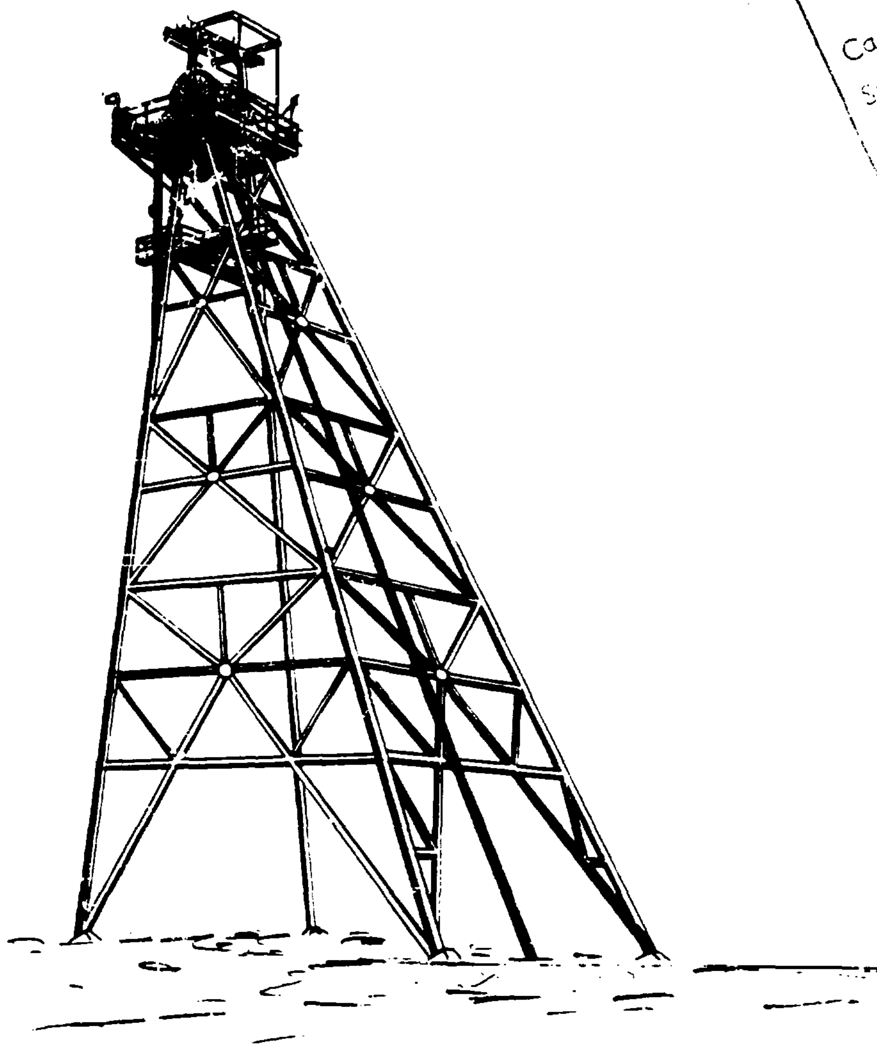
COMMENTS ON RULES FOR OIL AND GAS DRILLING IN THE POTASH BASIN EDDY COUNTY AND LEA COUNTY, NEW MEXICO

BEFORE THE
OIL CONSERVATION COMMISSION
Santa Fe, New Mexico
Case No. ______ Exhibit No. 4
Submitted by ______
Hearing Date ______



THE POTASH INDUSTRY
OF NEW MEXICO

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STATEMENT OF ISSUE AND AGENCY ACTION REQUESTED

Prepared by the New Mexico Potash Industry
April 15, 1992

I. Statement of Issue

Recent decisions of the Bureau of Land Management ("BLM") approving the drilling of oil and gas wells in the "Potash Area" near Carlsbad, New Mexico have increased significantly the safety hazards faced by underground miners in the Potash Area and have resulted in the unnecessary waste of over $450 million dollars in potash. In approving these oil and gas wells, the BLM has ignored, entirely, the provisions of an agreement reached by the Oil and Gas Industry and the Potash Industry on November 23, 1987 - almost five years ago - setting forth an agreed upon basis for the orderly and safe development of each industry's mineral resources despite the fact that this Industry Agreement, in significant respects, has been incorporated by BLM into a revised Secretarial Order signed on January 8, 1992, but not yet published in the Federal Register.

II. Impact on Potash Industry

Existing BLM policies and rules on the drilling of oil and gas wells in the Potash Area, which are set forth in the 1986 Order of the Secretary, 51 Fed. Reg. 39425 (October 28, 1986), do not reflect current knowledge of the hazards of methane gas to underground miners or the impact on mine operators of a release of methane gas into underground mine workings under the Federal Mine Safety and Health Act. Further delay, therefore, in the issuance of the revised Secretarial Order will adversely impact miner safety, result in the further wasting of valuable potash deposits, and expose mine operators to the possibility of having to implement more stringent - and prohibitively costly - safety requirements in the event methane gas is released into mine workings by oil and gas wells.

III. Agency Action Requested

Immediately publish the revised Secretarial Order in the Federal Register or adopt its provisions as a matter of policy until it can be published.

IV. Additional Information

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Comments of the New Mexico Potash Industry on Rules for Oil and Gas Drilling in the Potash Basin Eddy County and Lea County, New Mexico

EXECUTIVE SUMMARY

Introduction

The New Mexico Potash Industry welcomes this opportunity to comment on the 1991 proposed Order of the Secretary of the Interior regarding drilling for oil and gas within the Potash Basin of southeastern New Mexico.

These comments present the views of Eddy Potash Corporation, Horizon Potash Corporation, IMC Fertilizer, Inc., Mississippi Chemical Corporation, New Mexico Potash Corporation, Noranda Minerals, Inc. and Western Ag-Minerals Company, which together represent 85 percent of U.S. potash production. Collectively, these companies produce 100 percent of the potash mined in New Mexico and control 98.9 percent of the potash leases in the Basin. Accordingly, the views expressed in these comments reflect the position of the entire potash industry.

The potash industry strongly urges the implementation of the proposed Order of the Secretary of the Interior regarding "Oil, Gas and Potash Leasing and Development within the Designated Potash Area of Eddy and Lea Counties, New Mexico" (Federal Register, February 21, 1991). The Secretarial Order is crucial to establishing an orderly means of resolving conflicts arising from the occurrence of multiple natural resources within the Potash Area. It is vital to assuring safe working conditions for the underground mine work force and preventing undue waste of the potash resource. In the absence of the Order, needless waste of the potash resource has already occurred. If the Order is not implemented expeditiously, additional resources will be lost. Much more seriously, the entire potash industry could be jeopardized by the occurrence of even a single incidence of methane leakage into mine workings, as this event would force the implementation of unaffordable, stringent new safety regulations at least, or result in an underground mine disaster at worst. These regulations would require expenditures to retrofit mine electrical, mechanical and ventilation systems which would double the operating cost of mining potash. The encroachment of oil and gas drilling into the Potash Area could result in an underground explosion or hydrogen sulfide poisoning causing senseless loss of life.

Potash Industry Overview

Potash is an essential plant nutrient for which there is no substitute. The Potash Area of southeastern New Mexico contains the only potash deposits in the United States which can be produced by conventional mining methods. It accounts for approximately 85 percent of all domestic potash production.

Potash in the Basin is mined underground from bedded potash and salt deposits of the Salado Formation (Permian). Two ore minerals are produced. Sylvite (potassium chloride) is the more common mineral and is widely used as a source of agricultural potash, in drilling and fracturing fluids, and as a feed stock for other potassium chemicals. Langbeinite (potassium-magnesium sulfate) is a rare ore of potash which occurs commercially only in the Carlsbad area. It is a premium product which provides multiple nutrients and can be applied to soils which are chloride intolerant.

Conventional room and pillar and continuous mining methods are used in the Basin. A network of openings is made in the first stage of mining, leaving large pillars of ore for support. Toward the end of mining, earlier mined areas are re-entered and the pillars are removed, which leads to gradual subsidence of the ground over the ore deposit.

Ventilation of the underground working areas is supplied by large main fans which either push or pull surface air into the mine, where it is disbursed through the workings by booster fans. Air quality is obviously of high importance underground. Consequently, ventilation is strictly regulated by the Mine Safety and Health Administration.

In order to prevent explosion hazards, the methane concentration in each mine is carefully monitored. MSHA must be notified in the event air sample results indicate 0.25 percent or more methane in the mine atmosphere. The ventilation regulations are written such that if one mine in an area is found to have unacceptable concentrations of methane, all mines in the area will be regulated under the assumption that they, too, are potentially gassy. If methane concentrations were to exceed this amount, underground electrical, mechanical and ventilation systems would be required to be replaced with explosion proof systems. The industry simply does not have the resources to absorb such a capital outlay, nor can it recover the increased operating costs which would result.

Effects of Oil and Gas Activity on Potash Mining

The danger posed by oil and gas activity within the Potash Area is the potential for escape of methane or other petroleum gases into the mine workings. This could cause an explosion or, at a minimum, force abandonment of the workings owing to unsafe conditions.

The Salado Formation in the area of the nearby Hobbs Pool has been found to be charged with methane because of leakage from oil and gas wells. New Mexico subsequently established casing requirements designed to prevent recurrence of leakage. Unfortunately, casing alone cannot assure prevention of gas leakage into mine workings:

1. It is not known how closely to mine workings an oil or gas well can be drilled with assurance of safety. The petroleum and potash industry have jointly agreed to use one-half mile as a standard for deep oil and gas wells and one-quarter mile for oil wells less than 5,000 feet deep. Much research is needed to permit defining the "safe" distance more closely, particularly since ground conditions and the efficiency of casing can be expected to vary widely among individual wells. To drill more closely at present, would be to place human life at risk unnecessarily and could be interpreted as violating the intent of federal mine safety and health laws.

2. Casing programs cannot provide protection in the event of accidents. At least seventeen blowouts or oil-well fires have occurred in the area around the Potash Basin. It is a virtual certainty that others will occur from time to time.

3. Examples of oil migration into potash workings have already been documented. In the most serious of these, oil migrated 700 feet along mud seems from an improperly plugged well into the Eddy Potash mine. It should be clear that petroleum gases potentially can migrate much greater distances and in greater quantity than oil. Had the well been a high pressure gas well, the consequences could have been disastrous.

4. Practical experience has shown that it is unlikely that a casing and cementing program can give completely adequate assurance of protection against gas migration considering the enormity of the potential consequences. The occurrence of fractures and voids makes it difficult, at best to seal off formation fluids, particularly in salt or heavily fractured zones.

5. The occurrence of hydrogen sulfide can be predicted to have a highly corrosive effect on casing, which can lead to casing failure and leakage of both flammable and toxic gases long after the well has been abandoned.

Potential Effects on the Potash Industry

The potential effects of oil and gas hazards on the potash industry are significantly greater than they were when concurrent development of the two industries first began. In the 1950's, there were few safety requirements addressing flammable gases which were of economic consequence. Because of several mine disasters caused by flammable gases, significant changes in mine safety and health laws were made in 1959, 1969 and 1977. Each time the regulations became more stringent and the consequences of the presence of gas became more severe. Today, the consequences are such that a single release of flammable gas into any one mine could destroy the industry.

Under regulations promulgated pursuant to the federal Mine Safety and Health Act, non-coal mines will be regulated as gassy upon the finding of a single air sample containing 0.25 percent methane or some other flammable gas.

The direct consequence of such a finding would be that all mines in the Basin would be required to install supplemental ventilation; replace or modify equipment with explosion-preventing types; and replace most if not all electrical systems. In 1982, it was estimated that the capital cost of compliance with gassy mine regulations would be greater than $80 million and the operating cost would be doubled.

The economic consequences of oil and gas drilling have already been experienced through loss of reserves. The assets of the potash mining industry are contained mainly in its mineable reserves. Each encroachment of oil and gas drilling into the Potash Area measurably decreases the accessible potash resource. For example, recent drilling has advanced into the Potash Area along the eastern margin of the WIPP Site. The cumulative effect of seven wells during the last 2 years has been the loss of approximately 29 million tons of potash reserves with a gross value of about $450 million in the three ore zones present.

The financial effect of any single well proposal cannot be predicted with sufficient certainty. Owing to changes in market conditions and demand for products, mine plans change frequently. It is entirely within likelihood that what is a fringe zone today could be an important ore target in the near future. Using lower height mining techniques, one mine is now mining ores that were considered waste 5 years ago. Historically, the potash industry has mined ores that have ever decreasing potash grades.

Recommendations

The discussion above summarizes the hazards associated with oil and gas drilling in the Potash Basin. We, as an industry, firmly believe that the provisions of the 1986 Secretarial Order do not adequately protect our mines and miners from the hazards associated with oil and gas drilling in the Potash Basin. Several actions are available which, if taken, will promote the safety and well-being of the potash industry and lead to greater cooperation among all parties. Among these are:

1. **Implement Proposed Secretarial Order.** While not perfect in all respects, the proposed 1991 Secretarial order is the best vehicle available to protect the interests and orderly development of both industries. It is essential to protecting the safety of potash mines and miners. It has the advantage of reflecting the good faith effort of both industries to reach a mutually beneficial accord regarding drilling and mine development. We strongly urge that the new Secretarial Order be placed in effect without delay.

