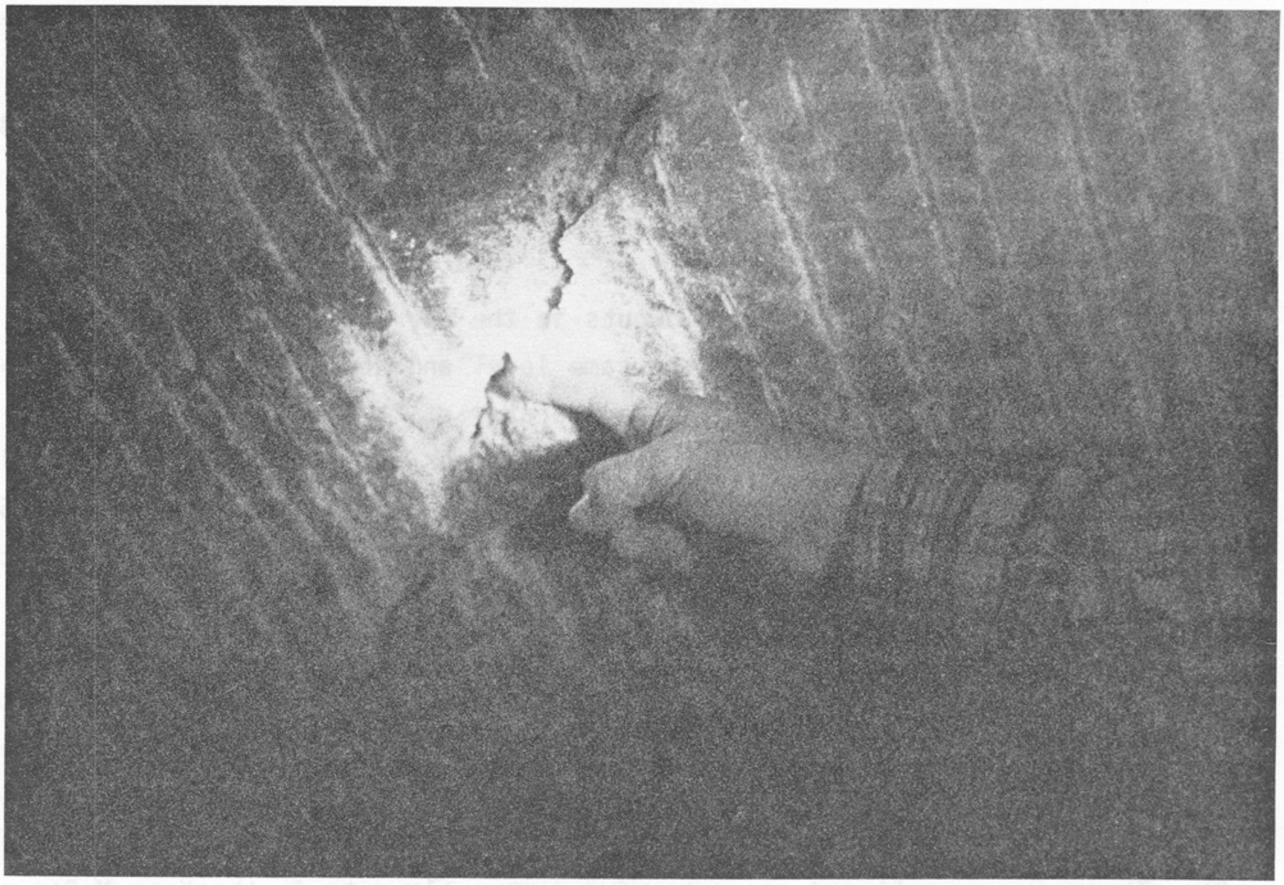

Figure 6. Fracture aligned 122° (N58°W, S88°E) in the back (ceiling) of the 12·13·1983 gas blowout in the Kerr-McGee mine. Picture looking SE in Room 1, Area 169 (See Fig. 3 for location).

within the blowout cavity taken by MSHA investigators on December 14, 1983 were analyzed to contain 89% nitrogen, 8% or less oxygen and from 3 to 6% methane. A report by Cavanaugh and Davidson dated January 16, 1984 provides details of this incident (App. A).

The second blowout in the Kerr-McGee mine occurred in Area 160 about 2 miles northwest of the first incident, on December 19, 1983. The outburst has left a vertical fracture trending 125° (N 65° W, S 65° E). The room at this location has been excavated to 12 ft above the floor to expose the fracture. About 8 ft above the floor, the fracture has been laterally displaced about 6 inches along a horizontal clay seam (Fig. 7).

The third of this series of gas blowouts in the Kerr-McGee mine occurred on January 23, 1984 at 4:50 p.m. at the same level and about 500 ft southeast of the December 13 blowout (Fig. 3). The operator of the continuous miner had started excavating in the face with the continuous cutter. There was a loud sound and debris started flying from the mining face near the cutter. The 50 ton continuous mining machine was knocked back about 2 feet as a result of the outburst and the operator was injured by flying debris. The mine personnel attribute the lack of a serious injury or fatality in this case to the protective metal grating which had been installed on the mining machine after the first two incidents (Fig. 8). An estimated 2 tons of rock was dislodged out of the cavity caused by this blowout. An open vertical fracture trending 110° (N 70° W, S 70° E) has been left in the face from which the gas escaped (Fig. 9). There are unconfirmed accounts of two more blowouts in the Kerr-McGee mine during February and March, 1984.

Duvall Nash Draw Mine - 1976

The Duvall-Nash Draw mine is located about 5 miles west of the WIPP site. The Sylvite level is only about 900 ft below the ground surface because of removal of rocks overlying the Salado in Nash Draw. A large roof-fall involving an estimated 180 tons of rock occurred at the sylvite level of this mine in early 1976. A report by Ellickson dated 4/7/76 provides the details of this incident (App. B). The investigation concluded that the roof-fall was caused by release of gases trapped above the roof. While examining the buried mining machine sometime after the roof-fall, the shift foreman died presumably of suffocation due to lack of oxygen.

Figure 7. Vertical fracture, trending 125° (N65°W - S65°E) laterally displaced along a clay seam at the location of 12•19•1983 gas blowout in area 160 of the Kerr-McGee mine (See Fig. 2 for location).

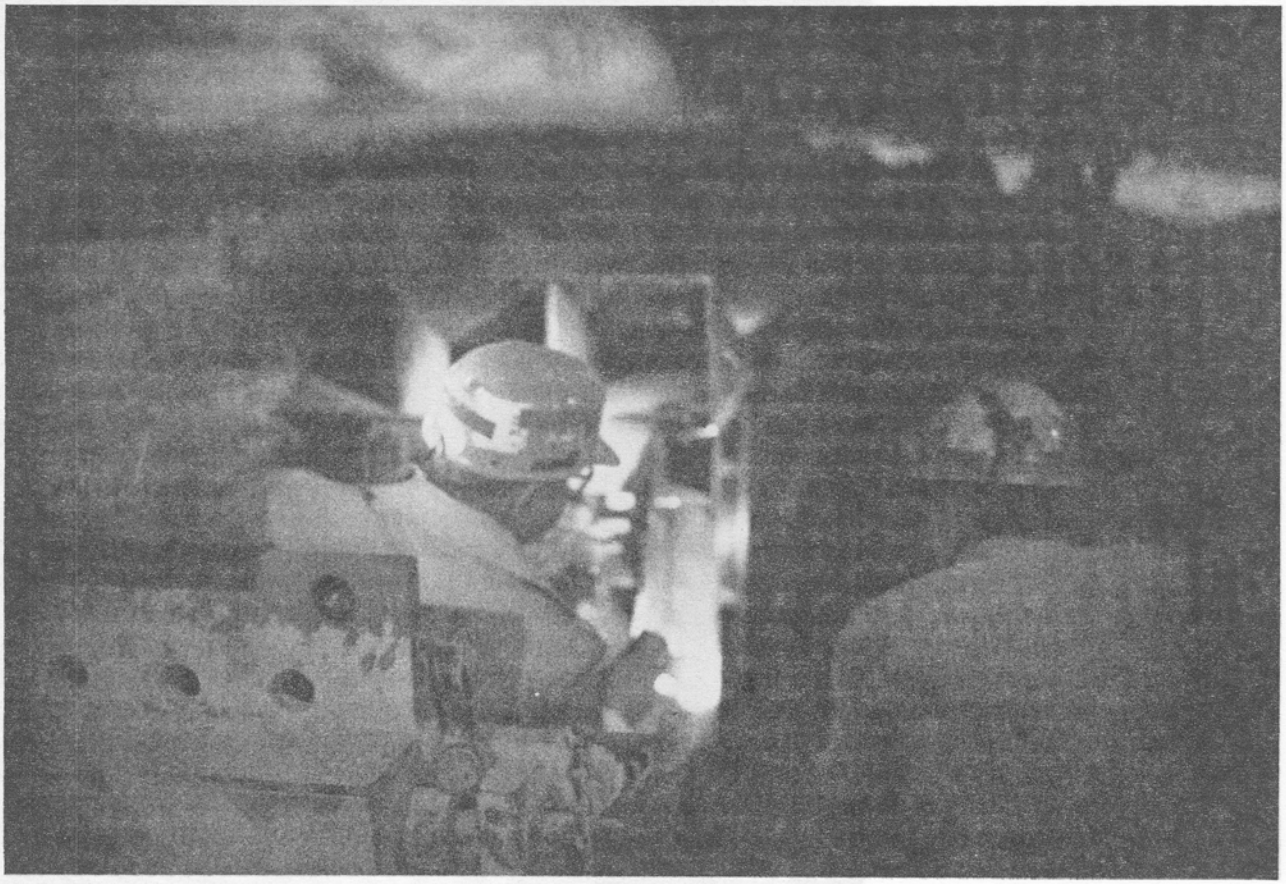

Figure 8. A continuous mining machine with a protective metal grating to protect the operator from debris resulting from a potential gas blowout. (Kerr-McGee mine).

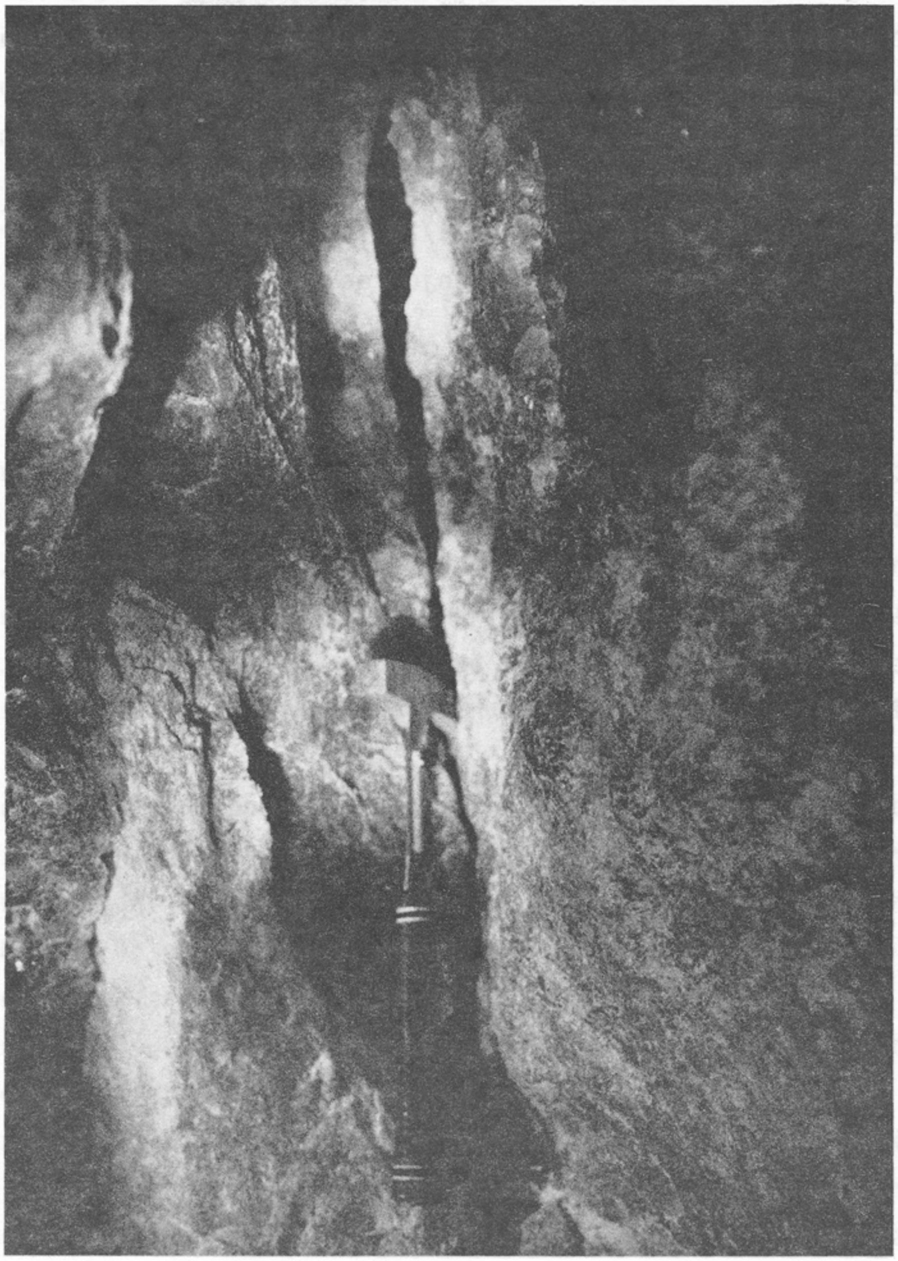

Figure 9. Near vertical open fracture trending 110° at the location of 1·23·1984 gas blowout in Room 5, Area 169 of Kerr-McGee mine (See Fig. 3 for location).