2. **Well Spacing and Studies of Gas Migration.** A spacing requirement (buffer zone) between oil and gas activities and ore deposits must be developed and implemented to ensure the safety of miners. The hazards involved are too great to rely solely on a casing and cementing program. The spacing requirement should consider the possible migration of gases as well as the spacing required to avoid damage from mining subsidence. The one-half mile buffer established by industry agreement is a current "best guess" regarding an appropriate spacing. Technical studies to better define the buffer requirements would serve to protect the valid interests of both industries.

3. **Responsibility for Actions.** There should be a clear recognition of liability for any damage caused by one industry to the other. For example, if a well is damaged by mining activity, the mine operator should be liable for any losses. Similarly, if a well releases hazardous gases which migrate into mine workings, the oil or gas operator should be liable for additional costs or loss of assets stemming from that release.

4. **Definition of Potash Resource.** Current procedures for identifying ore bodies and barren areas need to be improved to provide more guidance to both industries. In many instances commercial grade ore exists well beyond the boundaries of any existing potash leases or Life of Mine Reserves (LMR's). We believe the identification of these areas should be the shared responsibility of both industries. The BLM also has a major responsibility under federal law to conserve mineral resources.

5. **Directional Drilling Technology.** Increased use of directional and horizontal drilling should be promoted. The drilling technology available today virtually eliminates any technical limits on bottom hole displacement. Using this

capability, wells could be drilled from locations sufficiently removed from ore deposits that the attendant hazards would be reduced greatly. Any increase in costs, we believe, would be justified by the increased safety to miners. At the very least, the amount of potash known to exist should justify the additional cost of directional drilling.

6. **Increased Cooperation Between the New Mexico Oil Conservation Division and the BLM.** We believe that any real effort to address the hazards involved in oil, gas and potash production will require increased cooperation between the OCD and BLM. Because of the nature of the hazards involved, it is essential that whatever safety practices are adopted are applied equally on federal and state administered lands.

7. **Cooperation Between Industries.** It is in the best interests of both the petroleum and potash industries to work together to achieve orderly development of our resources and to protect each of our valid interests. The potash industry wishes to promote mutual trust and cooperation. We will work ability to establish mutual trust and good-faith relationships with the petroleum industry and the affected regulatory agencies.

COMMENTS OF THE NEW MEXICO POTASH INDUSTRY ON THE NEED FOR REVISIONS IN BLM POLICIES CONCERNING THE DRILLING OF OIL AND GAS WELLS IN THE POTASH AREA

I. Introduction

The New Mexico Potash Industry welcomes this opportunity to present its comments and recommendations to the Bureau of Land Management ("BLM") on the need for revision in BLM policies and rules governing the drilling of oil and gas wells in the Potash Area.

A. Unanimous Position of Potash Industry

The mine operators concurring in these Industry comments and recommendations are Horizon Potash Corporation, IMC Fertilizer, Inc., Eddy Potash Corporation, Mississippi Chemical Corporation, New Mexico Potash Corporation, Noranda Minerals, Inc., and Western-Ag Minerals Company, all of which have underground potash mining operations or potash properties in the Potash Basin near Carlsbad, New Mexico. Collectively, these companies produce 100% of all potash mined in New Mexico and hold 100% of the potassium leases granted by the State of New Mexico. They also hold 98.9% of all potassium leases in the Potash Basin, including both Federal and State. Accordingly, the views expressed in these comments clearly reflect the unanimous position of the entire Potash Industry.

B. Potash Industry Concerns Over Safety Hazards and Waste Created by BLM's Policies

Our concern with BLM's existing policies on the drilling of oil and gas wells in the Potash Area, simply stated, is that they have become obsolete both in what they provide and how they are interpreted and applied by BLM and no longer adequately protect our mines and miners from the hazards and waste associated with the increased oil and gas drilling activities in the Potash Area. We have expressed this concern on numerous occasions over the years to the BLM and the New Mexico Oil Conservation Division ("New Mexico OCD"), both of which have regulatory authority in the Potash Area.

C. State Study Committee and Negotiation of Joint Industry Agreement on Concurrent Development of Both Resources

In response to these concerns, the former Director of the New Mexico OCD, Mr. R. L. Stamets, by letter dated March 21, 1986, requested members from each industry to participate in a Special Rules Study Committee with the expressed purpose of developing rules and standards for the drilling of oil and gas wells in the Potash Area that would permit maximum development of both potash and oil and gas resources with maximum safety for both industries. Membership on this committee was open to any operator in either industry. We accepted this invitation and worked diligently with participants from the Oil and Gas Industry to arrive at an agreement that struck the proper balance between the safety of our miners and the development and production of our respective mineral resources. Representatives of the New Mexico OCD and the BLM also attended the negotiating sessions to assist and/or observe the discussions. After 18 months of negotiations, which included extensive education of each industry on the operations of the other, an agreement was reached. This agreement, a copy of which is attached as Exhibit 1 ("Industry Agreement"), required substantial compromises by each industry and was possible only because each recognized that concurrent development of multiple mineral resources places certain limits on each industry and that these limits can best be determined by the participants themselves.

For this reason, the Agreement specifically provided that it would become null and void unless adopted without substantial change by the New Mexico OCD and the BLM [Exhibit 1, p. 2].

D. **New Mexico OCC Hearing and Adoption of Industry Agreement**

Following the signing of the Industry Agreement by the appointed representatives of each industry, the New Mexico OCD mailed it to every operator on the "All Docket Mailing List" asking for comments on the agreement at an open hearing before the full New Mexico Oil Conservation Commission ("New Mexico OCC"). A copy of this Notice is included with Exhibit 1. At the hearing before the New Mexico OCC on February 18, 1988, representatives from the following organizations were present:

Oil and Gas Industry	Potash Industry
Yates Petroleum	Lundberg Industries
Bass Enterprises	Western-Ag Minerals
Exxon	New Mexico Potash
Gas Company of New Mexico	IMC Fertilizer
Chevron	Charles C. High, Jr., for the Potash Industry
Phillips	
Conoco	
Texaco	
Amoco	
Unocal	
Talisman Energy	
Mesa Ltd. Partnership	
Sun E & P	
Louisiana Land	
Hondo Oil	
Tenneco Oil	

A list of those in attendance at the hearing is attached as Exhibit 3.

Based upon the Industry Agreement and the comments and evidence offered at the hearing, the New Mexico OCC issued, on April 21, 1988, Order R-111-P adopting in modified form the Industry Agreement. A copy of this Order is attached as Exhibit 2.

While this Order did not resolve all questions or disputes between the two industries, it nevertheless captured the essence of the Industry Agreement and resolved many of the difficulties the two industries had faced in developing both resources in the Potash Area.

E. **Request That BLM Adopt Industry Agreement to Replace 1986 Secretarial Order and Secretary's Signing of New Proposed Order**

Thereafter, by letter dated January 11, 1989, a joint request was made by the two industries for the BLM to adopt the Industry Agreement in lieu of the Order of the Secretary issued on October 28, 1986, entitled Oil, Gas and Potash Leasing and Development Within the Designated Potash Area of Eddy and Lea Counties, New Mexico, 51 Fed. Reg. 39425 ("1986 Secretarial Order"). Adoption of the terms of the Industry Agreement by the BLM, as was true for the New Mexico OCD, was a condition the two industries agreed was essential if the Agreement was to serve its intended purpose. On February 12, 1991, some two years later, the Secretary published a revised Proposed Order in the Federal Register, 56 Fed. Reg. 5697, which incorporated many of the concepts agreed to in the Industry Agreement. This Proposed Order was to replace the 1986 Secretarial Order. Following a comment period, we understand the Proposed Order was signed by the Secretary of the Interior on January 8, 1992, but for reasons not entirely known to us, has not been published in the Federal Register. We also understand that the provisions of the Proposed Order, even though signed by the Secretary, are not being followed by the BLM as Departmental policy.

F. Delay in Publication of Proposed Order Has Resulted in Additional Safety Hazards and Waste of Potash

This delay in the publication of the Proposed Order has had an enormous impact on the Potash Industry. Indeed, since submission of the Industry Agreement to the BLM in January of 1989, the BLM has approved the drilling of oil and gas wells from surface locations prohibited by the Industry Agreement for safety reasons and, further, from surface locations which, in our judgment, are prohibited by the existing 1986 Secretarial Order. In the area just East of the Department of Energy's Waste Isolation Pilot Plant ("WIPP") alone, at least 13 wells have been approved from surface locations that are within the boundaries of commercial grade potash ore deposits, including one well which was within 520 feet of a core hole showing commercial grade ore. Another well located 1,050 feet from the same core hole showing commercial potash ore was denied at the local and district level but reversed and approved at the State Director's Office. In addition, 41 more wells were approved at surface locations which fall within the "buffer zones" agreed to in the Industry Agreement as being the spacing necessary between oil and gas operations and potash deposits for the protection of underground miners.

The location of these wells in areas of commercial grade potash ore presents the risk that the wells will release methane gas into the potash deposits and that the methane will either migrate into mine workings or be encountered in future mining operations. If this occurs, the entire Potash Industry could face the possibility of having to comply with more stringent - and prohibitively expensive - safety requirements under the Federal

Mine Safety and Health Act. In addition, using the one-half mile spacing requirements of the Industry Agreement and Order R-111-P, these wells have wasted 29 million tons of potash ore with a gross value of $450 million dollars. In human terms, this is enough potash ore to provide direct employment for at least 500 employees for 6 years.

G. The Reasons Supporting the Industry Agreement Support the Immediate Implementation of the Proposed New Secretarial Order

We believe the reasons that lead to the Industry Agreement and the wide participation by both industries in arriving at the Agreement, support the immediate implementation of the Proposed Secretarial Order. Further, we are confident that once the BLM fully understands the nature of our operations and the basis for our concern over existing BLM policies governing the drilling of oil and gas wells in the Potash Area, the need for the New Secretarial Order will become clear.

II. Special Characteristics of the Mining Industry

In evaluating the many issues involved in the drilling of oil and gas wells in the Potash Area, as well as our concerns, it is important to understand the nature of underground mining in general and potash mining in particular. We are unique in a number of ways.

A. Limited Ore Reserves

First of all, we are a geographically limited industry. The area of potash deposits in Southeastern New Mexico, commonly called the Potash Basin, is the only known deposit of potash in the United States that can be mined through conventional mining methods. These deposits were discovered in 1925 after several years of exploration by the U.S. Geological Survey and private industry to find a replacement source for potash when German imports ceased with the outbreak of World War I. Smaller deposits have been found in Utah and California but, for a number of reasons, these cannot be mined using conventional methods. As a result, mines in the Potash Basin account for 85% of all potash mined in the United States [Mineral Industry Surveys, U.S. Department of the Interior, Bureau of Mines (1991), attached as Exhibit 4].

B. Types and Characteristics of Potash Ore

There are two types of potash ore found in the Potash Basin. The first and primary ore is sylvite, which is or has been mined by all of the producers in the Basin. The second type of ore is langbeinite, which is mined by only two operators. This is a rare ore, and the Potash Basin is the only known commercial reserve of this commodity in the Western Hemisphere. Both of these ores are non-toxic, non-explosive, non-flammable, water soluble, and are used in the production of fertilizer. There is no known substitute for potash as an essential plant nutrient.

C. Underground Mine Development and Operations

Our method of operation also makes us unique. The potash deposits in the Basin are found in the McNutt Member of the Salado Formation, so we work underground at depths ranging from about 800 to more than 2000 feet. Twelve (12) bedded ore deposit horizons have been identified in the McNutt Member and are numbered sequentially upward, with the twelfth ore zone being the one closest to the surface and the first ore zone being the one deepest underground [see Figure 5, page 12, George B. Griswold, Geology of the Carlsbad Mining District (1982), attached as Exhibit 5]. These ore horizons comprise only about 3% to 5% of the McNutt Member [see Chaturvedi, Lokesh, Occurrence of Gases in the Salado Formation (1984), page 4, attached as Exhibit 6], and range in thickness from one (1) foot to ten (10) feet [Exhibit 5, page 11, Table 1, Salado].

1. **Access Through Vertical Shafts**

To reach these deposits, each of the potash mines has sunk from two to five shafts vertically into the ground down to whatever depth was required to reach the deposits at their mine site. These shafts are divided into vertical compartments with one or two compartments generally used as part of the mine ventilation system and the other compartments used for elevator-type devices that hoist miners, supplies, and ore in and out of the mine.

2. **Development of Underground Working Areas**

Horizontally off of these shafts are the working areas of the mine. The sinking of a shaft is extremely expensive, so they are strategically located so that mine development can proceed in all directions from the shaft. These working areas began as tunnels leading away from the shaft into whatever area of deposits the mine operator determined to mine. Other tunnels are then mined off of existing tunnels in all directions so that, after first mining, the only things left are pillars of predetermined size at specified distances to support the ceiling or overburden, as it is called. Because of the length of time mining has been going on in the Basin, the area of underground workings in the mines is quite large and may cover many square miles. In fact, it is not unusual to go into a mine and then travel several miles from the bottom of the shaft to the area where ore is being removed from the ore body.