Eddy Mine (National Potash Company) - 1973, 74

The Eddy mine is located about 17 miles northwest of the WIPP site (Fig. 2). Three incidents of roof and floor fall in this mine accompanied by sudden release of gas were reported in 1973 and 1974 (Table 1). Four reports by the State Inspector of Mines dated 12/20/73, 2/25/74, 4/18/74 and 11/27/74 described these incidents in detail (App. C). There were floor breaks and roof falls on 12/16/73, 2/24/74 and 11/27/74 due to release of pressurized gses in this mine. There were several injuries as a result of the 11/27/74 incident.

Gas Blowouts Prior to 1973

Written records of older incidents of gas blowouts in the Carlsbad area potash mines are difficult to trace, but several people associated with potash mining in the area remember such incidents. For example, Sidney R. Kirk (MSHA) recalls (verbal communication) an incident of sudden roof-fall, most likely associated with a gas blowout at the U. S. Borax mine (now known as Mississippi Chemical). This incident in which one miner was killed occurred around 1960.

The U. S. Bureau of Mines conducted a detailed investigation into the occurrence of gas in the Carlsbad Potash District mines in 1963-64. The report of their investigation (Rutledge, et al, 1964) is included as Appendix D of this report. A total of 169 vertical holes, 20 to 40 feet deep were drilled into the roof at six mines. Gas under pressure was found in 67 of these boreholes. A total of 91 "blows" were encountered, 87 of which came from the clay seams. Seventeen holes were examined with a stratascope and the examination revealed that the gas emitted from the clay seams was contained in small vugs about 0.1 inch in diameter, connected by hairline cracks. Gas pressure in clay seams was found only in holes drilled in intersections of drifts. Gas between intersections was found in only 1 hole where it occurred in a small pocket in salt. As the pressure of gas in boreholes was released the roof rose visibly. As a result of this investigation, the authors recommended that "stress on the immediate roof strata due to gas pressure may be relieved by drilling 10 to 20 foot deep vertical holes in each intersection as soon as practicable after first mining while ventilation is still intact." This practice has been adopted by several of the mines in the area.

Occurrence of Gas at WIPP Site

Gases have been encountered during the drilling of exploratory holes for WIPP at several stratigraphic horizons in the Salado formation. Table 2 summarizes the available information and was prepared from data provided in Griswold (1977) and the Basic Data Reports for the boreholes. Figure 10 shows the locations of these boreholes. It clearly demonstrates that gases occur in the upper, middle and lower sections of the Salado Formation.

More than 10,000 feet of excavation at the WIPP repository horizon has been completed to date. Although no written record of gas encounters, even minor "poofs", is available for the WIPP excavations, several project participants informally discussed with the author instances of release of minor amounts of gas accompanied by hissing sound during the excavations for WIPP. The occurrence of gas 10 to 15 feet above (in Anhydrite "a" and "b" layers) and 10 feet below the WIPP repository (in Marker Bed 139) has been studied in detail (U.S. DOE, 1983). The maximum rate of flow of gas was encountered 850 ft south of the 12 ft exploratory shaft. Hole S850A was drilled vertically upwards from the roof of the East 140 drift and encountered as much as 12,280 cc/minute flow rate of gas emanating from Anhydrite "b" layer. A hole (S850C) drilled vertically down at the same location, to a depth of 14.8 feet, intercepted gas in the clay layer below Marker Bed 139. The initial flow rate was approximately 1200 cc/minute. One day after completion of hole 850-C, the hole was found to contain approximately 2 liters of brine. Gas was encountered in 9 boreholes drilled from the roof and floor of WIPP drifts. Pressure buildup in these holes ranged from 10 to 120.6 psi. A typical flow hydrograph of the WIPP gas testing borehole shows a periodicity of flow. Each hole has a different magnitude and periodicity of flow. Although a possible explanation is that the flow may be influenced by changes in ambient pressure in the mine, it has not been demonstrated and there might be other explanations for the pulsating character of gas emanations.

Table 2. Encounter of Gas in the Salado Formation in WIPP Exploratory Holes

Hole	Depth (ft)	Stratigraphic Horizon	Comments
ERDA-9	1409	Between Vaca Triste and 11th ore zone (McNutt Potash Zone)	Trace H_2S
ERDA-6	1841	Between M.B. 134 and M.B. 135 ≈200 ft. above WIPP horizon	Blew for 30 minutes.
	2021	WIPP Repository Horizon - Between M.B. 138 and M.B. 139.	Blew for 45 minutes.
AEC-8	1100 - 1282	Between M.B. 101 and M.B. 109 Upper part of Salado	Produced N_2 gas for several months @ 35,000 cu.ft./day.
AEC-7	1610	Between 10th and 11th ore zones, McNutt Potash zone	Blew for 1 hour.
P-7	780 - 1234	Upper Salado	Numerous kicks.
P-12	1300?	Salado	Hole unloaded drill fluid over a weekend shutdown.
P-20	T.D. 1995	Lower Salado	Slight blow when hole reached final depth.

NOTE: See Figure 10 for the locations of these boreholes.

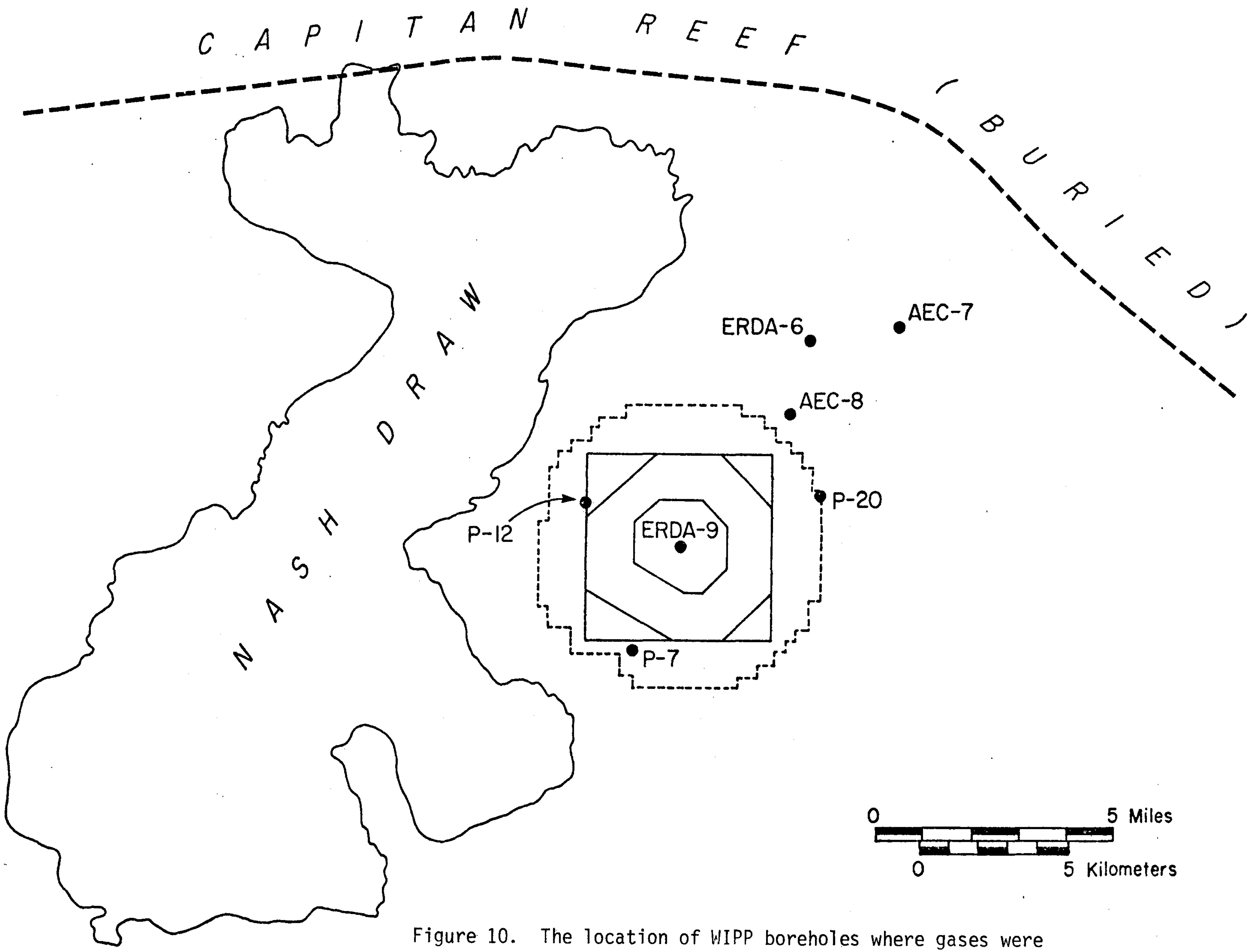

Figure 10. The location of WIPP boreholes where gases were encountered (See Table 2).

CHEMICAL COMPOSITION OF SALADO GASES

Table 3 shows a summary of the chemical analyses performed on Salado gases from near the WIPP repository horizon and from the McNutt Potash Zone. The analyses show that nitrogen is the primary constituent with concentrations recorded from 76.3% to 96.5%, oxygen accounts for 0.2% to as much as 22% and methane constitutes from 1.07% to a maximum of 7.8%. Very small amounts of CO_2 and C_2H_6 are also present. It should be kept in mind that the process of gas sampling is somewhat tricky and that it is quite likely that the samples showing oxygen content much above the average values may have been contaminated by air. The highest concentration of methane (7.8%) was found in the gas sample collected from the clay layer below Marker Bed 139 in the borehole 850-C drilled 15 feet into the floor of the East 400 drift, 850 feet south of the 12 foot exploratory shaft at WIPP.

There has been some confusion about the nature of gas outbursts in the Carlsbad area potash mines. Use of the word "explosion" to characterize the sudden release of pressure and consequent flying of rocks and debris has been misunderstood. It is therefore appropriate and pertinent here to examine the "explosibility" of Salado gases.

Webster's dictionary defines "explosion" as, "the act or an instance of exploding as a large scale, rapid and spectacular expansion, outbreak, or upheaval." Similarly, one of the meanings of the word "explode" is, "to burst violently as a result of pressure from within." The violent outbursts caused by the sudden expansion of gas due to release of pressure from the trapped gas in the rock strata can thus be best characterized as "explosion." However, the word also connotes explosibility in a chemical sense. The Salado gases do not appear to be "chemically explosive." For this reason the terms "outburst" or "blowout" have been used in this report.

Coward and Jones (1952) have discussed the potential for explosion of mixtures of methane, air and nitrogen. Figure 11 shows this relationship graphically. It shows that a minimum of 5% methane and 12% oxygen is required for a mixture to be explosive. Table 3 shows that the Salado gas typically contains about 2% methane and 7 to 11% oxygen. Such a mixture is not chemically explosive. The

Table 3. Major Constituents of Salado Gases

Stratigraphic Horizon	No. of Samples	Nitrogen (%)			Oxygen (%)			Methane (%)		
		High	Low	Ave	High	Low	Ave	High	Low	Ave
Marker Bed 138 Anhydrites "a" and "b"	4	96.5	85.8	90.8	13.0	3.1	6.9	2.0	0.51	1.07
Salt below Anhydrite "a" (10 to 15 ft above WIPP Repo.)	4	88.0	76.3	84.7	21.4	2.3	11.0	3.5	0.73	1.9
Anhydrite "b" (10 ft above WIPP Repo.)	6	95.7	78.0	87.7	22.0	0.2	8.8	4.0	0.02	2.1
Marker Bed 139 (10 ft below the WIPP Repo.)	1		90.5			1.4			7.8	
McNutt Potash Zone	14 (From 6 Mines)	97.3	91.2	96.0	6.0	0.4	1.47	4.7	0.06	1.8

NOTE: McNutt Potash Zone data from Rutledge et al (1964)
All other data from WIPP-DOE-177 (1983)