3. Final Mining and Ground Subsidence

The support pillars left by this first or developmental mining also contain large amounts of potash ore. Although the amounts vary depending upon a number of factors, most mines traditionally plan to recover from 50-70 percent of the ore during the first phase of mining. The remaining 30-50 percent of the ore is not, however, wasted. When first mining is completed in a particular deposit, the pillars are then mined so that this additional ore can be recovered. This removal of support for the overburden then causes a slow subsidence that eventually fills the void created by the removal of the potash ore. This displacement extends all the way to the surface at an angle of about 45° from the mined out area. A study discussing the extent of ground movement caused by subsidence is attached as Exhibit 7.

4. Mining Equipment and Support Facilities

The actual mining of the ore is performed with either continuous mining machines or by conventional drilling and blasting techniques. A continuous miner is a specially designed vehicle with drum-like devices on the front that rotate and cut the ore with teeth-like bits. A photograph of one type of continuous miner is included as Exhibit 8. As the ore is removed from the ore body by the continuous miner, it falls onto a conveyor system and is moved to the rear of the continuous miner where it is dropped into a "shuttle" or "ram" car for transport to a conveyor belt system that takes the ore to the bottom of the hoist. A photograph of one type of these vehicles is also included as Exhibit 8. From the bottom of the shaft, the ore is loaded onto a hoist and hoisted to the surface for refining.

The equipment used in underground mining, as shown by Exhibit 8, is heavy equipment. Other types of vehicles are also used to transport people and equipment. These pieces of equipment are either electrically powered or diesel powered. One mine has an electrically powered trolley system with a track system throughout the mine. In most instances, equipment to be used underground must be disassembled so that it will fit into a shaft for lowering underground and then reassembled for use once it is underground. There are generally one or more maintenance shops located underground with the same type equipment you would find in any typical maintenance shop. The maintenance shops perform the full range of maintenance activities, including complete engine and equipment overhauls.

5. <u>Ventilation of Underground Working Areas</u>

Ventilation to the underground working areas is provided by main fans which either push or pull surface ambient air into the mine, where it is then disbursed through active mine workings with booster fans. Directional control of the air, as well as the volume, is carefully controlled so that fresh air from the surface is routed to places work is being performed and then routed out of the mines back to a shaft where it exits to the surface. Because of the obvious importance of oxygen to human life, this aspect of underground mining, as well as many others, is heavily regulated by both the federal and state governments.

III. <u>Safety of Miners from An Industry Perspective</u>

These unique features of our Industry and the increased hazards inherent in underground work require, and we believe rightfully so, that the safety of our employees take precedence over production and development considerations. This is a clearly stated Federal policy and is perhaps best illustrated by the following statements of Senators Harrison Williams and Jacob Javits when the current Federal Mine Safety and Health Act was under consideration in 1977:

> "Our country is now turning to address our natural energy shortage. The President has already sent to us a comprehensive plan to increase the development and exploitation of our energy and mineral reserves. I believe that an effective mine safety and health program must be put in place first - and must be the firm foundation upon which we will build our national energy program. Otherwise, we will continue to pay for our energy and minerals with the dreadful currency of human lives and limbs.
>
> "Our national energy needs should not be met at the expense of our Nation's miners and their families. With the possibility of greatly increased mineral extraction on the near horizon, the time has come for reform of our inadequate mine safety and health program. Our miners should have to wait no longer. Our Nation should want to wait no longer."
>
> * * *
>
> "This bill is intended to strike a new balance in the longstanding antagonistic goals of maximizing production of energy and mineral resources on the one hand, and, on the other hand, affording the maximum safety and health protection of the workers who extract those resources in what all recognize is inherently a highly hazardous occupation."

[Congressional Record - Senate, June 20, 1977, p. 10204, attached as Exhibit 9].

While we like to think we have always struck this balance in favor of safety, we are nevertheless aware of and affected by the many disasters that have occurred in underground mines. The record of these is long and includes the loss of thousands of lives. Of particular concern to us, as it should be to the BLM, is the fact that the single most frequent cause of these disasters has been an unexpected encounter or accumulation of methane or some other flammable gas.

A. <u>Characteristics of Methane and Hydrogen Sulfide Gases</u>

Methane, as everyone in the Oil and Gas and Potash Industries knows, is a colorless, odorless, tasteless and non-poisonous gas that is highly flammable and explosive in concentrations containing as little as 5% methane and 12.1% oxygen [See Coward, H. F. and Jones, G. W. <u>Limits of Flammability of Gases and Vapors</u>, U. S. Bureau of Mines Bulletin No. 503 (1952), PP. 37-48, attached as Exhibit 10]. It is lighter than air and when present in an underground mine will generally accumulate near the roof or in high places. Once it become thoroughly mixed with mine air it will be found uniformly distributed across the moving air current and will not separate or stratify even if the air becomes still. [Forbes, J. J. and Grove, G. W., <u>Mine Gases and Methods for Detecting Them</u>, U. S. Bureau of Mines Miners' Circular 33 (1954), pp. 6-7, attached as Exhibit 11].

The characteristics of hydrogen sulfide are likewise well known. It is a colorless, toxic, flammable gas that has an odor of rotten eggs at low concentrations. Air that contains 4.3 to 45 percent hydrogen sulfide will ignite when subjected to ordinary flames and will explode. It is also very poisonous and will cause eye and respiratory tract irritation after exposure of one hour to concentrations as low as .005 to .01 percent (50 to 100 ppm). Concentrations above .07 percent (700 ppm) will cause a loss of consciousness, paralyze the respiratory system and cause death. Although hydrogen sulfide has a distinctive odor, the sense of smell cannot be relied upon as a means of detection because after one or two inhalations, the olfactory nerves become paralyzed and the hydrogen sulfide odor can no longer be detected [Forges, J. J.

and Grove, G. W., Mine Gases and Methods for Detecting Them, U. S. Bureau of Mines Miners' Circular 33 (1954), pp. 11-13, attached as Exhibit 12].

B. Hazards of Flammable Gas in an Underground Mine

It would be nice if we could say that the many mine disasters caused by these hazardous gases occurred in some deep, dark coal mine during an earlier, less sophisticated period of time where today's technology, knowledge and safety enforcement were not present. In fact, there is a tendency among people outside the mining industry to view these disasters in that perspective. However, that simply is not the case. A review of three selected examples of contemporary gas related mine disasters will illustrate this point. All three of the mines involved utilized state-of-the-art technology and engineering practices and were heavily regulated by federal and state mine safety agencies prior to the explosions.

The first occurred on August 27, 1963 at the Cane Creek potash mine in Grand County, Utah. A major inrush of flammable gas occurred from a single working face into a decline drift (tunnel) during routine mining operations. The gas was carried along the tunnel by the ventilation system, and about 20 minutes later reached the main shop area and ignited from one of three ignition sources. Twenty-five employees were working throughout the mine and 18 of them died from explosive forces, flames or asphyxiation. The methane entered the mine during blasting in the strata above the targeted potash deposits. The source of the methane was believed to be a clastic oil shale geological formation adjacent to the salt beds.

This incident illustrates the increased hazard of methane when encountered in an enclosed, underground environment. In addition to the fatalities and the injuries caused by the explosion, the containment of the explosion within the interior of the mine created such a force that it caused severe damage throughout the mine and up the shaft to the surface. One surface employee was injured when a wooden shed in the mine yard on the surface was destroyed by the blast pressure wave coming out of the shaft opening. The details of this explosion are set forth in an investigatory report by the U. S. Bureau of Mines, a portion of which is attached as Exhibit 13. A complete copy will be provided upon request.

The second example is more recent and occurred in domal salt deposits on June 8, 1979 at the Belle Isle Salt Mine of Cargil, Inc. near Franklin, Louisiana.

At the end of an evening shift, a gas outburst occurred following a regular production blast in the southeast part of the mine. Approximately ten minutes later, the methane gas had diluted to the explosive range and reached an electrical panel ignition source some distance away from the working face. The concussion from the resulting explosion caused four fatalities and one other employee died from concussion injuries and exposure to carbon monoxide. In addition, several of the 17 survivors suffered serious or permanently disabling injuries. Destruction of mine facilities and equipment was estimated to be in the millions of dollars.

This case, too, illustrates the tremendous amount of force generated by an explosion and the hazard it creates in an enclosed underground mine. The five victims of this explosion were located at distances of 2,600 feet to 4,600 feet away from the explosion area. One federal inspector calculated that the pressure wave velocities from the explosion exceeded 300 miles per hour through the underground workings and temperatures were more than 2000° Fahrenheit in the explosion fire-cloud. Selected portions of the final report of the U. S. Department of Labor, Mine Safety and Health Administration, on this disaster is attached as Exhibit 14. Copies of photographs attached to the Report illustrate the force of the explosion.

The third and final example is still more recent and occurred on April 15, 1981 at the Dutch Creek No. 1 coal mine in Pitkin County, Colorado. Late in the afternoon, a sudden rush of methane occurred during regular mining operations in a working face. Similar occurrences had been encountered previously and procedures had been adopted and put in place to dilute and remove the gas concentrations. The work crew in the immediate area was believed to have been implementing these procedures when a defective explosion proof switch arced as equipment lights were turned off. The resulting explosion killed the six members of the crew and nine additional employees at remote locations throughout the mine. This mine, like all coal mines, was being operated under Federal Mine Safety and Health Administration gassy mine regulations requiring approved, electrically-permissible equipment and special ventilation systems. Despite this, a minor error in the assembly of a light switch enclosure, combined with the methane encounter, caused the disaster. It should also be noted that the methane involved in this explosion was not the slow emanation of methane commonly associated with gassy coal mines. Instead, the methane entered the mine in a sudden outburst caused by relief of stresses in the strata surrounding the ore body. The investigatory report of this incident is too voluminous to attach as an exhibit but we will be glad to provide a copy to anyone who wants to see it.

These examples vividly demonstrate the potential dangers present whenever flammable gas is introduced into an underground mine environment. In all three of these examples, no one believed such an event could occur. Local knowledge of mine conditions, the contemporary technology being used, and the extensive regulation by both federal and state safety agencies may have reduced the odds but were not enough to prevent the unexpected events that occurred. In two of these examples, the flammable gas was not contained in the material being mined and was never supposed to be encountered during mining operations. However, in the Cane Creek example, the methane migrated through salt structures from adjacent formations and at the Belle Isle mine the gas was encountered in a geological discontinuity intersected by advancing underground workings. In the third example at the Dutch Creek mine, the mine was accustomed to controlling the traditional continuous emanation of methane from the ore body but was unable to safely control methane encountered from another, unexpected source.

C. Lack of Naturally Occurring Flammable Gas Hazard in the Potash Basin

In the Potash Basin we are fortunate that we have never had an accident involving methane, hydrogen sulfide, or any other flammable gas and because of the geology of the Basin, we have no expectation that such an event will ever occur. The natural occurrence of flammable gases in the Salado Formation where we mine has been carefully and extensively studied and in each case the conclusion was reached that these gases do not constitute a hazard to our miners or our underground mining operations.

The first of these studies, Investigation Into the Occurrence of Gas Pressure Above the First and Tenth Ore Zones in the Potash District, Carlsbad, New Mexico, was conducted by the U.S. Bureau of Mines in 1963 and is referenced in Exhibit 5. The second, entitled Geology of the Carlsbad Potash Mining District (with Emphasis on Brine and Inert Gases Adjacent to or Within the Ore Beds, was performed for the Potash Industry in 1982 by Dr. George B. Griswold, a well known geologist familiar with the Potash Basin, and is attached as Exhibit 5. A third study, Occurrence of Gases in the Salado Formation, was conducted by Dr. Lokesh Chaturvedi of the New Mexico Health and Environment Department for the Waste Isolation Pilot Plant ("WIPP") in 1984 and is attached as Exhibit 6.

These studies identified several reasons why the naturally occurring gases in the Salado are not a hazard. First, the gases encountered are primarily nitrogen with only minor amounts of methane and generally less than two percent oxygen. Even though the small amounts of methane are well below the hazardous level, the high nitrogen, low oxygen concentrations in which they occur are not capable of forming flammable mixtures with air as shown in Figure 22, Exhibit 10, p. 47.

Second, the minor amounts of gases encountered are intentionally released into the mine atmosphere through pressure relief holes where they are rapidly diluted by the mine ventilation system. Pressure relief holes are holes approximately 1 5/8" in diameter that are drilled into the back (ceiling) of a mine from 10 to 30 feet deep. These holes are drilled by all of the operators and are designed to relieve pressures caused by stress changes associated with mine development and thereby reduce the risk of a roof fall.

Third, and perhaps most importantly, there is no geological source for large concentrations of methane in the Salado. As explained by Dr. Griswold in his study of the Basin [Exhibit 5], the Salado was formed through a cyclical nature of deposition starting with a thin layer of clay covered by a thicker but still thin sheath of anhydrite followed by a much thicker bed of halite. The first phase of the cycle, the clay seam, represents an original drying and erosional surface at the top of the underlying halite due to the fact that clay minerals tend to concentrate at the surface. Sea water then re-entered the area, causing additional solution of the underlying halite. Clay buildup continued with the settling of fine particles carried in with the sea water. Third, the evaporation process recommenced, resulting in the formation and deposition of aragonite and then gypsum, which were later converted to dolomite of aragonite and then gypsum, which were later converted to dolomite and anhydrite by diagenetic processes. The next phase saw the halite start to crystallize and the sea water became highly concentrated by evaporation. In the final phase, drying continued and additional halite was formed. The surface was dry at this point and blowing winds and occasional rainfalls deposited more detrital material to the evaporation pan. Clay also began to be deposited with the halite. The cycle was then complete, setting the stage for the next cycle.