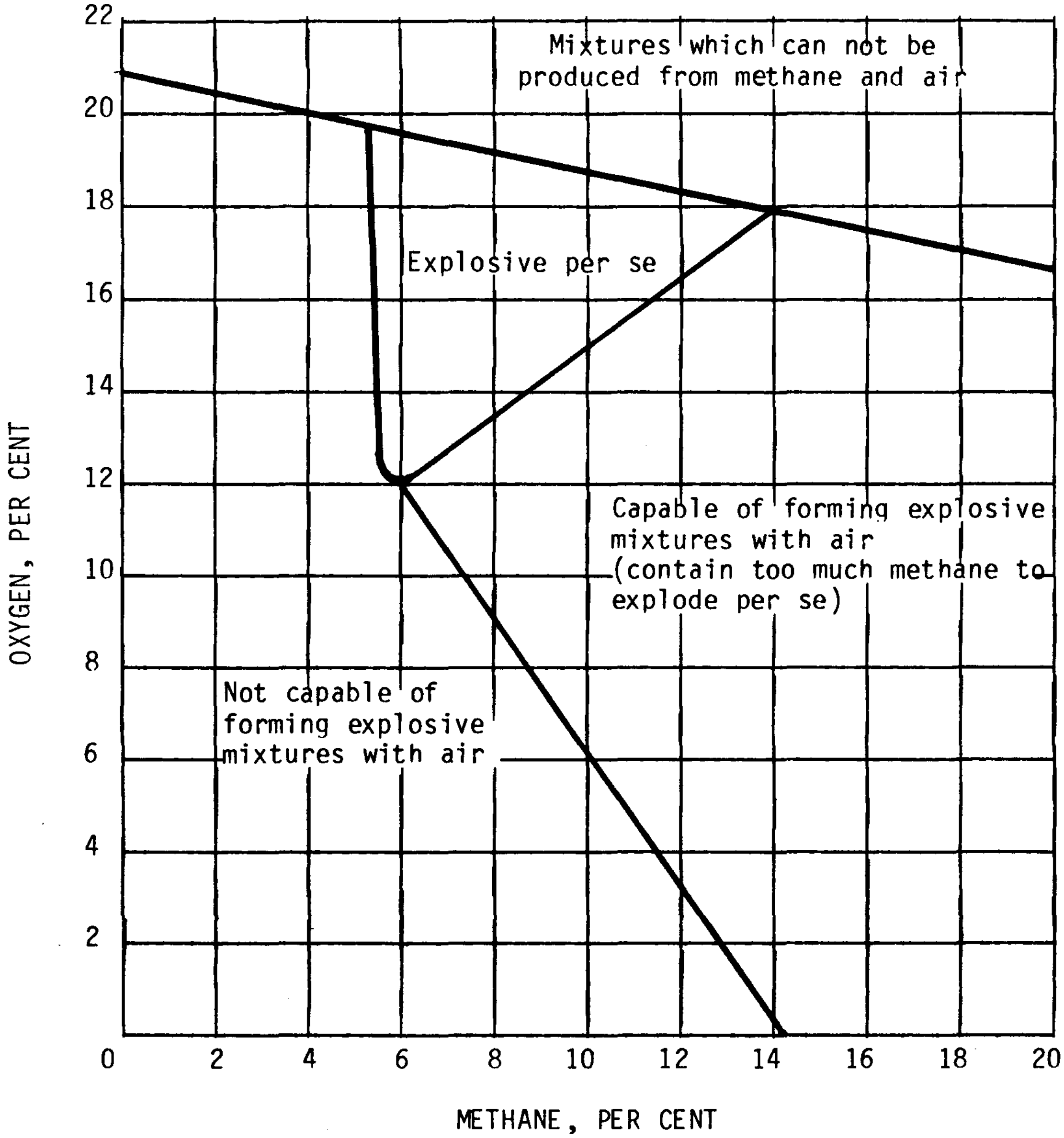

Figure 11. Relationship between the composition and the explosibility of mixtures of methane, oxygen and nitrogen (From Coward and Jones, 1952).

gas sample obtained from Marker Bed 139 at WIPP contains the highest percentage of methane (7.8%) but too little oxygen (1.4%) to make it explosive in a chemical sense. One sample from the Eddy Mine of National Potash Company was analyzed to contain 12% oxygen and 16% methane (App. C), but its accuracy is questionable.

THE ORIGIN OF GAS

All salt deposits contain some fluids (brine and gas) and the Salado formation is no exception. Within halite crystals, gas can often be seen as a bubble within a fluid inclusion. To estimate the percentage of fluids in the halite crystals of the Salado Formation, 35 selected core samples from ERDA-9 borehole were heated to 500°C and weighed before and after the expulsion of gas and brine. The results showed that more than half the specimens showed only 0.5% weight-loss. The maximum wight-loss recorded by one sample was 3.5% (Powers, et al, 1978). Since most of the fluid in the inclusions consists of brine, total amount of gas trapped within the salt crystals is negligible.

Almost every reported encounter of gas in the potash mines as well as near the WIPP repository is associated with either clay seams or clay-enriched zone of salt. The composition of the gas shows that it was most likely derived from the original atmospheric air at the time of deposition of Salado. The gas is depleted in oxygen most likely due to the high chemical activity of oxygen which allows it to react with a variety of elements to form oxides. Methane must have originated from decomposition of marine organic life during times when clays were deposited in the Salado sea. The presence of gas near the clay layers is probably due to the contrast in the mechanical properties of clay and salt. Gas originally trapped must have migrated along crystal boundaries until it reached the impermeable clay layer.

An important observation made in the Kerr-McGee mine is that the violent gas outbursts have left a near vertical fracture which can be seen in the roof and to 1-2 foot below the roof along the walls of the drift. Does a fracture represent a cavity in which the gas was trapped until released or was it created due to the sudden release of gas generally disseminated in "vugs and hairline cracks" as observed by Rutledge et al (1964) through a stratascope? If gas is contained in a discrete fracture until the pressure is released, it must be in equilibrium with the lithostatic pressure at that level. This could have happened by the trapped gas coalescing in a fracture, keeping it open as the gas became pressurized due to salt creep, until the gas pressure in the fracture reached the magnitude of lithostatic stress. This would mean that gas pockets in deeper strata would be more pressurized. Alternately, gas could remain trapped in permeable zone at the contact of salt and clay, without being pressurized to lithostatic levels. Release of pressure in such a case would be less violent and would not necessarily be higher at greater depth.

There appears to be a preferred direction of orientation of fractures associated with gas blowouts. The fractures are mostly oriented in a WNW-ESE direction. It is possible that the fractures were created by some geological activity in the past and gas from the surrounding region migrated into them and later became pressurized due to salt creep. The stress field which would induce WNW tensile fractures should have been perpendicular to that direction, i.e. NNE. There is a lamprophyre dike with an approximately NE trend which is exposed in the northwestern part of the Kerr-McGee mine. It is likely that these fractures were created when the dike intruded into the Salado salt about 37 million years ago. The fractures associated with gas blowouts are, however, not continuous for more than a few tens of feet--they are not intercepted in parallel drifts. This indicates that the fractures were either formed "en echelon" or that they result from the localized explosive activity associated with sudden release of pressure every time a blowout occurs. A clear answer to this question will require extensive experimental work in the areas where gas blowouts have been observed.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based upon the facts and discussions presented in this report, the following conclusions can be drawn concerning the occurrence of gas in the Salado Formation.

1. Gas can be found at almost any level within the Salado Formation, generally near clay seams associated with the marker beds.

2. The gas consists primarily of nitrogen with some oxygen and methane and lesser amounts of carbon-dioxide and ethane. The composition of the gas does not make it "chemically explosive."

3. Smaller amounts of gas in isolated pockets at low pressures is very common. Such pockets may consist of porous zones at the boundary of salt and clay where gas may be trapped in "vugs connected by hairline cracks." The pressure in such zones may be less than lithostatic. Encounter of such zones of small amounts of gas at low pressures (knows as "poofs") is almost a daily occurrence in the Carlsbad area potash mines.

4. Occassionally gas has been encountered under high pressure. Sudden expansion of gas due to release of high pressure creates an explosion or "outburst" which has occasionally resulted in death and/or injury to miners. At least seven such outbursts have been documented. Outbursts not involving a fatality or serious injury usually go unreported. No such incidents were reported to the state and federal authorities between April, 1976 and December 1983. After the fatal accident involving gas release on Dec. 13, 1983 at Kerr-McGee mine, two more incidents of gas outbursts at the same mine came to light within a month. Out of these, the one on Dec. 19, 1983 was not reported to the State Mines Inspector. It is thus a safe assumption that violent outbursts of gas are more common in the potash mines than generally assumed.

5. Each violent outburst exposes an open vertical fracture. Due to the similar alignment of these fractures in a WNW direction, it is thought that the gas is trapped in fractures which may have been opened due to a geological factor such as the emplacement of a dike. If this is true, the gas pressure within these vertical fractures would have to be in equilibrium with the horizontal component of the litholostatic stress, or approximately at 1500 psi pressure. Sudden release of such a high pressure would dislodge and move large chunks of rock and machinery if caught in the outburst.

6. Small amounts of gas, often emanating in a cyclic period, have been encountered in zones a few feet above the ceiling and below the floor of WIPP excavations. Chemical composition of this gas is similar to the gas found in potash mines, 600 feet stratigraphically above the WIPP repository.

7. No encounter of gas, not even small "poofs" have been officially reported from more than 10,000 feet of excavations for WIPP. However, there are hearsay accounts of such encounters.

8. There is a low probability of finding pockets of highly pressurized gas at WIPP since none have been encountered after 2 miles of drifts have been excavated. However, the possibility cannot and should not be ignored. If the hypothesis of gas filled fractures being at a pressure equivalent to the horizontal component of lithostatic stress is correct, such fractures if encountered at WIPP, would result in a larger pressure drop than the ones at potash mines level.

Recommendations

The following recommendations are made for future operations at the WIPP site.

1. Collect and publish the information on even minor encounters of gas "poofs" during the WIPP excavations - their location, description, associated fractures and any unusual geologic features in the vicinity. A form being used by Kerr-McGee mine for this purpose is attached as App. E.

2. Map any fractures and areas of excessive moisture seeps in the excavations.

3. Continue the practice of drilling advance exploratory holes before cutting a face with the continuous mining machines. These holes should be drilled slanted upwards to intersect the clay layer near the ceiling.

4. Install protective metal grating on the continuous mining machines similar or better than the ones installed at the Kerr-McGee mine.

5. Check the mining machines for any loose parts which may get removed and fly about in the event of an explosion. Remove or re-install such parts to prevent this possibility.

6. Establish procedures to not allow any unnecessary personnel near an operating mining machine.

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APPENDIX A

UNITED STATES DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION

TECHNICAL SUPPORT

GAS OUTBURST INVESTIGATION
KERR-MCGEE POTASH MINE

Kerr McGee Chemical Corporation
Carlsbad, New Mexico

December 14, 1983

by

John E. Cavanaugh
Mining Engineer

and

Jerry Davidson
Geologist

Issuing Office
Ground Support Division

SAFETY AND HEALTH TECHNOLOGY CENTER

D. K. Walker, Chief

P.O. Box 25367, Denver Federal Center
Denver, Colorado 80225

SUMMARY

In response to a request for assistance from the Dallas, Texas, MSHA, M&NMS&H, Subdistrict Office, two members of the Safety and Health Technology Center (S&HTC), Ground Support Division traveled to the Kerr McGee Potash Mine near Carlsbad, New Mexico, to investigate a large gas outburst that occurred in this potash mine on December 13, 1983. The outburst resulted in fatal injuries to a continuous miner operator, and less severe injuries to a shuttle car operator.

As a result of this investigation it is recommended that steps be taken to locate and to relieve the high pressure gassy regions in advance of mining and that mining procedures and mining equipment be modified to protect mining personnel from high pressure gas outbursts and associated fly rock and debris.

GENERAL INFORMATION

The Kerr McGee Chemical Corporation, Hobbs Potash Facility, was located 30 miles east of Carlsbad, New Mexico, south off of Highway 62-180. The product being mined was potash from the 1600 level of the underground room-and-pillar mine. Electric continuous mining machines with shuttle cars were used to mine the 6-foot high by 27-foot wide rooms in the herring bone-pattern development entries. These entries were used for ventilation, service and haulage during development advance mining and would continue to be used for these functions during subsequent retreat production mining from adjacent production panels.

Very little ground support had been required in the working sections of this mine. However, when bad ground conditions are encountered, such as the open brow left after this gas outburst, rock bolts are used to stabilize the potentially loose ground.

On December 13, 1983, at 4:27 a.m. a large gas outburst occurred on the 1600 level of the Kerr McGee Mine which resulted in the death of one miner and the injury of another.

The following individuals participated in the investigation of the area where the fatal gas outburst occurred.

Kerr McGee Corporation

Walter Case, Facility Manager
Melvin Pyiatt, Underground Superintendent
Raymond Nations, Safety Director
Barry A. Stewart, Corporate Safety
Curtis Davidson, Underground Safety Supervisor
C. E. Spears, Employee Relation Manager

New Mexico Bureau of Mines Inspection

L. A. Quinones
Felix T. Carrasio

Mine Safety and Health Administration

Doyle D. Fink, Dallas Subdistrict Manager
William R. Wilcox, Mining Engineer, Dallas Subdistrict
Sidney R. Kirk, Supervisory Mine Inspector, Carlsbad Field Office
David P. Lilly, Special Investigator
Charles E. Price, Mine Inspector
Jerry Davidson, Geologist, S&HTC
John E. Cavanaugh, Mining Engineer, S&HTC

OBSERVATIONS

The investigation party assembled at the facility safety office on the morning of December 14, 1983. After necessary administration and preparation, the group decended into the mine on the man cage and was driven to the accident scene on man-cars by company officials. Figure 1 is a schematic of Area 169. The accident location is shown on Figure 1 in Room 1 about halfway between x-cut 1 and x-cut 3. The blowout occurred on the outby side of a block of ore which extended in Room 1 approximately 42 feet to the mined-out dead end heading of x-cut 3. Reportedly no indication of high pressure gas had been encountered while mining in that crosscut.

The gas outburst occurred in the upper right side of the indented working face. Figures 2, thru 5 contain photos showing the cavity resulting from the outburst and the vertically-extending gas fissure within this cavity. Also shown is the continuous miner that had been operated by the victim and some of the large slabs of potash and rock salt that had been ejected from this outburst area.

The operator of the continuous miner was apparently killed as a result of being struck by a light fixture which had been torn loose from the continuous miner and hurled back into the victim's face. The shuttle car operator standing near his machine behind the continuous miner was injured by flying potash and rock salt, but was reported in stable condition at the time of the investigation.

CONCLUSIONS

1. It is probable that the continuous miner had mined to within a few inches of a large volume of high pressure gas occurring within a vertical, open fissure which cut across the horizontal strata in the roof. From the position of the continuous miner it appeared as though the operator had backed the machine out of, and diagonally to the left of, that working face, as if he were going to clean a pile of broken muck from the adjacent protruding face to the right of the machine. The testimony of the injured

shuttle car operator indicates that no gas was escaping at the time the continuous miner was backing out of the working face. It is therefore concluded that the potash rock in the working face had been mined to a thickness that would not contain the gas pressure. The remaining rock in this face was thus strained by this gas pressure beyond its ultimate strength and violently burst into the entry allowing a large outburst of high pressure gas to propel slabs and rock salt particles into the mine workings.

This sudden, explosive like yielding of the upper right side of the working face ejected large boulders (+500 lbs.) up to 63 feet from the face, and resulted in significant damage to the continuous miner. While the exact trajectories of these boulders remain undeterminable, the damage and rock debris on the continous miner indicated that a large piece of rock ricocheted off of the far left side of the drift before slamming into the left side of the machine.

2. Although no MSHA air samples (meeting the requirements of CFR 57.21-1) taken during this visit within Room 1 indicated flamable gas, several air samples taken in the open fissure within the blowout cavity contained from three to six percent methane. None of these samples were , however, in the flamable or explosive range due to the accompanying high nitrogen (greater than 89%) and low oxygen (less than 8%) concentrations.

3. The gas outburst had ejected about a ton of potash rock from the working face and roof into Room 1 and had created an open, jagged, arched brow. The company safety director stated that this brow would be reinforced by installing rock bolts and mats to minimize unstable ground conditions in that area.

4. According to company officials, a gas relief hole was drilled 20 to 28 feet up into the mine roof at each preceeding intersection. Intersections are driven on 160-foot centers.

RECOMMENDATIONS

1. Prior to advancing a face, a fan of long holes (150 - 200 feet) should be drilled. It is recommended that two horizontal holes be drilled in the upper ore zone. Two additional holes, inclined slightly upward, should be drilled through the upper ore zone to intersect the overlying shale beds. This fan of drill holes should intersect and bleed-off gas pockets in advance of mining in that area.

2. Vertical up holes (gas pressure relief holes) approximately 20 feet deep should be drilled in each intersection and along the centerline of each entry. Until such time as accurate overlying strata porosity, gas permeability, and radius of pressure relief can be determined from pressure build-up tests, a maximum spacing of 25 feet is recommended.

3. With each new cut, the cutter head of the continuous miner should be "sumped-in" at the back and advanced at least 1 foot farther into virgin ground beyond the intended new face position. The miner machine should then be backed out and the new face cut from the top down. This method of face advance would open ground beyond the new face, and would protectively place the cutter head between a possible gas pocket and the machine operator during the initial phase of the cut.

4. An expanded metal grating should be installed in front of the machine opoerator's station on the continuous miner to provide some degree of protection against flying debris.

5. Systematically record, analyze, and map the gas emission data from the gas pressure relief boreholes to include quantity, quality, and duration of flow. From the accumulated data, a characterization of ground condition or strata may be determined which could delineate high pressure gas zones.

6. Pursue pressure buildup testing of boreholes drilled into gas bearing strata to more accurately determine gas pressure, area of influence, and lithologic characteristics of the gas bearing strata.

7. Pursue cross-borehole accoustic emission technology recently developed by U.S. Bureau of Mines research studies to determine if the technology can assist in locating open fissures and high pressure gas zones in potash beds in advance of mining. The experience and expertise of the oil and gas production personnel within the Kerr McGee organization should also be utilized in seeking a technical solution to the gas outburst problem.

8. Provide air quality testing instrumentation to personnel performing drilling and mining operations to insure safe atmospheric conditions exist during these procedures. An oxygen monitor and an explosive atmosphere monitor are recommended.

9. Continue geologic and engineering studies of the mining district to seek additional solutions to the high pressure gas outburst problem.

John E. Cavanaugh

John E. Cavanaugh
Mining Engineer

Jerry Davidson

Jerry Davidson
Geologist

APPROVED:

R. J. Herriter

Acting Chief
Ground Support Division

January 16, 1984

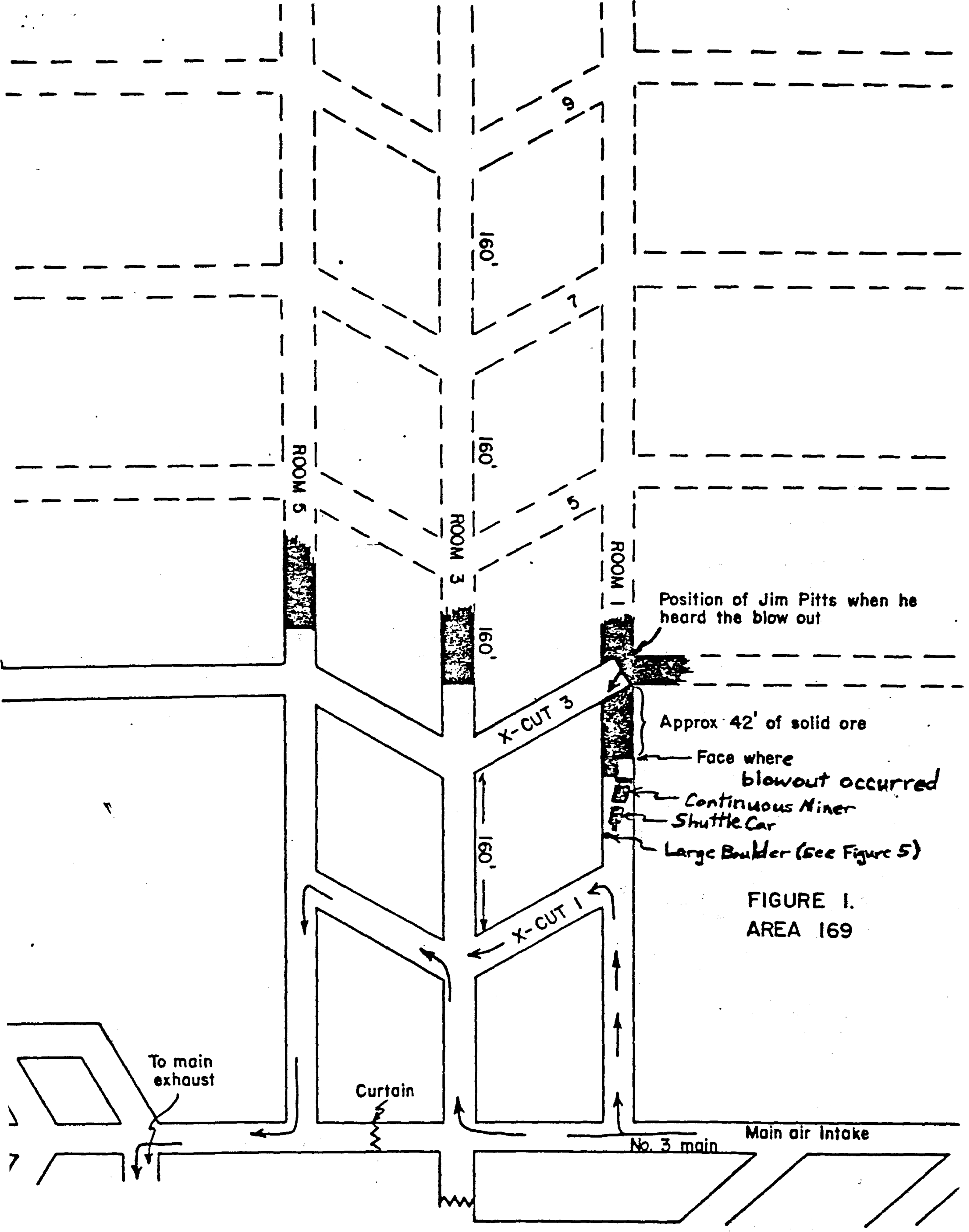
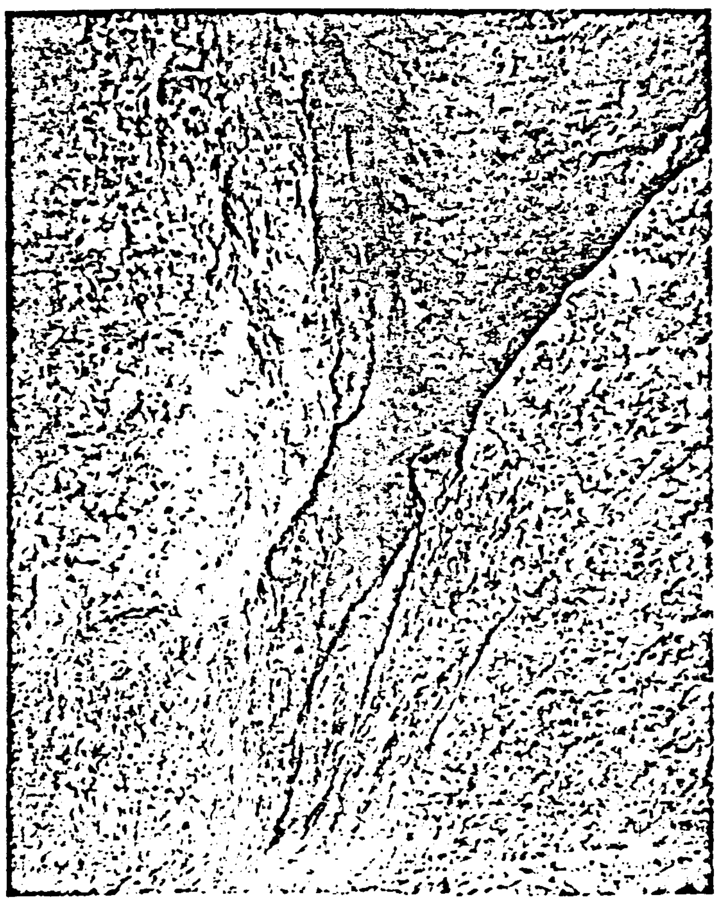


FIGURE 1.
AREA 169

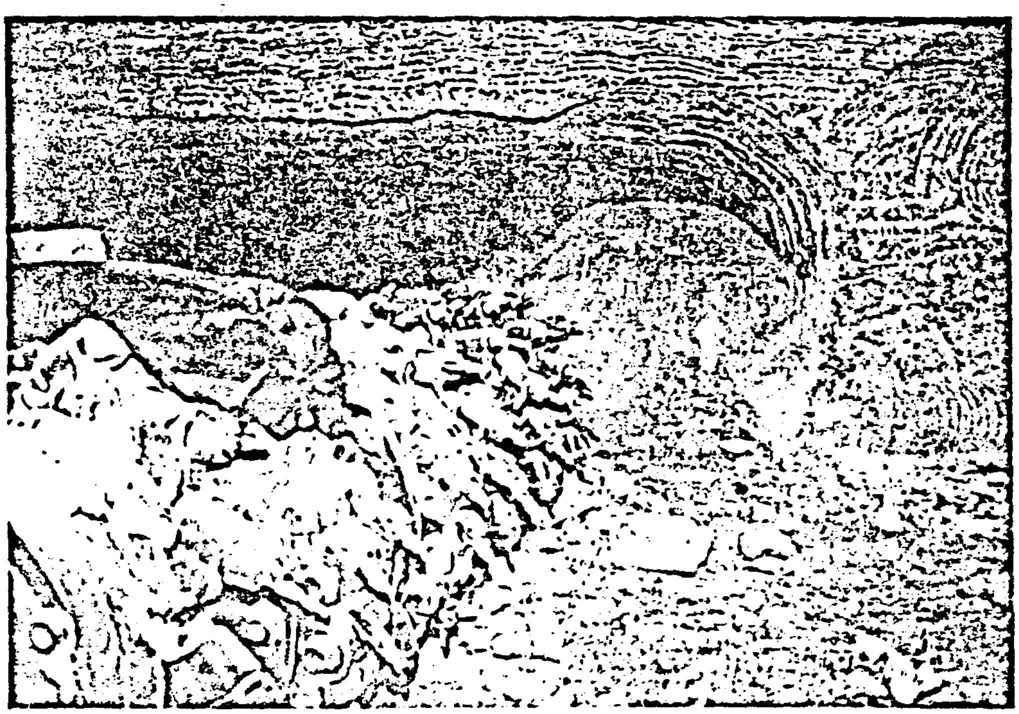
Cavity in upper right side of room 1. Working face created by the December 13, 1983, gas outburst.