The only period during these formation cycles when marine organic life could have existed was during the second phase when sea water re-entered the area. These marine waters were more saline than the open sea and, according to Dr. Griswold, were too hostile for any form of marine life other than algae and microscopic organisms. Higher order organisms could not have existed and no fossil remains have been identified in the Salado. This algae was identified by Dr. Griswold as being the probable source of the minor amounts of methane we encounter in the Basin.

This geological development not only rules out the presence of large concentrations of methane in the Salado, but protects us from any gases that may be present in the Guadalupian strata below. As noted by Dr. Griswold, the McNutt member of the Salado, where our deposits are located, is underlaid with an impermeable barrier of halite ranging from 400 to 1500 feet thick and overlaid with a similar layer of halite ranging from 100 to 500 feet thick [Exhibit 5, p. 19].

IV. <u>Hazards Created By Oil And Gas Activity</u>

A. <u>Possible Release of Flammable Gases</u>

The concern we have about oil and gas drilling activities in the Potash Area, of course, is that methane, hydrogen sulfide, or some other hazardous gas will be released into the Salado Formation and either migrate into our underground workings or be encountered at some future time and cause an explosion. We know that such releases have already occurred in the Hobbs area. As a result, the Salado in that area is charged with methane and has been since the

1950's. This came out in testimony before the New Mexico Oil Conservation Commission in 1955 in Case No. 862 when Mr. S. J. Stanley, an engineer for the New Mexico OCC, admitted that:

> "It has been definitely proven in the oil business that the salt section is charged in the Monument and Hobbs Pool and charged with gas. The charging of oil and gas in these pools was probably man-made by casing leaks." [Transcript of Hearing, p.6]

A copy of the transcript of this hearing, which includes Mr. Stanley's testimony, is attached as Exhibit 15.

B. <u>Likelihood of Releases Occurring</u>

We recognize that many, if not all, of the gas releases in the Hobbs area occurred prior to the requirement that oil and gas wells in the Potash Area follow special casing requirements. We do not, however, believe that these casing requirements and current BLM policies protect our mines and miners from similar occurrences in the future. There are several reasons for this.

1. **<u>Wells in Close Proximity to Mining</u>**

First, the polices being followed by the BLM in approving oil and gas wells in the Potash Area do not reflect current knowledge of the safety hazards involved when methane or hydrogen sulfide gases are introduced into an underground mining environment. During the last 30 years, a considerable amount of information and knowledge has been gained about the effects and risks of these and other flammable gases on underground miners. We now know they are extremely hazardous in all mines, not just coal mines, and can cause an explosion and death even when stringent safety practices are in place. The 1986 Secretarial Order seems to recognize this because it prohibits drilling from any location which would "constitute a hazard" to mining operations. However, no standards have been developed for use in determining if or when a proposed oil or gas well will constitute a hazard to potash mining. We do not even know how far an oil or gas well must be from a potash mine to avoid the release and migration of hazardous gases into mine workings or ore deposits. Yet, under current BLM policy, oil and gas wells are being approved in commercial deposits of potash without any apparent inquiry into their affect on the safety of potash miners.

Any policy, like that apparently followed by the BLM in approving the wells East of WIPP in commercial grade ore without an independent and automatic inquiry into its effect on safety is, in our opinion, dangerous and out of step with modern day standards for human safety. We also believe it is in conflict with the intent and purpose of Federal Mine Safety and Health Act.

2. Oil and Gas Accidents and Blowouts

Secondly, the well casing program alone, while providing some protection, is inadequate without more to protect us against the hazards involved. In the absence of additional safeguards, such as a spacing requirement between oil or gas wells and ore deposits, we must assume that the casing and cementing program will always be 100% effective in preventing the release of hazardous gases into the Salado Formation. We do no believe that is true and do not believe the BLM, OCD, or any responsible oil or gas operator will ever represent to us that it is true. Accidents happen and when they do gasses may be released into the surrounding strata, perhaps unknowingly, and either migrate into mine workings or be encountered during mining at some future date. No other conclusion is possible, we submit, when you review the number or magnitude of the accidents that have already occurred in and around the Potash Area.

Although information on oil or gas mishaps is difficult to obtain, we are aware of at least 16 instances prior to 1986 where there was a blowout and/or fire during drilling operations. A list of these and a map showing their location in relation to the Potash Area is attached as Exhibit 16. Since this list was compiled there have been even more mishaps, including one blowout that resulted in the death of an oil field worker. This well was within 100 yards of homes on the north end of Carlsbad. More detailed information on two of the earlier mishaps, which were within the Known Potash Area, is attached as Exhibit 17. Information on another blowout which occurred at only 3,047 feet is attached as Exhibit 18. Information on two deep wells where blowouts occurred is included as Exhibit 19. Miscellaneous additional information on these and several other accidents on which we could find no records is attached as Exhibit 20.

3. <u>Known Instances of Oil Seepage and Migration</u>

Third, we are concerned that even in the absence of an accident, hazardous gases may migrate upward along the outside of the casing and become a hazard to us when encountered. The casing rules required in the Potash Area offer us no protection against such a possibility or, for that matter, protection against the migration of gases accidentally released. This is particularly troubling because the available evidence clearly shows the potential for at least some migration in the Potash Area.

The clearest evidence of this possibility, of course, is the oil seepage that occurred at the Mississippi Chemical and Eddy

Potash mines. The oil seepage at the MCC mine was discovered near what is known as a "Breccia pipe". This is a vertical pipe or chimney-type displacement of the geologic formations downward. These are though to be the result of the dissolution of deep-lying formations. This oil and other oil spots detected in core tests in the breccia pipe were studied and analyzed by the U. S. Geological Survey a part of the WIPP project [Evaluation of Breccia Pipes in Southeastern New Mexico and their Relation to the Waste Isolation Pilot Plan (WIPP) Site, U. S. Geological Survey (1982), attached as Exhibit 21]. This Report reached the following conclusions regarding the source of the oil:

> "Minor amounts of oil-stained core from both WIPP 16 and WIPP 31, as well as oil seeps in the MCC drifts near Hill C, were analyzed to see if an answer could be found to account for the presence of the oil (Palacas and others, 1982). Gas chromatograph and geochemical analysis indicate that the three oils are related to the oil from wells to the north of the pipes taken from the Yates Formation. The Yates overlies the Captain reef on the backside of the reef. It is possible that oil from this formation migrated toward the area of the breccia pipes and either entered the rocks before collapse occurred or it was forcefully emplaced during collapse, being pushed stratigraphically upward by hydrostatic pressure as the water in the underlying void was forced upward by the infalling rocks. In WIPP 31, the oil stains were in rocks of Dewey Lake Red Beds and Rustler and Salado Formations consisting of siltstone, anhydrite, and dolomite fragments and a matrix of mud, recrystallized halite, and glauberite crystals. In WIPP 16, the oil stains were in the Rustler Formation in anhydrite above the Magenta Dolomite Member and in halite below the Culebra Dolomite Member. The oil seeping into the MCC mine appears to be coming from an early vertical fault about 43 M (140 ft.) from the edge of the breccia pipe." [Exhibit 21, p. 65].

Regardless of where it came from it is clear that the oil migrated into the mine.

The oil seepage at the Eddy Potash (old PCA mine) mine did not involve a breccia pipe. These oil seeps, however, were traced to an improperly plugged well in the Getty Field located about 700 feet away. Information on these oil seeps, which were discovered in 1962, is attached as Exhibit 22.

If oil will migrate the distances involved in these incidents, we shudder to thing what methane or hydrogen sulfide under high pressure would have done. We know from the Rutledge studies in 1963 [Exhibit 6, App. D] that the clay seams in the Basin have a degree of permeability and will allow gases to migrate a distance of at least seven feet when the pressure is 50 psi [Exhibit 6, App. D, p. 64]. These clay seams are uniform throughout the Potash Area so if they become charged with high pressure gas, no one can say, without additional study, how far they will migrate.

4. Industry Experience With Cementing

Our own experience also makes us question whether any casing and cementing program, unless supplemented with additional safeguards, is adequate protection against the hazards from oil and gas wells. In 1980, for example, AMAX (now Horizon Potash) drilled a bore hole from the surface to the mine workings to be used for electrical supply cables. In attempting to cement the casing, the cement was lost both above and in the salt section through, we assume, clay seams and fractures in the salt zone. In instances like this, we simply do not believe there is any reliable way to be certain that the voids and annulus of the casing are completely filled. Information on this bore hole is attached as Exhibit 23.

More recently, IMC Fertilizer, Inc. experienced similar difficulties in a grouting program to stop the migration of water. A summary of this experience is attached as Exhibit 24. If water at relatively low pressure can migrate as easily as occurred at IMC

Fertilizer, then we seriously question whether cementing programs can effectively prevent the migration of flammable gases under much higher pressures.

5. Corrosive Effects of Hydrogen Sulfide

Finally, we are not convinced that the well casing requirements in the Potash Area provide state-of-the-art protection against the release of gases. While the BLM relies on New Mexico State requirements for casing in the Potash Area, there is nothing in those requirements concerning the ability of the casing to resist corrosion from hydrogen sulfide or withstand high pressures. The presence of hydrogen sulfide in the Basin has been known for years [See Exhibit 15, p. 9, testimony of S. J. Stanley] and was encountered during the core hole drilling by the U. S. Geological Survey in 1982 while investigating the breccia pipe and oil seeps at the MCC Mine [See Exhibit 21, p. 39] and along with high pressure (1500 psi) resulted in a casing failure at the Washington Ranch Gas Storage Facility of El Paso Natural Gas Company.

V. Effects of Hazards from Oil and Gas Activities on the Potash Industry

The effects of these hazards on the Potash Industry are significant and far greater than they were when concurrent development was first adopted. In the 1950's, there were few safety requirements of economic consequences concerning flammable gases. Those in effect applied only to a few very gassy coal mines and were of no concern to the Potash Industry. However, that has all changed. As a direct result of the many mine disasters caused by flammable gases, significant changes in mine safety and health laws were made in 1959, 1969, 1977, and again in 1987. Each time the regulations became more stringent and the consequences of a gas encounter more severe. Today, the consequences are such that a the release of flammable gas into any one mine could destroy our Industry.

Under the Federal Mine Safety and Health Act, non-coal mines, like us, are placed into one of several different categories to protect miners against the hazards of methane and other explosive gases. Encounters with methane gas, however, can, in some circumstances, cause a mine to be moved from one category to another category with more stringent safety requirements. If this were to occur in the Potash Area, it would be economically devastating to the Industry. We would be required to comply with about 100 additional regulations, all designed to prevent an explosion.

These additional regulations would require us to sink more shafts for ventilation; replace all underground equipment or modify it to explosion-proof condition; and replace most if not all of our electrical systems. In 1982, we estimated this would cost over $80 million if all of the mines were forced to comply with these regulations.

This change in the consequences of encountering methane gas, of course, has made us much more defensive on the drilling of oil and gas wells in the Potash Area. We do not see any change in that position unless BLM policies on the drilling of oil and gas wells is revised to ensure that our Industry does not bear the risk and liability of a mishap while the Oil and Gas Industry receives the benefit of production.

These activities also affect us in other ways. Our operations like all others, have assets. These assets are, in large part, our recoverable ore reserves. It is the value of these reserves that tell us whether it is economically possible to sink a shaft or continue mine operations. If an oil or gas operator wants to drill a well through these reserves, he is asking us to permanently forfeit some of our assets because once a well is drilled we cannot safely mine in close proximity to that casing regardless of whether it is producing or was a dry hole. The value of the ore lost will depend upon a number of factors, including market price, but it is nevertheless a significant loss to us.

Such activities also impact our mine development. In our Industry, there is simply no way to accurately predict where we will be mining next month, much less ten years hence. If the demands for our product change, we may need a different grade or mix of ore and have to mine in a direction not shown by any projected mine plan. Copies of the mine development plan filed by IMCF in 1981 and a map updated to January 1, 1986, showing all mining through 1985, is attached as Exhibit 25 for reference. Thus, and for this reason, we are forced many times to protest a well to ensure that it does not interfere with the orderly but unpredictable development of our mine.

VI. <u>Factors That Must be Considered to Address Hazards</u>

In addressing the hazards created by oil and gas drilling in the Potash Basin, we believe there are a number of factors that must be considered. Many of these are currently being done or are in place, but others are the result of new technology and capabilities that did not exist until relatively recently.

1. **Safety of Miners**

We firmly believe, as stated in these comments, that current BLM policies, including the current provisions of 1986 Secretarial Order, do not adequately protect our mines and miners from the hazards associated with oil and gas drilling in the Potash Basin. The New Secretarial Order recognizes this and offers greater protection but also will allow development of both resources.

2. **Spacing Between Oil and Gas and Potash Deposits**

A spacing requirement between oil and gas activities and ore deposits is absolutely essential to ensure the safety of miners. The hazards involved are simply too great to rely solely upon a casing and cementing program. Any spacing requirement must consider the possible migration of gases as well as the spacing required to avoid damage from mining subsidence. The one-half mile "buffer Zone" agreed to in the Industry Agreement is not based on any actual measurements, but affords the best measure of safety for underground miners.