Open fissure within the gas outburst cavity in the roof at the working face in room 1.

FIGURE 2.

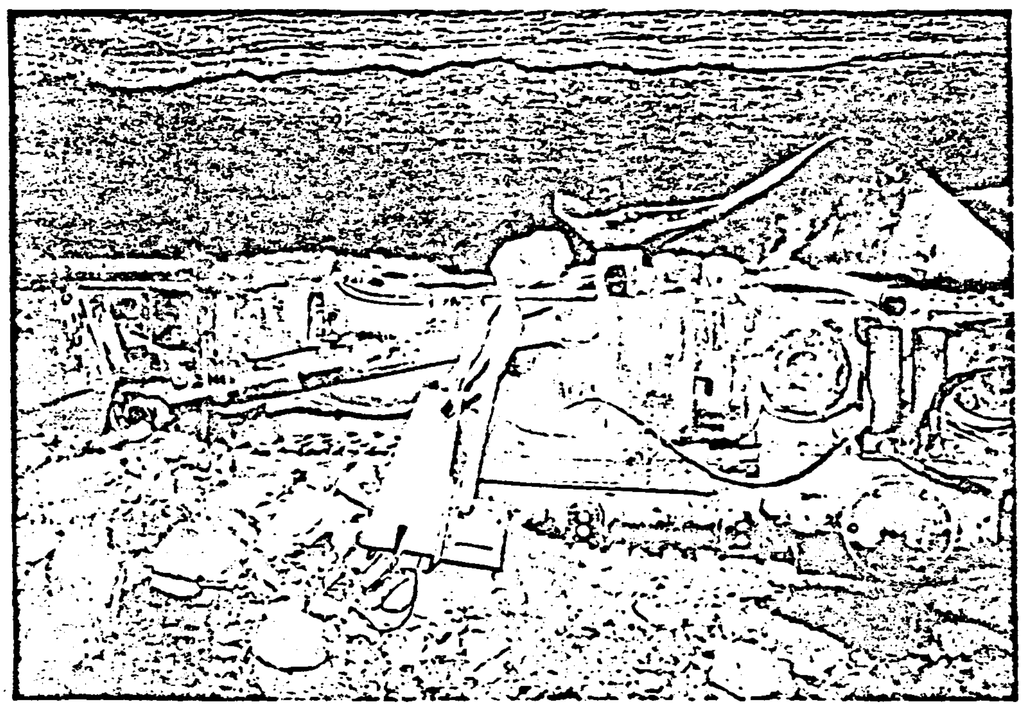
Picture taken from near the center of the blowout face looking out at the cutter head. Note corner of protruding half of working face on the right side of this photo.



Picture showing continuous miner cutter head with the pile of muck to the left of the machine and in front of the protruding half of the drift working face where the continuous miner was apparently being moved when the gas blowout occurred.

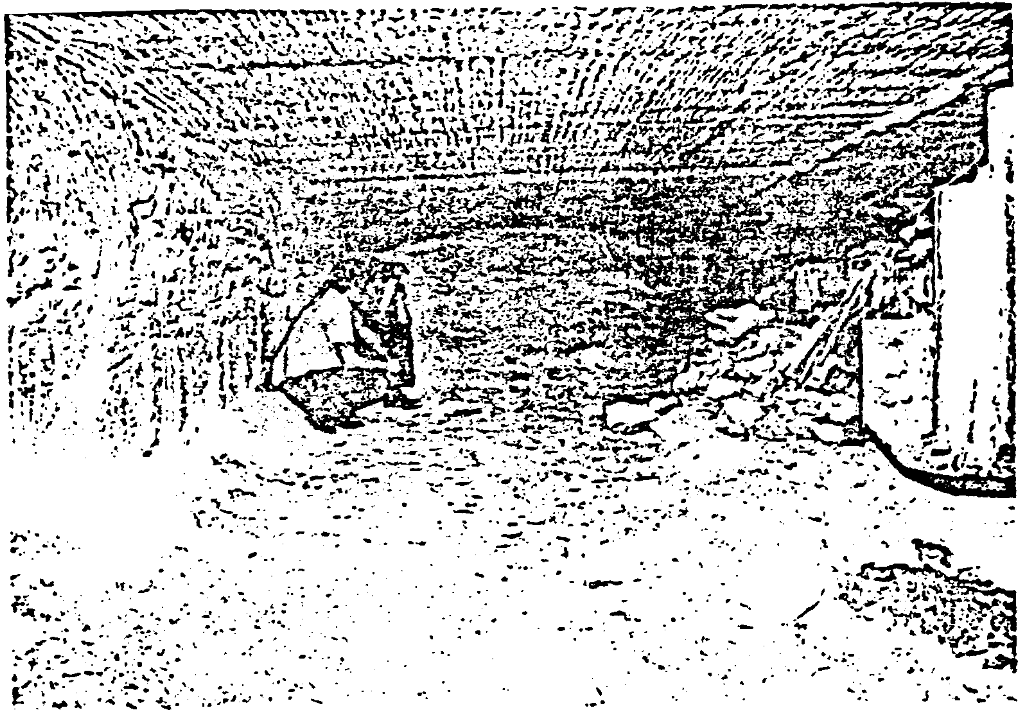
FIGURE 3.

Looking into the left front side of the continuous miner near the working face where the December 13, 1983, gas outburst occurred.

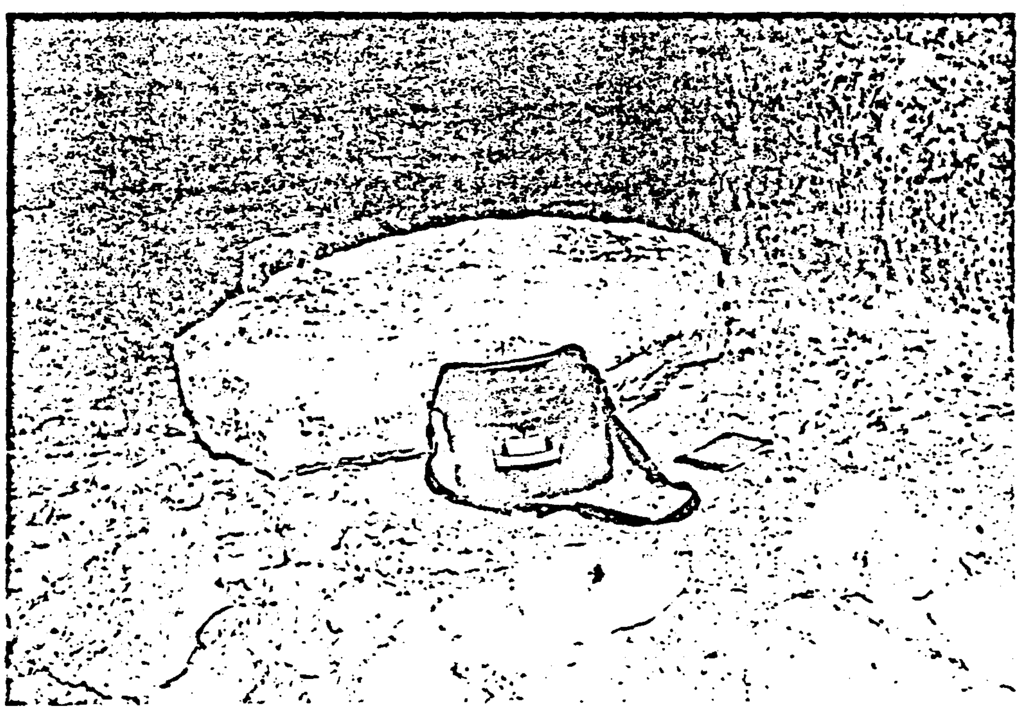


Looking into the left side of the continuous miner. Note structural damage, including dislodged electrical box, wrinkled protective rubber sheeting, and broken hydraulic hoses.

FIGURE 4.



Picture taken from left side and behind shuttle car with camera just above large boulder that was ejected from the working face 63 feet away. Note broken rock from outburst.



Largest intact boulder (+500 lbs.) ejected from the gas blowout. The boulder was 63 feet from the blowout cavity.

FIGURE 5.

APPENDIX B

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D1005
Copies made 6-7-76

UNITED STATES DEPARTMENT OF THE INTERIOR
MINING ENFORCEMENT AND SAFETY ADMINISTRATION

TECHNICAL SUPPORT

GROUND CONTROL INVESTIGATION
NASH DRAW POTASH MINE

DUVALL CORPORATION
CARLSBAD, NEW MEXICO

April 7, 1976

by

M. L. Ellickson
Mining Engineer

Issuing Office
Division of Safety Technology

DENVER TECHNICAL SUPPORT CENTER

A. Z. Dimitroff, Chief

P.O. Box 25367, Denver Federal Center
Denver, Colorado 80225

INTRODUCTION

In response to a request from the District Manager, Metal and Nonmetal, Dallas, Texas, a ground control survey of the Nash Draw Potash Mine was conducted on April 7, 1976. The following personnel conducted the Survey: M. L. Ellickson, Supervisory Mining Engineer, Denver Technical Support Center; T. J. Castor, Supervisory Mining Inspector, Albuquerque Field Office; Norman Gonder, Safety Supervisor for the Nash Draw Mine. The survey was conducted as the result of a recent roof fall and subsequent fatality at the mine.

BACKGROUND

The Nash Draw Potash Mine is located several miles east of Carlsbad in a level and very arid region of Southeast New Mexico. The facilities include the underground mine, shafts, offices and various mine buildings. Mining has been in progress for several years with a large area of the underground mine mined out.

Access to the underground workings is by two vertical shafts. The shafts are 900 feet deep and extend to the Sylvite level. The Langbeinite level is 170 feet below the Sylvite level and access to this level is by inclined entries from the Sylvite level. Both levels are mined using belt haulage to transport the ore in the underground workings. The mine uses one shaft for intake air and the other shaft for exhaust air. Total airflow throughout the mine is approximately 140,000 CFM and is circulated to three active working sections. Several small underground booster fans are used to help the movement of air in the underground portion of the mine.

FATALITY

A massive roof fall occurred on the Sylvite level which had completely covered an undercutter machine near a dead-ended active working face. The fall was approximately 48 feet long, 32 feet wide and 5 feet deep. It was estimated that 180 tons of roof material fell in this intersection of a butt entry and the working face. The operator of the undercutter machine was unhurt except for a minor injury when he was crawling out from beneath the canopy. Sometime after the roof fall the shift foreman attempted to examine the buried undercutter machine. The cause of his death was attributed to suffocation. A booster fan was later located in the corner of the working entry and using "Chemox" rescue units, the victim was removed from the scene of the accident.

This mine and the nearby mines have a history of nitrogen and other gases entrapped in their immediate roofs and this gas pressure was probably the major contributing factor in the roof fall. It was also assumed that air bleeding from the roof forced the fresh air out of the entry. The investigation of the roof fall area gave no indication the roof in this area was any different than other areas of the mine. This indicates the roof fall was caused by the trapped gases above the roof and the gases had exerted enough pressure to cause this roof fall.

The roof at the Nash Draw Mine appears competent with very little supplementary support necessary. Roof falls are rare at this mine and the roof is competent enough that problems have been encountered when trying to cave pillaring areas.

RECOMMENDATIONS

It is recommended that 8-foot bleed holes at every round in the center-line of the entries and a 30-foot bleed hole in each intersection be maintained. These bleed holes are in the present mining plans and were discussed at length with company officials as a means to relieve the gas pressures in the immediate roof. The drill hole spacing should be helpful in relieving gas pressures unless the gas pockets are confined in extremely small areas above the roof. No known data exists on the size or extent of these gas pockets. If one or more roof falls are encountered in the future from these trapped gases then other methods of detecting and bleeding gases would be necessary. Seismic, infrared, and/or advance drilling could be considered as a means to detect and bleed off the trapped gases.

It is recommended that the 2-foot roof bolts currently used in this mine be phased out of the mining plan. The 2-foot bolts are too short to build an effective "beam" across an entry which is over 20 feet wide. The present use of the 2-foot bolts in holding localized loose slabs could be done with longer bolts and the longer bolts would be much more effective in creating a competent roof.

It is recommended that the underground booster fans be located so that the dead-ended active entries will receive circulating airflow whenever miners are working or are present in a dead-ended entry. Discussion with company officials indicated they are revising their booster fan movement cycle to assist in keeping the air circulating to the active working faces.

M. L. Ellickson

M. L. Ellickson

Approved:

Edward E. Hollop date: 5/24/76

Edward E. Hollop, Chief
Ground Support Branch

APPENDIX C

[illegible]

SK-2
S-2
5-75

STATE OF NEW MEXICO
INSPECTOR OF MINES DEPARTMENT
505 Marquette, N.W., Room 1103
Albuquerque, New Mexico 87101

REPORT OF GROUND FALL
EDDY MINE, NATIONAL POTASH COMPANY
I.D. No. 2900172
ON NOVEMBER 27, 1974

INTRODUCTION

On the Wednesday afternoon shift at approximately 8:40 p.m., November 27, 1974, a strong sudden airblast hit the North pillar section throwing the miners down or about their equipment followed almost instantaneously by falls of large salt slabs from the backs or roofs of entries and pieces of various sizes from the ribs or sides. This caused numerous injuries to eleven employees, most of which were abrasions and cuts. Results were one serious injury and seven other lost-time injuries, two of which were only one day lost.

GENERAL INFORMATION

The mine is owned and operated by National Potash Company and is located approximately 16 miles east of Carlsbad, New Mexico via Hwys. 62-180.

Company officials: Charles Cable, Resident Manager
Paul Brewer, Mine Superintendent
Harry Bibby, Maintenance Superintendent
Carl Giaudrone, Assistant Mine Superintendent

Employment: 126 total
121 underground

Work schedule: 8 hour shifts
3 shifts per day
7 days per week

EXTENT OF INVESTIGATION ON NOVEMBER 27, 1974

The company notified Joe D. Longacre, Sr., State Inspector of Mines, soon after the accident occurred, but Mr. Longacre was unable to contact the writer. Mr. Longacre called Mr. John E. Brosky, Deputy Inspector of Mines, Electrical and Mrs. Brosky informed Mr. Longacre that Mr. Brosky had heard about the accident and was on his way to the mine. Mr. Longacre was in constant contact (by telephone) with company officials during the rescue work.

The writer was gone from his home for a few hours the evening of the accident and became aware of it on a state-wide newscast at 10 p.m. after phoning Mr. Brosky's home and being informed he had gone to the mine about 9:15 p.m. The writer proceeded to the mine. The last ambulances were enroute to town at that time.

Upon arrival at the mine office and after contacting Joe D. Longacre, the inspection party proceeded underground with the following persons:

T. G. Ferguson, Engineering Consultant
Paul Brewer, Mine Superintendent
Harry Bibby, Maintenance Superintendent
Carl Giaudrone, Assistant Mine Superintendent
Tommy Williams, Surface General Superintendent
John E. Brosky, Deputy Inspector of Mines, Electrical
Robert A. White, Deputy Inspector of Mines

The writer and the inspection party proceeded to the North Section where the pillar extraction had been underway. All of that crew had been sent out to the hospital at this time and the South Section crew and several supervisors had just finished with a number of roof props (stulls), some of which were installed to recover the loader operator trainee who was under the tail boom of the loader with several large salt slabs over it. After all injured persons had been removed and sent to the hospital, the South crew had started to recover the shuttle car which had large slabs on it. The area was checked, the air was tested for oxygen and explosive gases and the falls were charted, as much as could safely be done. Then the miners went off shift and the inspection party, after checking the entire section and ventilation and main blowers, decided that the 12 midnight shift could go to work in the South section and the North Section would be made safe for recovery of equipment to pull back and start a new section on advance. No further mining would be done in the pillar section. Each mine section has its own separate ventilation.

On December 2, 1974, an investigation of the scene of the accident was made. The inspection party was as follows:

Paul Brewer, Mine Superintendent
Carl Giaudrone, Assistant Mine Superintendent
Tom Castor, Mining Enforcement & Safety Administration Mine Inspector
Donald Morris, Mining Enforcement & Safety Administration Mine Inspector
Robert A. White, Deputy Inspector of Mines

The writer and the inspection party proceeded to the North Section where the crew had repaired the equipment and started advance mining in a new section back from the pillar extraction areas. The roof falls had not changed particularly and were all dangered off. Several bottle samples of air were taken by Mr. Morris for analysis. Two members (Messrs. R. Mitchell and W. Lester) of the crew that were in the accident were interviewed.

DESCRIPTION OF THE ACCIDENT

The crew in North Section on evening shift November 27 were as follows:

Robert Mahaffey, section boss, one day lost time
Sammy Collins, instructor for loader, serious injuries, in hospital (still off)
James Howard, driller, lost time, still off 12-2-74
L. Barnett, shotfirer, lost time, still off 12-2-74
R. Rascon, shuttlecar operator, lost time, still off 12-2-74

North Section crew (cont'd.):

Tony Lujan, loader operator, lost time, still off 12-2-74
Thomas Gere, dozer operator, lost time, still off 12-2-74
Ronald Geckler, shuttlecar operator, lost time, one day
R. Hinojosa, repairman, no lost time
W. Lester, driller, no lost time
R. Mitchell, cutter operator, no lost time

According to interviews, statements and observations, as far as can be determined, there was apparently a large fall in the older mined-out sections which caused an airblast and blew the men about and caused a sudden shift of weight over the working section. This caused considerable roof falls and crushing of ribs, pulling roof bolts out or snapping them off. Fortunately, the equipment caught the major portions of salt slabs and kept most of the men from being injured more seriously.

Statistics pertaining to the one serious injury at the Eddy Mine:

Sam Collins, birthdate 9-28-52
Social Security 302-50-7268
Married, one son
Mining experience: coal mining West Virginia underground, February 1971 to 1974; underground potash mining March 1974 to present

RECOMMENDATIONS

At the time of the next pillar extraction in this mine, the roof conditions will be closely examined to determine what type of control will be used. Some of which may be use of headboards on roof bolts, checking roof bolts that were installed during the advance mining, retorquing if necessary and the use of timbers, T stulls, etc., by the miners working in the pillar mining.

ACKNOWLEDGMENT

The cooperation and consideration of officials and employees and union representatives are acknowledged.

Investigated and Reported by:
Robert A. White
Deputy Inspector of Mines

Approved: Joe D. Longacre Sr.
JOE D. LONGACRE, SR.
State Inspector of Mines

Ferguson
Fulton
Mesa
Kirk

STATE OF NEW MEXICO
INSPECTOR OF MINES DEPARTMENT
505 MARQUETTE, N.W., ROOM 1103
ALBUQUERQUE, NEW MEXICO 87101

5-9-74

SAFETY FIRST

JOE D. LONGACRE, SR.
STATE INSPECTOR OF MINES

OFFICE TELEPHONE 842-3055
RESIDENCE PHONE 344-1129

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SAFETY
REPORT OF INSPECTION

I.D. No. 2900172 — Typed April 18, 1974

Eddy Mine (National Potash Company)	Mine	April 1, 1974
(Name)		(Date of Inspection)

Potash	Eddy	
(Classification of Mine)	(County in which located)	(Company representative present at inspection)

Pursuant to the Mining Laws of the State of New Mexico, Section 63-4-8, an inspection, as designated above, has been made. During this inspection the following was noted:

GENERAL INFORMATION

The mine is owned and operated by National Potash Company and located approximately eighteen (18) miles east of Carlsbad, New Mexico, via U. S. Routes Nos. 62-180.

Employment: 16 salaried
98 hourly

Work schedule:
Hours per shift 8
Shifts per day 3
Days per week 7

Company officials:
T. G. Ferguson, president
Paul Brewer, mine superintendent
Carl Gladrone, assistant mine superintendent

This report is the last of a series of inspections made in the North Section of National ~~Potash Company's Eddy~~ Eddy Mine where a floor break released trapped gases on or about December 16, 1973 of which methane gas was being emitted from at least one floor bleeder at 15.94%. (See analyses report dated 12-20-74.)

Periodic inspections and readings have been made and recorded by the Deputy Inspector of Mines of New Mexico and Metal and Nonmetal Mine Inspector of M.E.S.A., Mr. Donald K. Morris. Management made and recorded the readings at least once every eight hours. Field equipment and vacuum bottles were used. (See analyses reports for bottle samples.)

On February 24, 1974, an area of bottom fell and shortly after the fall, methane gas as well as others started diminishing. On February 25, 1974, the bottle analyses report showed methane to be from .01 - .04% and on March 11, 1974, the bottle analyses report showed methane to be 0.00 at four different locations.

On April 1, 1974, a complete tour of the area was made by Messrs. Donald Morris, Metal and Nonmetal Mine Inspector, Paul Brewer, Mine Superintendent, and Sidney R. Kirk, Deputy Inspector of Mines. By field instruments, no methane nor CO could be

JOE D. LONGACRE, SR.
State Inspector of Mines

found. Three vacuum bottles were taken and sent to the United States Bureau of Mines Laboratory at Mount Hope, West Virginia.

CONCLUSION

Since methane and carbon monoxide gases have diminished (since falling of the flooring of the mine where gas was being emitted), it was the opinion of the investigating parties that since there no longer appeared to be any danger, the area of the mine should be released to permit the regular mining cycle.

RECOMMENDATIONS

A routine check for methane shall be made at least once every twenty-four hours. If there are any detection of gases or significant changes in the normal mining pattern, management will notify the State Inspector of Mines or his representative.

ACKNOWLEDGMENT

The courtesy and cooperation extended are hereby gratefully acknowledged.

Inspected and Reported by:
Sidney R. Kirk
Deputy Inspector of Mines

Approved: [signature]
JOE D. LONGACRE, SR.
State Inspector of Mines

Harrison
Morris
Kirk

STATE OF NEW MEXICO
INSPECTOR OF MINES DEPARTMENT
505 MARQUETTE, N.W., ROOM 1103
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JOE D. LONGACRE, SR.
STATE INSPECTOR OF MINES

SAFETY FIRST

OFFICE TELEPHONE 842–3055
RESIDENCE PHONE 344-1129

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5-AR-2

SAFETY

REPORT OF INSPECTION

I.D. No. 2900172
Eddy Mine (National Potash Company) — Mine — Typed March 6, 1974 — February 25, 1974
(Name) (Date of Inspection)

Potash — Eddy
(Classification of Mine) (County in which located) (Company representative present at inspection)

Pursuant to the Mining Laws of the State of New Mexico, Section 63-4-8, an inspection, as designated above, has been made. During this inspection the following was noted:

GENERAL INFORMATION

Employment: 16 Salaried
98 Hourly

Work Schedule:
Hours per shift 8
Shifts per day 3
Days per week 7

Company Officials:
T. G. Ferguson, President
Paul Brewer, Mine Superintendent
Carl Giaudrone, Assistant Mine Superintendent

This report covers a return inspection of the Eddy Mine where the bottom heaved and burst, and was permitting trapped gases to enter the mine atmosphere. (See report of December 20, 1973.

The investigating party was as follows:

National Potash Company
Paul Brewer, Mine Superintendent

M.E.S.A.
Donald K. Morris, Metal and Nonmetal Inspector

State of New Mexico
Sidney R. Kirk, Deputy Inspector of Mines

The mine is located approximately eighteen (18) miles east of Carlsbad, New Mexico, via U. S. Routes Nos. 62-180.

The mine is opened by two vertical shafts of approximately eight hundred (800) feet deep and sixteen feet in diameter.

The production shaft is also used for intake ventilation.

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State Inspector of Mines

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The man and materials shaft is used also for exhaust ventilation with main exhaust fans being located underground near the shaft bottom.

Conventional mining, room and pillar extraction, cut, drill, blast, loading, shuttle car haulage to conveyor belt; the ore is transported from that point to the shaft bottom by conveyor belt, then hoisted to the surface where it is loaded into railroad cars and transported to the refinery.

The north section where the floor breaks appeared, was in recovery cycle.

A map at the State Inspector of Mines office shows all bleeders and percentage of gases being released. (See investigation report of December 20, 1973, for complete readings of each working pillar and ventilation streams.)
Findings during investigation of February 25, 1974, an area of bottom approximately 230 feet by 230 feet had fallen down into what would appear to be an underground cavern.

(By rechecking location of the bleeders of gases it would appear this cavern is very possibly where the gases were entrapped.)

The bottom had fallen what appeared to be a distance of some thirty to forty feet down. Some pillars were hanging from the roof yet and some had submerged with the floor.

A roof fall of approximately six to eight feet thick had also fell at one intersection in or very near the center of the area of floor fall.

The following indicates bottle samples taken, ventilation readings, and methane percentages as shown on the methane detector used by Mr. Donald K. Morris, Metal and Nonmetal Inspector, M.E.S.A.

Total Exhaust:
Location: near fan at shaft bottom
Area: 108 x 1421 = 153,468 c.f.m.
No. 1 and No. 4 bottle sample taken here
Detector of CH_4 = 0

Exhaust of first left off second west, north section:
Location: No. 7 entry at 33+00 B.T.
Area 161 x Velocity 180 = 28,980 c.f.m. with booster fan off.
Detector of CH_4 = 0.1%

Intersection of Nos. 1 and 2 entry at 9+30 B.T.
Detector of CH_4 =0.1%
No. 2 bottle sample taken at this location

Room No. 5 at 9+30 B.T.
Detector of CH_4 = 0.2%
Bottle sample No. 3 taken here

Several other areas were checked for methane all along the perimeter of the bottom cave area and only a trace to 0.1% of CH_4 was detected.

Tests were also made for carbon monoxide with colorimetric testers but none showed on stain.

The bottle samples will be sent to the United States Bureau of Mines laboratory at Mount Hope, West Virginia by Mr. Morris. A copy of analysis report will be submitted to the State Inspector of Mines Department.

A weekly report and check will be made by the same partie's until all gases have been emitted from the area.