3. **Subsidence**

Mining subsidence must, of course, be considered. It is well known that the extraction of ore from support pillars during second mining causes subsidence or a "sinking" of the ground. The effects of this are well known and require, for the protection of the well casing, that second mining not occur within a distance equal to the depth of the ore plus ten percent to any oil or gas well. This protection was incorporated into the Industry Agreement. BLM policies should likewise.

4. <u>Responsibility for Gas Releases</u>

We believe BLM policies should make a clear regulatory assignment of economic responsibility for any damage caused by one industry to the other. For example, if a well is drilled at a location determined by the BLM to be safe and we damage or destroy that well by our mining activities, it will be our economic responsibility to restore production or incur the liability for whatever loss is incurred. Similarly, if a well is drilled at a location determined to be safe by the BLM and the well thereafter releases hazardous gases into the strata which migrate into our underground workings, the oil or gas operator will be economically responsible for whatever additional costs or loss of assets we incur as a result of that release.

5. **<u>Identification of Ore Bodies and Barren Areas</u>**

Current procedures for identifying ore bodies and barren areas need to be improved to provide more guidance to both Industries. In many instances, commercial grade ore exists well beyond the boundaries of any potash operator's leases and beyond the measured reserves shown on BLM's own Potash Area Map. We believe the identification of these areas should be the shared responsibility of both the Industries and the BLM because of its obligation under Federal law to conserve those mineral resources.

6. **<u>Increased Use of State-Of-The Art Directional Drilling Technology</u>**

Current BLM policies do not make sufficient use of directional drilling. The technology available today virtually eliminates any technical limits on bottom hole displacement. Using this capability, wells could be drilled from locations sufficiently removed from ore deposits that the affects of the hazard would be greatly reduced. Any increase in costs, we believe, would be justified by the increased safety to miners.

7. **Increased Cooperation Between the OCD and BLM**

We believe that any real effort to address the hazards involved in oil and gas and potash production will require increased cooperation between the OCD and BLM. Because of the nature of the hazards involved, it is essential that whatever safety practices are adopted are applied equally without regard to whether the drilling is on state of federal property.

8. **Increased Cooperation between Industries**

We would like to see increased cooperation between our two Industries to ensure that all developmental activities in the Potash Area are performed in a manner that does not endanger our miners. The New Mexico State Study Committee was a good start and we hope it will lead to a greater mutual understanding of the many issues involved.

VII. Conclusion

For the reasons set forth in these comments, we believe that the New Secretarial Order must be placed in effect without delay. It is the most reasonable solution available at this time to protect our mines and miners form the hazards associated with oil and gas drilling activities while, at the same time, allowing the concurrent development of both mineral resources. Any other approach would elevate development and production over safety in violation of stated National policy.

Chd. lic [illegible]

STATE OF NEW MEXICO

ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT

OIL CONSERVATION DIVISION

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DEC 7 0 1987

MINE ENG.

MEMORANDUM

TO: ALL DOCKET MAILING LIST

FROM: WILLIAM J. LEMAY, DIRECTOR

SUBJECT: REVISION OF ORDER NO. R-111 (POTASH AREA)

DATE: NOVEMBER 30, 1987

Attached hereto is an agreement which was executed by members of the Potash-Oil and Gas Work Committee in an attempt to clarify the co-existent rights of lessees within the potash area. This agreement culminates an effort begun on May 1, 1986 in which representatives of the two industries met to gain basic knowledge of each industry and document the concerns of each industry brought about by the operations of the other. Membership in this committee was open to any operator in either industry. At the conclusion of the educational phase, each industry elected three representatives and an alternate as a work committee to develop a mutually agreeable program to permit maximum development of both resources with maximum safety for both industries. The agreement was duly completed and signed November 23, 1987.

The Oil Conservation Commission contemplates a hearing, probably on January 21, 1988 to consider on its own motion the amendment of Order R-111. At this hearing we will entertain comments on:

1) the attached agreement which may be pertinent to the amendment of Order R-111;
2) the area to be covered by R-111, as amended (note - we are proposing the area be expanded to the BLM "known Potash Leasing Area");
3) the casing-cementing requirements of Order R-111-A;
4) directional drilling procedures for inclusion in the order;
5) a procedure for expanding/contracting the effected area by the pool nomenclature procedure rather than amendment to Order R-111. This would be responsive to changes in the KPLA by BLM.
6) Revisions to notice requirements.

dr/

STATEMENT OF AGREEMENT BETWEEN THE POTASH INDUSTRY AND OIL AND GAS INDUSTRY ON CONCURRENT OPERATIONS IN THE POTASH AREA IN EDDY AND LEA COUNTIES, NEW MEXICO

Introduction

This Statement of Agreement sets forth the joint agreement of the Potash Industry and Oil and Gas Industry on important issues concerning the concurrent development of potash and oil and gas reserves in Eddy and Lea Counties, New Mexico. It represents the efforts of numerous representatives from each Industry over many months and is intended to resolve many of the disputes that have arisen as a result of concurrent oil and gas drilling activities in the vicinity of underground potash mining.

The parties recognize that this Agreement will not resolve all disputes or disagreements that may arise and that regulatory intervention may still be necessary in some instances. By entering into this Agreement, however, each industry recognizes the right of the other to develop its mineral resources in a safe and economical manner and acknowledges that concurrent development of multiple mineral resources places certain limits on each industry. Each also agrees that these limits can be better defined through good faith discussions among industry representatives familiar with industry technology and practices than repeated and prolonged litigation or administrative proceedings.

In attempting to accomplish this, each Industry has made concessions on issues considered critical to it in a good faith effort to obtain concessions from the other. For this reason, both Industries agree that the terms of this Statement of Agreement are subject to the following conditions:

1. Upon approval by representatives of each Industry, the terms of the Agreement will be submitted to and must be adopted without substantial change by the New Mexico Oil Conservation Commission ("OCC") in lieu of the current Order R-111A, as amended;

2. The terms of the Agreement will be submitted to and must be adopted without substantial change by the U. S. Department of Interior, Bureau of Land Management ("BLM") in lieu of Section III (E) of the Secretary of the Interior's Order of October 21, 1986 [51 Fed. Reg. 39425];

3. Each Industry will use its best efforts to secure approval of the terms of the Agreement from the OCC and BLM; and

4. In the event the terms in the Agreement are not adopted without substantial change by both the OCC and the BLM, this Statement of Agreement will become null and void and will not be referred to by any Industry representative on the Study Committee in any future proceeding before the OCC or BLM.

It is the intention of the parties to this Agreement that: (1) certain areas of potash deposits, called "life-of-mine-reserves" or "LMR's," be permanently protected from oil and gas drilling activities; and (2) to make available for oil and gas drilling activities, certain areas within the Potash Area. The area of potash deposits protected will be determined in accordance with this Agreement but, generally speaking, will encompass the yellow, orange and a major portion of the blue

areas shown on the BLM Potash Resources Map as it existed on October 1, 1984. Areas in the Potash Area that will be available for oil and gas drilling activities will be those areas outside the designated LMR's which, generally speaking, will be the red, green, grey and a minor portion of the blue areas shown on the BLM Potash Resources Map as it existed on October 1, 1984, less areas designated as buffer zones by this Agreement.

I. The Potash Area

A. The Area covered by this Agreement shall be known as the "Potash Area".

B. The "Potash Area" includes those tracts of land in Southeastern New Mexico, from the surface downward, which are designated as a "potash area" by the Secretary of the Department of Interior in Section V of the Order dated October 21, 1986 and published in the Federal Register on October 28, 1986 [51 Fed. Reg. 39426]. It shall also include any subsequent revisions to such designations. The terms "potash" and "commercial deposits of potash" shall have the same meaning as assigned by the U. S. Department of Interior.

C. It is the intent of the parties to this Agreement that the "Potash Area" designated by the State of New Mexico be identical to that designated by the U. S. Department of Interior. Accordingly, if the "potash area" designated in the Secretarial Order of October 21, 1986 [51 Fed. Reg. 39425] is revised, the OCC, on its own motion after notice and hearing as

provided by applicable laws and regulations, will adopt the same revision.

II. Designation of Mine Reserves

A. Within ninety (90) days following adoption of this Agreement by the OCC and BLM and annually thereafter by January 31 if revised, each potash lessee, without regard to whether the lease covers State or Federal lands, shall file with the District Manager, BLM, a designation of the potash deposits considered by the potash lessee to be its life-of-mine reserves ("LMR"). For purposes of this Agreement, "life-of-mine reserves" means those potash deposits within the Potash Area reasonably believed by the potash lessee or the BLM to contain potash ore in sufficient thickness and grade to be mineable using current day mining methods, equipment and technology. Information used by the potash lessee in identifying its LMR shall be filed with the BLM but will be considered privileged and confidential "trade secrets and commercial . . . information" within the meaning of 43 C.F.R. §2.13(c)(4) (1986) and not subject to public disclosure.

B. An authorized officer of the BLM shall review the information submitted by each potash lessee in support of its LMR designation and verify, upon request, that the data used by the potash lessee in establishing the boundaries of its LMR is consistent with data available to the BLM. Any disputes between the BLM and potash lessee concerning the boundary of a designated LMR shall be resolved in accordance with the

Department of Interior's Hearings and Appeals Procedures, 43 C.F.R. Part 4 (1986).

C. A potash lessee may amend its designated LMR by filing a revised designation with the BLM accompanied by the information referred to in Section A above. Such amendments must be filed by January 31 next following the date the additional data becomes available.

D. An authorized officer of the BLM shall commit the designated LMR of each potash lessee to a map(s) of suitable scale and thereafter revise the map(s) as necessary to reflect the latest amendments to any designated LMRs. These maps shall be considered privileged and confidential and exempt from disclosure under 43 C.F.R. Part 2 and will be used only for the purposes set forth in this Agreement.

III. Drilling in the Potash Area

A. All oil and gas wells drilled in the Potash Area after approval of this Agreement by the OCC and BLM, including those currently pending before the OCC and/or BLM, shall be subject to the terms of this Agreement.

B. It is the policy of the OCC and BLM to approve or deny applications for permits to drill (APD's) in the Potash Area in accordance with the following:

1. LMR and Buffer Zone. No oil or gas well shall be allowed from a surface location: (a) within the LMR of any potash lessee; (b) within one-fourth (1/4) mile, or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, of the LMR of any potash lessee; or (c) where the well casing will pass within one-fourth (1/4) mile, or a distance equal to

the depth of the ore plus ten percent (10%), whichever is greater, of the LMR of any potash lessee.

2. Outside Buffer Zone But Within One-Half (1/2) mile of LMR. An APD for an oil or gas well at a location more than one-fourth (1/4) mile, or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, but less than one-half (1/2) mile from the LMR of any potash lessee may be approved only if: (a) the bottom hole location does not extend below the base of the Delaware Mountain Group, and (b) the well is drilled in accordance with the cementing and casing requirements set forth in Section V.

3. More Than One-Half Mile But Less Than One Mile From LMR. An APD for an oil or gas well at a location more than one-half (1/2) mile but less than one mile from the LMR of any potash lessee may be approved regardless of the depth of the bottom hole location provided: (a) wells :h bottom hole locations below the base of the Delaware Mountain Group are drilled in accordance with the cementing and casing requirements set forth in Section V of this Agreement, and (b) wells to bottom hole locations above the base of the Delaware Mountain Group may be drilled without regard to the requirements in Section V of this Agreement but must be drilled in accordance with then current Industry safety standards.

4. More Than One Mile From LMR. An APD for an oil or gas well at a location more than one mile from the LMR of any potash lessee may be approved regardless of the depth of the bottom hole location and without regard to the requirements of Section V of this Agreement.

5. Open Mine Workings. No oil or gas well shall be allowed from any location where the well casing will pass within one-fourth (1/4) mile or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, of any open mine workings.

6. Abandoned Mine Workings. No oil or gas well shall be allowed from any location where the well casing will pass through or within one-fourth (1/4) of a mile or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, of any abandoned mine workings that are connected to an existing mine by an opening or barrier of one-hundred (100) feet or less unless the APD is accompanied by the sealing and safety plan and certification described in Paragraph C below.

7. An APD for a directionally drilled oil or gas well to a bottom hole location underlying the LMR of any potash lessee may be approved subject to the limitations and requirements set forth in Paragraphs 1 - 6 above. Directionally drilled holes shall be drilled vertically until they have completely penetrated Marker Bed No. 126 (U.S.G.S.) of the Salado Formation at which time they may be deviated.

C. An oil and gas operator desiring to drill a well to a bottom hole location that does not extend below the base of the Delaware Mountain Group from a surface location where the well casing will pass through or within one-fourth (1/4) of a mile or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, of abandoned mine workings that are connected to an existing mine by any opening or a barrier of one-hundred (100) feet or less shall prepare and submit to all affected potash lessees a plan and program for sealing off the area to be penetrated from other mine workings. Approval of any such plan shall be in the sole discretion of the affected potash lessees. Any approved plan shall be attached by the oil and gas operator to the APD for filing with the OCC, and/or BLM. The oil and gas operator shall also complete a certification in the form prescribed by the OCC and/or BLM that the drilling of such well will not create a safety hazard to affected potash lessees.

D. It is the belief of both parties that the provisions of this Agreement eliminate the need for drilling islands and three-year mining plans and, therefore, both agree that no drilling islands will be established in the Potash Area and the filing of three-year mining plans will be eliminated.

IV. Location of Wells and Notice to Potash Lessee

A. The BLM, upon request, will advise oil and gas lessees of the surface locations where wells will be allowed to develop the leases. Oil or gas leases covering areas designated a LMR by a potash lessee will be unitized to the extent possible with other areas where drilling is allowed.

B. An oil or gas operator desiring to drill an oil or gas well in the Potash Area or within one (1) mile of a potash lease shall prepare and file an APD with the OCC and/or BLM along with a map or plat showing the location of the proposed well. One copy of the APD and map or plat shall be served by registered mail, return receipt requested, on all potash leaseholders within one (1) mile of the proposed well location. However, if the APD is for an oil or gas well that will penetrate abandoned mine workings, all potash leaseholders in the Potash Area shall be notified. Proof of such service shall be attached to the APD and filed with the OCC and/or BLM. Within twenty (20) days of service of an APD and required documents, any potash leaseholder within one (1) mile of the proposed well location (or any affected potash lessee if the proposed well will penetrate abandoned mine workings) may file an objection with the OCC to the proposed well. If the objections cannot be resolved by agreement of the parties, the matter shall be referred for hearing before the OCC.

C. The failure of a potash leaseholder to object to a well location or its agreement to the drilling locations

referred to in this Agreement shall not constitute a release of liability. Oil and gas leaseholders and those persons and/or entities involved in the development of the lease shall be responsible as provided by law for any damages caused by them to any person by the release of gases or liquids into the strata or atmosphere as a result of drilling activities.

V. Drilling and Casing Program

[Same as current R-111-A]

VI. Drilling Fluid for Salt Section

[Same as current R-111-A]

VII. Plugging and Abandonment of Wells

[Same as current R-111-A]

VIII. Filing of Well Surveys

The OCC may require an oil and gas operator to file a certified directional survey from the surface to a point below the lowest known potash bearing horizon on all wells drilled in the Potash Area. All encounters with flammable gases, including H_2S, shall be reported by the operator to the OCC.

IX. Additional Safety Requirements and Emergency Action

A. All oil and gas drilling activities within the Potash Area shall be performed using appropriate technology, equipment, and procedures to reduce the hazards of such activities to underground mines and miners and be conducted in accordance with the prudent operator standard.

B. Only the minimum number of wells necessary to develop an oil or gas lease will be allowed within the Potash Area.

C. In the event the increased oil and gas drilling activities allowed by this Agreement result in a safety hazard or if data developed in the course of such increased activities make it reasonably appear that such activities are or will become a hazard to underground miners or mining activities, the BLM and/or OCC will, upon request, initiate proceedings in accordance with NMSA 70-2-23 and/or other applicable laws and regulations to review such data and take whatever emergency steps are found necessary to eliminate such hazard. Potash lessees may, in addition, initiate actions for injunctive relief under NMSA 70-2-29. The taking or failure to take such action by the OCC or any potash lessee shall not relieve the oil and gas lessee from liability for any damages caused by its oil and gas activities.

AGREED TO AND APPROVED THIS 23rd DAY OF November, 1987, BY THE FOLLOWING REPRESENTATIVES OF EACH INDUSTRY COMPRISING THE POTASH-OIL AREA SPECIAL RULES STUDY COMMITTEE:

For the Oil and Gas Industry:	For the Potash Industry:
[signature]	[signature]
[signature]	W. E. [signature]
Robert [signature]	[signature]
	Donald [signature]

1727L-7

STATE OF NEW MEXICO
ENERGY, MINERALS AND NATURAL RESOURCES DEPT.
OIL CONSERVATION COMMISSION

IN THE MATTER OF THE HEARING CALLED BY THE OIL CONSERVATION COMMISSION OF NEW MEXICO FOR THE PURPOSE OF CONSIDERING:

CASE NO. 9316
Order No. R-111-P

APPLICATION OF THE OIL CONSERVATION DIVISION UPON ITS OWN MOTION TO REVISE ORDER R-111, AS AMENDED, PERTAINING TO THE POTASH AREAS OF EDDY AND LEA COUNTIES, NEW MEXICO.

ORDER OF THE COMMISSION

BY THE COMMISSION:

This cause came on for hearing at 9:00 a.m. on February 18, 1988, at Santa Fe, New Mexico, before the Oil Conservation Commission of New Mexico, hereinafter referred to as the "Commission."

NOW, on this 21st day of April, 1988, the Commission, a quorum being present, having considered the testimony presented and the exhibits received at said hearing, and being fully advised in the premises,

FINDS THAT:

(1) Due public notice having been given as required by law, the Commission has jurisdiction of this cause and the subject matter thereof.

(2) Order R-111-A was entered July 14, 1955, and since that time no amendments have been entered, except amendments to Exhibit "A" attached thereto, despite significant advances in drilling technology and practices.

(3) Operation under Order R-111-A has become virtually unworkable because of 1) the lack of tolerance on the part of both oil/gas and potash industries in regarding the activities of the other industry in areas where leasehold interests are overlapping and 2) confusion recording the boundaries of the known Potash Leasing Area (KPLA) established by the U.S. Bureau of Land Management (BLM) and the R-111-A area as amended by Orders R-111-B through O.

(4) The then Director of the Oil Conservation Division (OCD) by memorandum dated March 21, 1986 convened a study committee of volunteer representatives from the oil and potash industries and other interested parties.

(5) The committee met May 29, September 25-26, and November 13-14 (field trip) in 1986 and on March 19, 1987.

(6) By committee agreement a work committee was formed from the larger committee consisting of three members and one alternate from each industry and this work committee was chaired by the OCD Chief Petroleum Engineer and charged with the responsibility to develop proposed amendments to Order R-111-A. It met on April 30, May 1, July 23-24 and November 23, 1987.

(7) Each meeting of the work committee was held in the presence of representatives of both BLM and OCD; and at its final meeting November 23, 1987 an agreement was reached and signed by the committee members present, which agreement is attached hereto as Exhibit "B", for the purpose of providing background information and acknowledging the concensus reached by representatives of the Oil and Gas and Potash industries relating to the multiple use of resources in the potash area.

(8) Exhibit "B" is regarded by the Commission as a report of both the work committee and the full study committee since a draft copy of a nearly identical agreement was furnished to each member of the study committee for comment, and comments received thereon were addressed at the final meeting.

(9) The agreement represents a compromise by both industries, the potash operators relinquishing lower grade marginal or uneconomic ore deposits in order to more fully protect their higher grade ore deposits; and the oil/gas operators receiving such lands containing sub-economic ore deposits as prospective drill-sites.

(10) The Oil and Gas Act, 70-2-3 F NMSA 1978, declares as waste "drilling or producing operations for oil or gas within any area containing commercial deposits of potash where such operations would have the effect unduly to reduce the total quantity of such commercial deposits of potash which may reasonably be recovered -- or where such operations would interfere unduly with the orderly commercial development of such potash deposits".

(11) The Oil and Gas Act in 70-2-12 B(17) empowers the Division "to regulate and, where necessary, prohibit drilling

or producing operations for oil and gas" in areas which would cause waste as described in 70-2-3 F.

(12) The report of the work committee presents a reasonable process for determining where wells for oil and gas would cause waste of potash and the pertinent portions of said report should be contained in the order as a reasonable process for prohibiting oil and gas drilling in such areas in the absence of substantial evidence that waste of potash as described by the statute would not result.

(13) Release of methane into potash mine workings would endanger the lives of miners and would render further mining activities uneconomic because of the additional, and more expensive safety requirements which would be imposed by the Mine Safety and Health Administration (MSHA) of the U.S. Department of Labor.

(14) Salt and potash deposits are essentially non-porous and impermeable but are inter-bedded with clay seams which, in an undisturbed state are porous but of extremely low permeability.

(15) Primary mining activity creates minor localized disturbance but secondary mining causes subsidence of the overburden the effects of which tend to expand beyond the mined out area a distance approximately equal to the depth of the mined area.

(16) During the drilling of wells for oil and gas, measures should be taken to protect the salt-protection casing from internal pressures greater than the designed burst resistance plus a safety factor so as to prevent any possible entry of methane into the salt and potash interval.

(17) A proposed revision of Order R-111-A was presented at the hearing and comments were received thereon both orally at the hearing and in writing subsequent to the hearing, the record being held open for two weeks subsequent to the hearing, as announced by the Chairman.

(18) Testimony and comments both in support and in opposition to the proposed revision of the order were received at the hearing and subsequent thereto, some pointing out that the number of oil or gas wells which could be drilled under the terms of the committee report would be reduced but no comments addressed the possible waste of potash as a result of additional drilling.

(19) One member of the work committee from the potash industry testified the proposed revision of Order R-111-A failed to prohibit drilling in the commercial ore areas and was therefore contrary to the work committee report and the Oil and Gas Act.

(20) The Commission cannot abdicate its discretion to consider applications to drill as exceptions to its rules and orders but in the interest of preventing waste of potash should deny any application to drill in commercial potash areas as recommended in the work committee report, unless a clear demonstration is made that commercial potash will not be wasted unduly as a result of the drilling of the well.

(21) Confusion can be reduced and efficiencies can be obtained by making the area covered by Order R-111 coterminous with the KPLA as determined by the BLM, and the area should be expanded and contracted by the regular pool nomenclature procedure rather than by separate hearings and further revisions of Order R-111.

(22) Expansion of the R-111 area to coincide with the KPLA will bring under the purview of this order areas where potash is either absent or non-commercial and such areas should be granted less stringent casing, cementing and plugging requirements, at the discretion of the OCD district supervisor.

(23) The proposed revision of Order R-111-A will permit the drilling of wells for oil or gas in areas previously not available for such drilling and will prevent waste of potash, and further, will serve to reduce confusion and uncertainty in the conduct of operations by both the potash and oil/gas industries, all to the benefit of the state and its citizens.

IT IS THEREFORE ORDERED THAT:

This order shall be known as The Rules and Regulations Governing the Exploration and Development of Oil and Gas in Certain Areas Herein Defined, Which Are Known To Contain Potash Reserves.

A. OBJECTIVE

The objective of these Rules and Regulations is to prevent waste, protect correlative rights, assure maximum conservation of the oil, gas and potash resources of New Mexico, and permit the economic recovery of oil, gas and potash minerals in the area hereinafter defined.

B. THE POTASH AREA

(1) The Potash Area, as described in Exhibit A attached hereto and made a part hereof, represents the area in various parts of which potash mining operations are now in progress, or in which core tests indicate commercial potash reserves. Such area is coterminous with the Known Potash Leasing Area (KPLA) as determined by the U.S. Bureau of Land Management (BLM).

(2) The Potash Area, as described in Exhibit "A" may be revised by the Division after due notice and hearing at the regular pool nomenclature hearings, to reflect changes made by BLM in its KPLA.

C. DRILLING IN THE POTASH AREA

(1) All drilling of oil and gas wells in the Potash Area shall be subject to these Rules and Regulations.

(2) No wells shall be drilled for oil or gas at a location which, in the opinion of the Division or its duly authorized representative, would result in undue waste of potash deposits or constitute a hazard to or interfere unduly with mining of potash deposits.

No mining operations shall be conducted in the Potash Area that would, in the opinion of the Division or its duly authorized representative, constitute a hazard to oil or gas production, or that would unreasonably interfere with the orderly development and production from any oil or gas pool.

(3) Upon discovery of oil or gas in the Potash Area, the Oil Conservation Division may promulgate pool rules for the affected area after due notice and hearing in order to address conditions not fully covered by these rules and the general rules.

(4) The Division's District Supervisor may waive the requirements of Sections D and F which are more rigorous than the general rules upon satisfactory showing that a location is outside the Life of Mine Reserves (LMR) and surrounding buffer zone as defined hereinbelow and that no commercial potash resources will be unduly diminished.

(5) All encounters with flammable gas, including hydrogen sulfide, during drilling operations shall be reported immediately to the appropriate OCD District office followed by a written report of same.

D. DRILLING AND CASING PROGRAM

(1) For the purpose of the regulations and the drilling of wells for oil and gas, shallow and deep zones are defined as follows:

(a) The shallow zone shall include all formations above the base of the Delaware Mountain Group or, above a depth of 5,000 feet, whichever is lesser.

(b) The deep zone shall include all formations below the base of the Delaware Mountain Group or, below a depth of 5,000 feet, whichever is lesser.

(c) For the purpose of identification, the base of the Delaware Mountain Group is hereby identified as the geophysical log marker found at a depth of 7485 feet in the Richardson and Bass No. 1 Rodke well in Section 27, Township 20 South, Range 31 East, NMPM, Eddy County, New Mexico.

(2) Surface Casing String:

(a) A surface casing string of new or used oil field casing in good condition shall be set in the "Red Bed" section of the basal Rustler formation immediately above the salt section, or in the anhydrite at the top of the salt section, as determined necessary by the regulatory representative approving the drilling operations, and the cement shall be circulated to the surface.

(b) Cement shall be allowed to stand a minimum of twelve (12) hours under pressure and a total of twenty-four (24) hours before drilling the plug or initiating tests.