On behalf of management of the National Potash Company:

Since the day of the first bleeder being located, the management has had a scheduled fire boss report and record of gases in the area. (Records can be seen at mine office.) Management has also kept the writer informed of these and any other events at the mine.

A copy of the area map, bottom fall, and gas samples by bottles is attached to inspection report.

ACKNOWLEDGMENT

The courtesy and cooperation extended are hereby gratefully acknowledged.

Inspected and Reported by:
Sidney R. Kirk
Deputy Inspector of Mines

Approved: ....

JOE D. LONGACRE, SR.
State Inspector of Mines

Fulton
Meza
Kirk

STATE OF NEW MEXICO

INSPECTOR OF MINES DEPARTMENT
505 MARQUETTE, N.W., ROOM 1103
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SAFETY FIRST

E. D. LONGACRE, SR.
STATE INSPECTOR OF MINES

V1-9-74
SR-1 Mess-20
622 AR-4

OFFICE TELEPHONE 842-3055
RESIDENCE PHONE 344-1129

SPECIAL REQUEST
REPORT OF INSPECTION

I.D. No. 2900172 — Typed December 28, 1973

Eddy Mine (National Potash Company) (Name) — Mine — December 20, 1973 (Date of Inspection)

Potash (Classification of Mine) — Eddy (County in which located) — (Company representative present at inspection)

Pursuant to the Mining Laws of the State of New Mexico, Section 63-4-8, an inspection, as designated above, has been made. During this inspection the following was noted:

GENERAL INFORMATION

The mine is owned and operated by the National Potash Company and located approximately eighteen miles east of Carlsbad, New Mexico via U. S. Routes 62-180.

Employment: 16 salaried
98 hourly

Work schedule:
Hours per shift 8
Shifts per day 3
Days per week 7

Company officials:
T. G. Ferguson, president
Charles Grosso, mine superintendent
Paul Brewer, assistant mine superintendent
Harry Bibby, maintenance superintendent

Prior inspection: 9-18-73

This report covers an investigation of the North Section of the Eddy Mine where the bottom heaved, broke and was permitting trapped gases to enter the mine atmosphere. The writer was notified by management on December 18, 1973.

The investigating party was as follows:

National Potash Company
T. G. Ferguson, President
Charles Grosso, mine Superintendent
Paul Brewer, Assistant Mine Superintendent

State of New Mexico
Sidney R. Kirk, Deputy Inspector of Mines

The mine is opened by two shafts approximately 800' deep and 16' in diameter. The production shaft is also used for intake ventilation. The man and materials shaft is used as exhaust shaft with fans mounted underground near shaft.

The mine is operated by room and pillar method. Conventional mining, drilling, cutting (bottom cut), blasting, loading and shuttle car haulage to a conveyor

JOE D. LONGACRE, SR.
State Inspector of Mines

ONE COPY OF THIS REPORT SHALL BE POSTED IN A CONSPICUOUS PLACE AT THE MINE belt; the ore is transported from that point to the shaft bottom by conveyor belt and then hoisted to the surface where it is loaded into railroad cars and transported to the refinery.

The North Section where floor-breaks appeared was in the recovery cycle. A map on file in the office of the State Inspector of Mines office shows bleeders and percentages of gas being released.

Ventilation readings and methane gas test percentages:

Intake ventilation (North Section)
Location: Between B.T. 8+15 and 9+30 B.T. in room No. 1 north
Area 26'x7 = 182 x Vel. 272 = 49,504 c.f.m.
Time: 9:15 am
Methane (CH_4) = 0

Working faces (B block - pillar block)
Room No. 1, B block
Time: 9:07 am
CH_4 = 1.1%

Room No. 2, B block
Time: 9:04 am
CH_4 = 0.4%

Room No. 3, B block
Time: 9:02 am
CH_4 = 0.2%

Room No. 4, B block
Time: 8:59 am
CH_4 = 0.9 - 1.0%

Room No. 5, B block
Time: 8:56 am
CH_4 = 0.9%

Room No. 6, B block
Time: 8:50 am
CH_4 = 0.5%

Room No. 7, B block
Time: 8:46 am
CH_4 = 0.5%

Room No. 8, B block
Time: 8:43 am
CH_4 = 0.4%

Room No. 9, B block
Time: 8:40 am
CH_4 = 0.5%

Room No. 10 at A block
Time: approx. 8:38 am
CH_4 = 0.5%

North Section exhaust ventilation, Split A
Location: No. 10 north room at No. 9+30 B.T.
Time: 8:35
Area 7'x26' = 182 x Vel. 167 = 30,394 c.f.m.
CH_4 = 0.5%

Split B
Location: No. 7 south room at No. 32+40 B.T.
Area 22'x7' = 154 x Vel. 185 = 28,490 c.f.m.
Time: 9:35 am
CH_4 = 1.0%

Total mine exhaust near fans at bottom of man-material shaft
Area 136 x Vel. 1,501 = 204,136 c.f.m.
CH_4 = 0.2%

All methane readings were taken on a P-2 methane detector.

Bleeders of gases and locations:

1. In floor of room No. 2 inby corner, time 9:18 am
   CH_4 at bleeder outlet 0.5%
   CH_4 in roof near outlet area 0.5%

2. In floor of 9+30 B.T. between Nos. 3 and 4 room, time 9:20 am
   CH_4 at bleeder outlet 0.5%
   CH_4 in roof near outlet 0.1%

3. In floor at 11+60 B.T. in room No. 5 north, time 9:27 am
   CH_4 at outlet 2.2%

4. In floor of No. 11+60 B.T. between rooms Nos. 6 and 7 north, time 9:48 am
   CH_4 at outlet 1.4%

With all tests made and readings recorded, the management was requested to stop this section (first left off 2nd west, north section) and pull all equipment out to an area where none of the escaped gases would pass through or over an active part of mining. Mr. Joe D. Longacre, Sr., State Inspector of Mines, was notified via telephone at approximately 8:30 a.m. on December 21, 1973 of events and will issue further instructions.

Three bottled samples were mailed to the State Inspector of Mines on December 21, 1973 and forwarded to M.E.S.A. for laboratory analysis.

The courtesy and cooperation extended by management are hereby gratefully acknowledged.

Inspected and Reported by:
Sidney R. Kirk
Deputy Inspector of Mines

Approved: Joe D. Longacre Sr.
JOE D. LONGACRE, SR.
State Inspector of Mines

Send copy To Mr. Kirk & Mass
Sent 1-14-74 abw

TABLE 1 - ANALYSES OF AIR SAMPLES COLLECTED December 20, 1973

MINE Eddy COMPANY National Potash Co. COLLECTED BY Sid Kirk

BOTTLE NUMBER	LOCATION IN MINE	PERCENT IN VOLUME					CUBIC FEET AIR PER MINUTE	CUBIC FEET METHANE IN 24 HOURS
		CARBON DIOXIDE	OXYGEN	METHANE	CARBON MONOXIDE	ETHANE		
NPC No. 1	floor bleeder A-Block, No. 5 at 11 + 60	0.03	11.98	15.94	0.0006	0.80		
NPC No. 2	No. 10 room at 9 + 30	sample destroyed in transit						
NPC No. 3	No. 7 room at 18 + 30	.05	20.77	0.23	.001	.00		

THE PERCENTAGE OF NITROGEN CAN BE DETERMINED BY SUBTRACTING THE SUM OF THE REPORTED VALUES FROM 100.00

January 7, 1974

Mr. Longacre:

The attached results of samples did not have company name nor collected by. The typed data is all that was on the air sample cards.

Lab Office,
Mount Hope, West Virginia

APPENDIX D

Summary

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
HEALTH AND SAFETY ACTIVITY

INVESTIGATION INTO THE OCCURRENCE OF GAS PRESSURE ABOVE THE FIRST AND TENTH ORE ZONES IN THE POTASH DISTRICT, CARLSBAD, NEW MEXICO

December 3, 1963 through March 5, 1964

By

Peter A. Rutledge, Mining Health and Safety Engineer
E. A. Morgan, Subdistrict Supervisor
Julian Kennedy, Mining Health and Safety Engineer

Originating Office - Bureau of Mines
5043 Federal Building - Phoenix 25, Arizona
E. A. Morgan, Subdistrict Supervisor

INVESTIGATION INTO THE OCCURRENCE OF GAS PRESSURE ABOVE THE FIRST AND TENTH ORE ZONES IN THE POTASH DISTRICT, CARLSBAD, NEW MEXICO

December 3, 1963 through March 5, 1964

INTRODUCTION

This report summarizes the investigation of the occurrence of gas pressure above the ore zones at six mines in the potash district, Carlsbad, New Mexico. Individual reports have been submitted for each mine investigated.

Four of the mines were mining sylvite from the first ore zone, one was mining sylvite from the tenth ore zone (located about 200 feet above the first ore zone[1]), and one was mining sylvite from the first ore zone and langbeinite from the fourth ore zone. Tests at this last mine were confined to the first ore zone. Cover ranged from about 883 feet to 1698 feet. Four mines were being worked by a room-and-pillar system, and two mines by a retreating panel system.

Test areas were selected for their physical characteristics, and the probability of finding gas pressure. Areas investigated ranged from newly mined sections to sections that had been open up to 26 years. Pillars had not been extracted in any of the test areas; however, at three mines the test areas were adjacent to sections where pillars had been extracted. At one mine pillars showed evidence of weight, and three old roof falls were observed.

At all the mines investigated, programs of drilling holes to relieve gas pressure were in operation. Methods varied from drilling 40-foot verticle holes in every intersection to drilling occasional inclined holes which released any pressure within a few feet of the back. At several mines, holes for rock bolts, in and between intersections, relieved any pressure within 6 feet of the back.

EQUIPMENT

Holes were drilled in the back with roof bolting machines, using sectionalized auger steel and tungsten carbide-tipped fishtail bits. Three-inch diameter holes for the stratascope were drilled with special one-pass bits, or small holes were enlarged with a locally designed reamer.

Rock strata was observed with a stratascope on loan from the Bureau of Mines Roof Control Research Group. The stratascope consisted of a sectionalized periscope equipped with a light in the head of the instrument for illumination.

1. C. L. Jones, C. G. Bowles, and A. E. Disbrow, Generalized Columnar Section and Radioactivity Log, Carlsbad, Potash District, 1954.

Four sections of 5-foot tube allowed observations to be made as far as 20 feet into the hole; however, as the optics in this instrument did not provide progressive magnification of the image as additional sections of tube were added, a very small image was obtained at 15 to 20 feet. The stratascope was equipped with a camera.

Gas samples were obtained with an aspirator bulb and tubing and collected in vacuum bottles. A packer and pressure gage assembly was used to measure gas pressure. A dial gage, capable of detecting movement of 0.001 inch, was used to determine roof movement when gas pressure was released. Velocity of gas escaping from drill holes was measured with a velometer capable of reading to 9,000 feet per minute.

PROCEDURE AND DATA

At the six mines investigated, a total of 169 vertical holes were drilled from 20 to 40 feet into the roof; 115 of the 169 holes were drilled in intersections. Gas under pressure was found in 67 (58 percent) of the intersections drilled. A total of 91 "blows" were encountered; 15 were in intersections containing gas at 2 elevations above the back; and 4 were in intersections containing gas at 3 elevations above the back. Forty-eight holes were in intersections containing gas at 1 elevation. Gas pressure was released in only 1 of the 42 holes drilled between intersections. This "blow" was classed as light and the gas appeared to have been released from a salt layer.[1] In order to determine if one hole relieved all the gas pressure in an intersection, 12 additional holes were drilled in 10 intersections. None of these additional holes released gas pressure.

Thirty-three holes were examined with the stratascope in order to determine the characteristics of the roof and the location of gas-bearing strata. At one mine the roof strata was examined without instruments in two raises driven to a height of about 11 feet above the back. Locations of mud and polyhalite seams in the roof, as determined by observation of drill cuttings, agreed closely with locations determined by the other methods. In all mines except one, the 20 feet of strata above the back contained two or three mud seams and a polyhalite seam. The polyhalite seam was not observed in mine "F"[2]. Most mud seams were made up of interbeded salt and mud, and the polyhalite seam was composed of interbeded salt and polyhalite. Thin mud bands were generally present at the top and bottom contacts of the polyhalite layer and salt members. The mud and polyhalite seams were found to be continuous over each area investigated, and were probably continuous over considerably larger areas. At one mine, openings up to two inches in thickness were found in the first and second mud seams. This area had been opened approximately 20 years prior to this investigation, and gas pressure was not found in these mud seams.

1. A "blow" is classed as light when the release of pressure from a hole can be detected. A medium "blow" will clean the settled dust from the rotary head of the drilling machine. A heavy "blow" will clean the settled dust from the floor of an intersection.
2. See appendix 2 (list of mud seams)

Eighty-seven of the 91 "blows" encountered came from the mud seams, or mud bands at the contacts of the polyhalite band and salt. Seventeen holes, which produced 19 of the 87 "blows", were examined with the stratascope. The examination of the holes revealed that the gas emitted from the mud seams or mud bands which contained small vuggs, about 0.1 inch in diameter, connected by hairline cracks.[1] This pattern was found in every examined hole that "blew". Three holes produced light "blows" from salt members, and stratascope examination of one of these three holes revealed that gas emitted from a small vugg, 0.1 inch in diameter, in a zone of what appeared to be coarse salt crystals.[2] One hole produced a light "blow" from small pin holes in a polyhalite band.