(c) Casing and water-shut-off tests shall be made both before and after drilling the plug and below the casing seat as follows:

(i) If rotary tools are used, the mud shall be displaced with water and a hydraulic pressure of six hundred (600) pounds per square inch shall be applied. If a drop of one hundred (100) pounds per square inch or more should occur within thirty (30) minutes, corrective measures shall be applied.

(ii) If cable tools are used, the mud shall be bailed from the hole, and if th hole does not remain dry for a period of one hour, corrective measures shall be applied.

(d) The above requirements for the surface casing string shall be applicable to both the shallow and deep zones.

(3) Salt Protection String:

(a) A salt protection string of new or used oil field casing in good condition shall be set not less than one hundred (100) feet nor more than six hundred (600) feet below the base of the salt section; provided that such string shall not be set below the top of the highest known oil or gas zone. With prior approval of the OCD District Supervisor the wellbore may be deviated from the vertical after completely penetrating Marker Bed No. 126 (USGS) but that section of the casing set in the deviated portion of the wellbore shall be centralized at each joint.

(b) The salt protection string shall be cemented, as follows:

(i) For wells drilled to the shallow zone, the string may be cemented with a nominal volume of cement for testing purposes only. If the exploratory test well is completed as a productive well, the string shall be re-cemented with sufficient cement to fill the annular space back of the pipe from the top of the first cementing to the surface or to the bottom of the cellar, or may be cut and pulled if the production string is cemented to the surface as provided in sub-section D (5)(a)(i) below.

(ii) For wells drilled to the deep zone, the string must be cemented with sufficient cement to fill the annular space back of the pipe from the casing seat to the surface or to the bottom of the cellar.

(c) If the cement fails to reach the surface or the bottom of the cellar, where required, the top of the cement shall be located by a temperature, gamma ray or other survey and additional cementing shall be done until the cement is brought to the point required.

(d) The fluid used to mix with the cement shall be saturated with the salts common to the zones penetrated and with suitable proportions but not less than 1% of calcium chloride by weight of cement.

(e) Cement shall be allowed to stand a minimum of twelve (12) hours under pressure and a total of twenty-four (24) hours before drilling the plug or initiating tests.

(f) Casing tests shall be made both before and after drilling the plug and below the casing seat, as follows:

(i) If rotary tools are used, the mud shall be displaced with water and a hydraulic pressure of one thousand (1000) pounds per square inch shall be applied. If a drop of one hundred (100) pounds per square inch or more should occur within thirty (30) minutes, corrective measures shall be applied.

(ii) If cable tools are used, the mud shall be bailed from the hole and if the hole does not remain dry for a period of one hour, corrective measures shall be applied.

(g) The Division, or its duly authorized representative, may require the use of centralizers on the salt protection string when in their judgment the use of such centralizers would offer further protection to the salt section.

(h) Before drilling the plug a drilling spool installed below the bottom blowout preventer or the wellhead casing outlet shall be equipped with a rupture disc or other automatic pressure-relief device set at 80% of the API-rated burst pressure of new casing or 60% of the API-rated burst pressure of used casing. The disc or relief device should be connected to the rig choke manifold system so that any flow can be controlled away from the rig. The disc or relief device shall remain installed as long as drilling activities continue in the well until the intermediate or production casing is run and cemented.

(i) The above requirements for the salt protection string shall be applicable to both the shallow and deep zones except for sub-section D (3) (b) (i) and (ii) above.

(4) Intermediate String:

(a) In drilling wells to the deep zone for oil or gas, the operator shall have the option of running an intermediate string of pipe, unless the Division requires an intermediate string be run.

(b) Cementing procedures and casing tests for the intermediate string shall be the same as provided under sub-sections D (3) (c), (e) and (f) for the salt protection string.

(5) Production String:

(a) A production string shall be set on top or through the oil or gas pay zone and shall be cemented as follows:

(i) For wells drilled to the shallow zone the production string shall be cemented to the surface if the salt protection string was cemented only with a nominal volume for testing purposes, in which case the salt protection string can be cut and pulled before the production string is cemented; provided, that if the salt protection string was cemented to the surface, the production string shall be cemented with a volume adequate to protect the pay zone and the casing above such zone.

(ii) For wells drilled to the deep zone, the production string shall be cemented with a volume adequate to protect the pay zone and the casing above such zone; provided, that if no intermediate string shall have been run and cemented to the surface, the production string shall be cemented to the surface.

(b) Cementing procedures and casing tests for the production string shall be the same as provided under sub-section D (3) (c), (e) and (f) for the salt protection string; however if high pressure oil or gas production is discovered in an area, the Division may promulgate the necessary rules to prevent the charging of the salt section.

E. DRILLING FLUID FOR SALT SECTION

The fluid used while drilling the salt section shall consist of water, to which has been added sufficient salts of a character common to the zone penetrated to completely saturate the mixture. Other admixtures may be added to the fluid by the operator in overcoming any specific problem. This requirement is specifically intended to prevent enlarged drill holes.

F. PLUGGING AND ABANDONMENT OF WELLS

(1) All wells heretofore and hereafter drilled within the Potash Area shall be plugged in a manner and in accordance with the general rules or field rules established by the Division that will provide a solid cement plug through the salt section and any water-bearing horizon and prevent liquids or gases from entering the hole above or below the salt section.

(2) The fluid used to mix the cement shall be saturated with the salts common to the salt section penetrated and with suitable proportions but not more than three (3) percent of calcium chloride by weight of cement being considered the desired mixture whenever possible.

G. DESIGNATION OF DRILLABLE LOCATION FOR WELLS

(a) Within ninety (90) days following effective date of this Order and annually thereafter by January 31 if revised, each potash lessee, without regard to whether the lease covers State or Federal lands, shall file with the District Manager, BLM, and the State Land Office (SLO), a designation of the potash deposits considered by the potash lessee to be its life-of-mine reserves ("LMR"). For purposes of this Agreement, "life-of-mine reserves" means those potash deposits within the Potash Area reasonably believed by the potash lessee to contain potash ore in sufficient thickness and grade to be mineable using current day mining methods, equipment and technology. Information used by the potash lessee in identifying its LMR shall be filed with the BLM and SLO but will be considered privileged and confidential "trade secrets and commercial. . . .information" within the meaning of 43 C.F.R.§2.13(c)(4) (1986), Section 19-1-2.1 NMSA 1978, and not subject to public disclosure.

(b) Authorized officers of the BLM and SLO shall review the information submitted by each potash lessee in support of its LMR designation on their respective lands and verify upon request, that the data used by the potash lessee in establishing the boundaries of its LMR is consistent with data available to the BLM and SLO. Any disputes between the BLM and potash lessee concerning the boundary of a designated LMR shall be resolved in accordance with the Department of Interior's Hearings and Appeals Procedures, 43 C.F.R. Part 4 (1986).

(c) A potash lessee may amend its designated LMR by filing a revised designation with the BLM and SLO accompanied by the information referred to in Section A above. Such amendments must be filed by January 31 next following the date the additional data becomes available.

(d) Authorized officers of the BLM and SLO shall commit the designated LMR of each potash lessee to a map(s) of suitable scale and thereafter revise the map(s) as necessary to reflect the latest amendments to any designated LMRs. These maps shall be considered privileged and confidential and exempt from disclosure under 43 C.F.R. Part 2 and §19-1-2.1 NMSA 1978, and will be used only for the purposes set forth in this Order.

(e) The foregoing procedure can be modified by policy changes within the BLM and State Land Office.

(2) Before commencing drilling operations for oil or gas on any lands within the Potash Area, the well operator shall prepare a map or plat showing the location of the proposed well, said map or plat to accompany each copy of the Notice of Intention to Drill. In addition to the number of copies required by the Division, the well operator shall send one copy by registered mail to each potash operator holding potash leases within a radius of one mile of the proposed well, as reflected by the plats submitted under paragraph I (2). The well operator shall furnish proof of the fact that said potash operators were notified by registered mail of his intent by attaching return receipt to the copies of the Notice of Intention to Drill and plats furnished the Division.

(3) Drilling applications on federal lands will be processed for approval by BLM. Applications on state or patented lands will be processed by the Division and, in the case of state lands, in collaboration with the SLO. The Division will first ascertain from the BLM or SLO that the location is not within the LMR area. Active mine workings and mined-out areas shall also be treated as LMR. Any application to drill in the LMR area, including buffer zones, may be approved only by mutual agreement of lessor and lessees of

both potash and oil and gas interests. Applications to drill outside the LMR will be approved as indicated below; provided there is no protest from potash lessee within 20 days of his receipt of a copy of the notice:

(a) a shallow well shall be drilled no closer to the LMR than one-fourth (1/4) mile or 110% of the depth of the ore, whichever is greater.

(b) A deep well shall be drilled no closer than one-half (1/2) mile from the LMR.

H. INSPECTION OF DRILLING AND MINING OPERATIONS

A representative of any potash lessee within a radius of one mile from the well location may be present during drilling, cementing, casing, and plugging of any oil or gas wells to observe conformance with these regulations. Likewise, a representative of the oil and gas lessee may inspect mine workings on his lease to observe conformance with these regulations.

I. FILING OF WELL SURVEYS, MINE SURVEYS AND POTASH DEVELOPMENT PLANS

(1) Directional Surveys:

The Division may require an operator to file a certified directional survey from the surface to a point below the lowest known potash-bearing horizon on any well drilled within the Potash Area.

(2) Mine Surveys:

Within 30 days after the adoption of this order and thereafter on or before January 31st of each year, each potash operator shall furnish the Division two copies of a plat of a survey of the location of his leaseholdings and all of his open mine workings, which plat shall be available for public inspection and on a scale acceptable to the Division.

J. APPLICABILITY OF STATEWIDE RULES AND REGULATIONS

All general statewide rules and regulations of the Oil Conservation Division governing the development, operation, and production of oil and gas in the State of New

Mexico not inconsistent or in conflict herewith, are hereby adopted and made applicable to the areas described herein.

IT IS FURTHER ORDERED THAT:

(1) Order R-111 and amendments through R-111-O are hereby rescinded.

(2) Jurisdiction of this cause is retained for the entry of such further orders as the Commission may deem necessary.

Done at Santa Fe, New Mexico on the day and year hereinabove designated.

STATE OF NEW MEXICO
OIL CONSERVATION COMMISSION

WILLIAM R. HUMPHRIES, Member

ERLING A. BROSTUEN, Member

WILLIAM J. LEMAY, Chairman
and Secretary

EXHIBIT "A"
CASE 9316
ORDER R-111-P

CONSOLIDATED LAND DESCRIPTION OF THE KNOWN POTASH LEASING AREA, AS OF FEBRUARY 3, 1988

EDDY COUNTY, NEW MEXICO

TOWNSHIP 18 SOUTH, RANGE 30 EAST, NMPM
Section 10: SE/4 SE/4
Section 11: S/2 SW/4
Section 13: W/2 SW/4 and SE/4 SW/4
Section 14: W/2 NE/4, NW/4 and S/2
Section 15: E/2 NE/4, SE/4 SW/4 and SE/4
Section 22: N/2, N/2 SW/4, SE/4 SW/4 and SE/4
Section 23: All
Section 24: N/2 NW/4, SW/4 NW/4 and NW/4 SW/4
Section 26: NE/4, N/2 NW/4 and SE/4 NW/4
Section 27: N/2 NE/4 and NE/4 NW/4

TOWNSHIP 19 SOUTH, RANGE 29 EAST, NMPM
Section 11: SE/4 SE/4
Section 12: SE/4 NE/4 and S/2
Section 13: All
Section 14: NE/4, SE/4 NW/4 and S/2
Section 15: SE/4 SE/4
Section 22: NE/4, E/2 W/2 and SE/4
Section 23: All
Section 24: All
Section 25: NW/4 NW/4
Section 26: N/2 NE/4 and NW/4
Section 27: NE/4 and E/2 NW/4

TOWNSHIP 19 SOUTH, RANGE 30 EAST, NMPM
Section 2: SW/4
Section 3: W/2 SW/4, SE/4 SW/4, S/2 SE/4 and NE/4 SE/4
Section 4: Lots 3 and 4, SW/4 NE/4, S/2 NW/4 and S/2
Section 5: Lots 1, 2, and 3, S/2 NE/4, S/2 NW/4 and S/2
Section 6: S/2 SE/4 and NE/4 SE/4
Sections 7 to 10 inclusive
Section 11: S/2 NE/4, NW/4 NW/4 and S/2
Section 12: NE/4, S/2 NW/4 and S/2
Section 13: NE/4, W/2, N/2 SE/4 and SW/4 SE/4
Sections 14 to 18 inclusive
Section 19: Lots 1, 2, and 3, NE/4, E/2 NW/4, NE/4 SW/4, E/2 SE/4 and NW/4 SE/4
Sections 20 to 23 inclusive
Section 24: NW/4, NW/4 SW/4 and S/2 SW/4

Section 25: NW/4 NW/4
Section 26: NE/4 NE/4, W/2 NE/4, W/2, W/2 SE/4 and SE/4 SE/4
Section 27: All
Section 28: All
Section 29: E/2, E/2 NW/4 and NW/4 NW/4
Section 32: E/2 and SE/4 SW/4
Section 33 to 35 inclusive
Section 36: NW/4 NW/4, S/2 NW/4 and S/2