A series of 4 holes were drilled in 1 intersection to determine the lateral extent of vuggs and hairline cracks. The first hole relieved gas pressure at the contact between polyhalite and salt. Examination of this hole showed that the gas was released from 0.1-inch diameter vuggs connected by hairline cracks. The second hole drilled 18 inches from the original hole did not release gas; however, vuggs and hairline cracks were visible at the same elevation as in the original hole. The third hole was drilled near the pillar line, 16 feet 6 inches from the original hole. Gas was not released but vuggs and cracks were visible. The fourth hole was drilled 35 feet from the original hole, and 8 feet outside of the intersection; no gas pressure was detected, and no vuggs and cracks were visible in this hole.

In order to determine whether gas was present in areas other than intersections, a series of 5 holes on 20-foot centers were drilled into the roof between 2 intersections that had produced "blows". None of the 5 holes released gas. Since the possibility existed that holes drilled in intersections could have relieved any gas pressure in the area between intersections, a series of holes were drilled in rooms and breakthroughs before drilling the intersections. None of the holes in the rooms and breakthroughs relieved gas pressure; however, 6 holes in 6 of the intersections produced "blows".

Gas pressure in one hole in the center of an intersection was sealed in, by means of the packer and gage, and pressure built up to 50 psi. A second hole drilled 20 feet from the original hole, and 6 feet outside of the intersection, did not reduce the pressure in the original hole. Another hole drilled in the intersection, 7 feet from the original hole, relieved the pressure in the original hole.

From the data collected during this investigation, no explanation can be offered as to why only certain intersections contained gas. Mud seams must have a certain degree of permeability to permit gas to collect in intersections;

1. See appendix 1.
2. See appendix 1, photograph No. D2

however, the permeability must be very low, or significantly reduced by pressure due to mining as attempts to relieve gas pressure from intersections by drilling in rooms and breakthroughs did not produce any noticeable results.

The back could be heard "working" when gas pressure was released through drill holes. Measurements with a dial gage indicated that the back moved upward when gas pressure was released.[1] Roof movement ranged between 0.001 and 0.030 inches when "blows" were encountered from 2 feet to 17 feet above the back. The maximum movement of 0.030 inches was observed when 3 "blows", at elevations above the back of 5 feet 9 inches, 9 feet, and 10 feet 6 inches, were relieved with a single drill hole. The upward movement of the roof took place rapidly, and the total rise apparently depended on the volume of gas relieved and height above the back of the gas-bearing strata.

Direct readings of gas pressure were difficult to obtain due to the short duration of the "blows" and the time required to remove drill steel from a hole; however, three pressure readings were obtained in 3 separate holes.[2] These measurements were taken where gas was emitted from the mud band at the top of a polyhalite layer, and from the second mud seam. All 3 "blows" were classed as light; however, a pressure of 60 psi was recorded at one hole. Pressure built up rapidly after the packer was installed, reached a maximum within 20 minutes, then dropped off very slowly, probably due to leakage around the packer and/or leakage into the lower mud seams. It is believed that the pressures measured were only a fraction of the original pressures in the intersections, due to the volume of gas lost while removing the drill steel and setting the packer.

Fourteen vacuum-bottle samples were taken by aspirating gas out of plugged holes which were still "blowing" at the time of sampling.[3] Thirteen of the analyses indicated that the gas was not explosive. Sample W-1588 contained 9.24 percent effective combustible material[4] and would become explosive, over a limited range, when mixed with air.[5] The gas represented by this sample did not create a hazard due to the short duration of the "blow" and the rapid dilution in the ventilating current.

Velometer readings could not be used to calculate initial pressures due to the high velocities of the escaping gas, the presence of the drill steel in the holes, and the time necessary to "blow" out the cuttings. "Blows" classed as approaching medium had velocities in excess of 9,000 feet per minute.

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1. See appendix 3.
2. See appendix 4.
3. See appendix 5.
4. Effective combustible equals percent methane plus 1.25 times percent hydrogen plus 0.4 times percent carbon monoxide.
5. M. C. Zabetakis, R. W. Stahl, and H. A Watson, Determining the Explosibility of Mine Atmospheres, Bureau of Mines Information Circular 7901, 1959, 11 pp.

SUMMARY

1. Gas under pressure was found primarily in 3 mud seams, and in mud bands at the top and bottom contacts of polyhalite layers.

2. Gas pressure in mud seams or bands was confined to intersections. Gas between intersections was found in only 1 hole where it occurred in a small pocket in the salt.

3. Mud and polyhalite seams were continuous over each area investigated.

4. Where gas occurred in mud seams or bands in intersections, it emitted from small vuggs 0.1 inches in diameter connected by hairline cracks. The vuggs and cracks were observed to be distributed through out the area of the intersections, and one hole was sufficient to relieve all pressure to the depth drilled.

5. All "blows" encountered were classed as light or medium, and were of short duration. The volume of gas released appears to be consistent with that volume which could be expected to be confined in the vuggs and cracks in the area of an intersection. Large pockets of gas were not found during this investigation.

6. Analyses of vacuum-bottle samples showed that gas emitting from roof strata, with one exception, was nonexplosive. One sample indicated that gas emitting from the third mud seam at 1 mine would become explosive, over a very limited range, as the gas was diluted with air; however, the gas represented by this sample did not create a hazard due to the short duration of the "blow" and the rapid dilution in the ventilating current.

7. Direct readings of gas pressure indicated that initial pressure in mud seams can be greater than 60 psi.

8. In the intersections that were measured, the back rose from 0.001 to 0.030 inches when gas pressure was released.

9. "Blows" classed as approaching medium had velocities in excess of 9,000 feet per minute.

10. Gas pressure in the roof strata has a definite effect on the roof, as evidenced by measurements of gas pressure and the rise of the back as pressure was relieved.

11. During this investigation, the relief of gas pressure through small diameter drill holes did not present an explosion hazard.

12. Determination of initial formation pressures, and the pressures necessary to cause failure of the roof were beyond the scope of this investigation; however, this inf rmation could be of considerable value to the parties involved.

CONCLUSION

The information obtained during this investigation indicates that stress on the immediate roof strata due to gas pressure may be relieved by drilling 10 to 20-foot deep vertical holes in each intersection, as soon as practicable, after first mining while ventilation is still intact.

Means should be provided to sample the atmosphere in the vicinity of the drill holes for total combustible content in the event of an unusually long or violent "blow".

ACKNOWLEDGMENT

The cooperation of the management and employees of the International Minerals and Chemical Corporation, the National Potash Company, the Duval Corporation, the Potash Company of America, and the United States Borax and Chemical Corporation, is gratefully acknowledged.

Respectfully submitted,

Peter A. Rutledge

Peter A. Rutledge
Mining Health and Safety Engineer

E. A. Morgan

E. A. Morgan
Subdistrict Supervisor

Julian Kennedy

Julian Kennedy
Mining Health and Safety Engineer

APPENDIX

1. Photographs
2. Average location and thickness of mud seams and polyhalite seam
3. Dial gage readings
4. Pressure measurements
5. Gas analyses results

APPENDIX 2

Average Location and Thickness of Mud Seams and Polyhalite Seam Above the Back

MINE	First Mud Seam	Thickness	Second Mud Seam	Thickness	Polyhalite Seam	Thickness	Third Mud Seam	Thickness
A	3' 11"	0' 6"	5' 11"	1' 0"	18' 6"	2' 0"	(2)	-----
B	2' 2"	0' 6"	5' 4"	1' 6"	9' 5"	1' 6"	15' 7"	5' 0"
C	4' 5"	0' 6"	7' 10"	1' 6"	14' 0"	2' 0"	(2)	-----
D	0' 9"	0' 6"	2' 1"	0' 6"	3' 9"	0' 6"	9' 10"	1' 0"
E	2' 7"	0' 6"	6' 9"	1' 0"	7' 9" (3)	1' 0"	16' 2"	2' 6"
F	2' 2"	0' 9"	4' 8"	1' 0"	(1)	-----	15' 5"	3' 0"

(1) No evidence of a polyhalite seam was found within 20 feet of the back at mine "F".

(2) No evidence of a third mud seam was found within 20 feet of the back at mines "A" and "C".

(3) The polyhalite seam at mine "E" was located directly on top of the second mud seam.

APPENDIX 3

Dial Gage Readings

Hole	Strength of "Blow"	Rise of Back In Inches	Height Above The Back of Gas Bearing Strata
108	Light	.004	3' 0"
	Light	.002	6' 6"
	Medium	.007	9' 6"
113	Light		2' 0"
	Light	.007 Total Movement	5' 0"
114	Medium	.004	8' 9"
116	Light	.001	5' 6"
117	Light		3' 0"
	Light		6' 3"
	Light	.009 Total Movement	9' 6"
118	Light		5' 9"
	Light		9' 0"
	Medium	.030 Total Movement	10' 6"
202	Light	.015	14' 6"
203	Light	.003	17' 6"
310	Light		3' 2"
	Light	.006 Total Movement	9' 2"
312	Medium	.013	10' 11"
314	Medium	.010	10' 11"
315	Light	.002	9' 8"
318	Medium	.020	10' 11"
401	Light	.002	6' 9"
406	Medium	.018	8' 0"
407	Light		10' 6"
	Light	.005 Total Movement	17' 6"

Appendix 3 (Cont.)

408	Medium		6' 6"
	Light	.013 Total Movement	17' 0"
409	Light	.005	7' 0"
410	Light	.002	6' 0"
414	Light	.003	14' 0"
415	Light	.002	7' 6"
416	Light	.003	7' 6"
420	Light	.002	17' 0"
421	Light	.001	17' 0"
422	Light	.001	17' 0"
423	Light	.005	7' 0"
425	Light	.004	5' 6"
	Light	.002	9' 6"
428	Light		5' 9"
	Light	.005 Total Movement	15' 6"
512	Light		14' 0"
	Light	.002 Total Movement	17' 0"
513	Light	.003	16' 6"
514	Light	.006	16' 6"
515	Medium	.006	17' 6"
	Medium	.007	15' 0"
516	Medium	.008	17' 6"
517	Light	.002	17' 6"

APPENDIX 4

Pressure Readings

Hole	Strength of Blow	Height Above Back of Gas Bearing Strata	Maximum Pressure	Comments
416	Light	7'6"	30 psi	Reached 10 min. after packer was set
425	Light	9'6"	50 psi	Reached 20 min. after packer was set
429	Light	9'6"	60 psi	Reached 5 min. after packer was set.

APPENDIX 5

Gas Analysis Results

SAMPLE NO.	X351	X352	X367	X368	X349	X350	X338
Mine	A	A	B	B	C	C	D
Mud Seam No.	Poly[1]	Poly	Second	Second	Poly	Poly	2
Carbon dioxide	0.06%	0.08%	0.04%	0.04%	0.03%	0.05%	0.04%
Oxygen	1.15%	1.14%	0.56%	0.51%	1.79%	0.42%	0.96%
Hydrogen	-----	-----	1.26%	0.91%	0.00%	0.00%	1.57%
Carbon monoxide	-----	-----	-----	-----	-----	-----	0.05%
Methane	3.1%	2.6%	1.10%	1.42%	0.24%	0.21%	0.06%
Nitrogen	95.7%	96.2%	97.04%	97.12%	97.94%	99.32%	97.32%

1. Poly indicates mud slips at the contacts of the polyhalite band and salt members.
2. This "blow" emitted from a small vugg in the salt below the third mud seam.

Appendix 5 (Cont.)

Sample No.	X356	Z376	Z377	W1587	W1588	X334	X335
Mine	D	E	F	E	E	F.	F
Mud Seam No.	Third	Second	Second	Second	Third	Bottom of Third	Top of Third
Carbon dioxide	0.04%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Oxygen	1.28%	1.8%	6.0%	2.2%	0.4%	1.6%	0.8%
Hydrogen	1.30%	0.0%	0.1%	0.2%	3.6%	0.5%	0.4%
Carbon monoxide	0.04%	0.0%	0.0%	0.004%	0.11%	0.013%	0.012%
Methane	0.06%	3.2%	2.8%	3.8%	4.7%	0.8%	0.7%
Nitrogen	97.28%	95.0%	91.1%	93.8%	91.2%	97.1%	98.1%

APPENDIX E

AIR RELIEF RECORD

Size

small pop	☐	Crew	____________
Bang & blow	☐	Shift	____________
Rock Moved		Date	____________
Less than one cu. ft.	☐	Time	____________
Between 1 ft.^{3} and 4 cu. yd.	☐	Area	____________
More than 4 cu. yd.	☐		

Floor	☐	Full Pass	☐
Middle Mud	☐	Half Pass	☐
Top Mud	☐	Face	☐
Salt	☐	Rib	☐
		Smell	☐

Location

Room No./B.T. No.____

Distance & Direction from which intersection____________________________

Other/Comments____

____

____

____

Instructions

1. Mark only one box under Size, and one under Rock moved
2. Gas seeping from clay goes under Other/Comments
3. If rock moved, is larger than 1 cubic ft., notify the shift foreman who will notify general foreman