TOWNSHIP 19 SOUTH, RANGE 31 EAST, NMPM
Section 7: Lots 1, 2, and 3 and E/2 NW/4
Section 18: Lots 1, 2, and 3 and SW/4 NE/4, E/2 NW/4 and NE/4 SW/4
Section 31: Lot 4
Section 34: SE/4 SE/4
Section 35: S/2 SW/4 and SW/4 SE/4
Section 36: S/2 SE/4

LEA COUNTY, NEW MEXICO

TOWNSHIP 19 SOUTH, RANGE 32 EAST, NMPM
Section 31: Lot 4
Section 33: Lots 1 to 4 inclusive and N/2 S/2
Section 34: Lots 1 to 4 inclusive and N/2 S/2
Section 35: Lots 1 to 4 inclusive and N/2 S/2
Section 36: Lots 1 to 4 inclusive, SE/4 NE/4, NW/4 SW/4 and NE/4 SE/4

TOWNSHIP 19 SOUTH, RANGE 33 EAST, NMPM
Section 22: SE/4 NE/4, E/2 SW/4 and SE/4
Section 23: S/2 NW/4, SW/4, W/2 SE/4 and SE/4 SE/4
Section 25: SW/4 NW/4, W/2 SW/4 and SE/4 SW/4
Section 26: All
Section 27: All
Section 28: S/2 SE/4 and NE/4 SE/4
Section 30: Lots 2 to 4 inclusive, S/2 NE/4, SE/4 NW/4, E/2 SW/4 and SE/4
Section 31: All
Section 32: NE/4, S/2 NW/4 and S/2
Sections 33 to 35 inclusive
Section 36: W/2 NE/4, SE/4 NE/4, NW/4 and S/2

TOWNSHIP 19 SOUTH, RANGE 34 EAST, NMPM
Section 31: Lots 3 and 4

EDDY COUNTY, NEW MEXICO

TOWNSHIP 20 SOUTH, RANGE 29 EAST, NMPM

Section 1: SE/4 NE/4 and E/2 SE/4
Section 13: SW/4 NW/4, W/2 SW/4 and SE/4 SW/4
Section 14: NW/4 NE/4, S/2 NE/4, NW/4 and S/2
Section 15: E/2 E/2, SE/4 SW/4 and W/2 SE/4
Section 22: E/2 and E/2 NW/4
Section 23: All
Section 24: SW/4 NE/4, W/2, W/2 SE/4 and SE/4 SE/4
Section 25: N/2, SW/4, W/2 SE/4 and NE/4 SE/4
Section 26: All
Section 27: E/2
Section 34: NE/4
Section 35: N/2
Section 36: W/2 NE/4 and NW/4

TOWNSHIP 20 SOUTH, RANGE 30 EAST, NMPM

Sections 1 to 4 inclusive
Section 5: Lots 1 to 3 inclusive, S/2 N/2 and S/2
Section 6: Lots 5, 6, and 7, S/2 NE/4, E/2 SW/4 and SE/4
Section 7: Lots 1 and 2, E/2 and E/2 NW/4
Sections 8 to 17 inclusive
Section 18: E/2
Section 19: E/2 and SE/4 SW/4
Sections 20 to 29 inclusive
Section 30: Lots 1 to 3 inclusive, E/2 and E/2 W/2
Section 31: NE/4 and E/2 SE/4
Sections 32 to 36 inclusive

TOWNSHIP 20 SOUTH, RANGE 31 EAST, NMPM

Section 1: Lots 1 to 3 inclusive, S/2 N/2 and S/2
Section 2: All
Section 3: Lots 1 and 2, S/2 NE/4 and SE/4
Section 6: Lots 4 to 7 inclusive, SE/4 NW/4, E/2 SW/4, W/2 SE/4 and SE/4 SE/4
Section 7: All
Section 8: S/2 N/2 and S/2
Section 9: S/2 NW/4, SW/4, W/2 SE/4 and SE/4 SE/4
Section 10: E/2 and SW/4
Sections 11 to 36 inclusive

LEA COUNTY, NEW MEXICO

TOWNSHIP 20 SOUTH, RANGE 32 EAST, NMPM
Sections 1 to 4 inclusive
Section 5: S/2 SE/4
Section 6: Lots 4 to 7 inclusive, SE/4 NW/4, E/2 SW/4 and SW/4 SE/4
Sections 7 to 36 inclusive

TOWNSHIP 20 SOUTH, RANGE 33 EAST, NMPM
Sections 1 to 36 inclusive

TOWNSHIP 20 SOUTH, RANGE 34 EAST, NMPM
Section 6: Lots 3 to 7 inclusive, SE/4 NW/4, E/2 SW/4, W/2 SE/4 and SE/4 SE/4
Section 7: All
Section 8: SW/4, S/2 NW/4, W/2 SE/4 and SE/4 SE/4
Section 16: W/2 NW/4, SE/4 NW/4, SW/4 and S/2 SE/4
Sections 17 to 21 inclusive
Section 22: N/2 NW/4, SW/4 NW/4, SW/4, W/2 SE/4, and SE/4 SE/4
Section 26: SW/4, W/2 SE/4 and SE/4 SE/4
Sections 27 to 35 inclusive
Section 36: SW/4 NW/4 and W/2 SW/4

EDDY COUNTY, NEW MEXICO

TOWNSHIP 21 SOUTH, RANGE 29 EAST, NMPM
Sections 1 to 3 inclusive
Section 4: Lots 1 through 16, NE/4 SW/4 and SE/4
Section 5: Lot 1
Section 10: N/2 NE/4, SE/4 NE/4 and SE/4 SE/4
Sections 11 to 14 inclusive
Section 15: E/2 NE/4 and NE/4 SE/4
Section 23: N/2 NE/4
Section 24: E/2, N/2 NW/4 and SE/4 NW/4
Section 25: NE/4 NE/4 and S/2 SE/4
Section 35: Lots 2 to 4 inclusive, S/2 NE/4, NE/4 SW/4 and N/2 SE/4
Section 36: Lots 1 to 4 inclusive, NE/4, E/2 NW/4 and N/2 S/2

TOWNSHIP 21 SOUTH, RANGE 30 EAST, NMPM

TOWNSHIP 21 SOUTH, RANGE 31 EAST, NMPM
Sections 1 to 36 inclusive

LEA COUNTY, NEW MEXICO

TOWNSHIP 21 SOUTH, RANGE 32 EAST, NMPM
Sections 1 to 27 inclusive
Section 28: N/2 and N/2 S/2
Sections 29 to 31 inclusive
Section 32: NW/4 NE/4, NW/4 and NW/4 SW/4
Section 34: N/2 NE/4
Section 35: N/2 N/2
Section 36: E/2, N/2 NW/4, SE/4 NW/4 and NE/4 SW/4

TOWNSHIP 21 SOUTH, RANGE 33 EAST, NMPM
Section 1: Lots 2 to 7 inclusive, Lots 10 to 14 inclusive, N/2 SW/4 and SW/4 SW/4
Sections 2 to 11 inclusive
Section 12: NW/4 NW/4 and SW/4 SW/4
Section 13: N/2 NW/4, S/2 N/2 and S/2
Sections 14 to 24 inclusive
Section 25: N/2, SW/4 and W/2 SE/4
Sections 26 to 30 inclusive
Section 31: Lots 1 to 4 inclusive, NE/4, E/2 W/2, N/2 SE/4 and SW/4 SE/4
Section 32: N/2 and NW/4 SW/4
Section 33: N/2
Section 34: NE/4, N/2 NW/4 and E/2 SE/4
Section 35: All
Section 36: W/2 NE/4, NW/4 and S/2

TOWNSHIP 21 SOUTH, RANGE 34 EAST, NMPM
Section 17: W/2
Section 18: All
Section 19: Lots 1 to 4 inclusive, NE/4, E/2 W/2, N/2 SE/4 and SW/4 SE/4
Section 20: NW/4 NW/4
Section 30: Lots 1 and 2 and NE/4 NW/4
Section 31: Lots 3 and 4

EDDY COUNTY, NEW MEXICO

TOWNSHIP 22 SOUTH, RANGE 28 EAST NMPM

TOWNSHIP 22 SOUTH, RANGE 29 EAST, NMPM
Sections 1 and 2 inclusive
Section 3: SE/4 SW/4 and SE/4
Section 9: S/2 NE/4 and S/2
Sections 10 to 16 inclusive
Section 17: S/2 SE/4
Section 19: SE/4 NE/4 and E/2 SE/4
Sections 20 to 28 inclusive
Section 29: N/2 N/2, S/2 NE/4 and SE/4
Section 30: NE/4 NE/4
Section 31: Lots 1 to 4 inclusive, S/2 NE/4, E/2 W/2 and SE/4
Sections 32 to 36 inclusive

TOWNSHIP 22 SOUTH, RANGE 30 EAST, NMPM
Sections 1 to 36 inclusive

TOWNSHIP 22 SOUTH, RANGE 31 EAST, NMPM
Sections 1 to 11 inclusive
Section 12: NW/4 NE/4, NW/4 and NW/4 SW/4
Section 13: S/2 NW/4 and SW/4
Sections 14 to 23 inclusive
Section 24: W/2
Section 25: NW/4
Section 26: NE/4 and N/2 NW/4
Sections 27 to 34 inclusive

LEA COUNTY, NEW MEXICO

TOWNSHIP 22 SOUTH, RANGE 32 EAST, NMPM
Section 1: Lot 1
Section 6: Lots 2 to 7 inclusive and SE/4 NW/4

TOWNSHIP 22 SOUTH, RANGE 33 EAST, NMPM
Section 1: Lots 1 to 4 inclusive, S/2 N/2 and N/2 S/2
Section 2: All
Section 3: Lot 1, SE/4 NE/4 and SE/4
Section 6: Lot 4
Section 10: NE/4
Section 11: NW/4 NE/4 and NW/4

TOWNSHIP 22 SOUTH, RANGE 34 EAST, NMPM
Section 6: Lots 4 to 6 inclusive

EDDY COUNTY, NEW MEXICO

TOWNSHIP 23 SOUTH, RANGE 28 EAST, NMPM
Section 1: Lot 1

TOWNSHIP 23 SOUTH, RANGE 29 EAST, NMPM
Sections 1 to 5 inclusive
Section 6: Lots 1 to 6 inclusive, S/2 NE/4, SE/4 NW/4, E/2 SW/4 and SE/4
Section 7: NE/4 and NE/4 NW/4
Section 8: N/2, N/2 SW/4, SE/4 SW/4 and SE/4
Sections 9 to 16 inclusive
Section 17: NE/4 and E/2 SE/4
Sections 21 to 23 inclusive
Section 24: N/2, SW/4 and N/2 SE/4
Section 25: W/2 NW/4 and NW/4 SW/4
Section 26: All
Section 27: All
Section 28: N/2, N/2 SW/4, SE/4 SW/4 and SE/4
Section 33: N/2 NE/4 and NE/4 NW/4
Section 34: NE/4, E/2 NW/4, NW/4 NW/4, NE/4 SW/4 and SE/4
Section 35: All
Section 36: W/2 NE/4, NW/4 and N/2 SW/4

TOWNSHIP 23 SOUTH, RANGE 30 EAST, NMPM
Sections 1 to 18 inclusive
Section 19: N/2, N/2 SW/4, SE/4 SW/4 and SE/4
Section 20: All
Section 21: All
Section 22: N/2, S/2 SW/4, N/2 S/2 and SE/4 SE/4
Sections 23 to 25 inclusive
Section 26: E/2, SE/4 NW/4 and SW/4
Section 27: N/2 NW/4, SW/4 NW/4, SE/4 SW/4, S/2 SE/4 and NE/4 SE/4
Section 28: N/2 and SW/4
Section 29: N/2 and SE/4
Section 30: N/2 NE/4
Section 32: N/2 NE/4
Section 33: SE/4 NE/4, N/2 NW/4, NE/4 SE/4 and S/2 SE/4
Sections 34 to 36 inclusive

TOWNSHIP 23 SOUTH, RANGE 31 EAST, NMPM
Section 2: Lot 4, SW/4 NW/4 and W/2 SE/4
Sections 3 to 7 inclusive
Section 8: NE/4 NE/4, W/2 NE/4 and W/2
Section 9: N/2 N/2
Section 10: NW/4 NW/4 and SE/4 SE/4
Section 11: [illegible]

Section 12: SW/4 NW/4 and SW/4
Section 13: SW/4 NE/4, W/2 and W/2 SE/4
Section 14: All
Section 15: E/2, SE/4 NW/4 and SW/4
Section 16: SW/4 and S/2 SE/4
Section 17: NW/4 and S/2
Sections 18 to 23 inclusive
Section 24: W/2 NE/4 and W/2
Section 25: W/2 NE/4, NW/4, N/2 SW/4 and NW/4 SE/4
Sections 26 to 34 inclusive
Section 35: N/2 NW/4 and SW/4 NW/4

TOWNSHIP 24 SOUTH, RANGE 29 EAST, NMPM
Section 2: Lots 2 to 4 inclusive
Section 3: Lot 1

TOWNSHIP 24 SOUTH, RANGE 30 EAST, NMPM
Section 1: Lots 1 to 4 inclusive, S/2 N/2, SW/4 and NW/4 SE/4
Section 2: All
Section 3: All
Section 4: Lots 1 and 2, S/2 NE/4, SE/4 NW/4, SW/4 SW/4, E/2 SW/4 and SE/4
Section 9: N/2, N/2 SW/4, SE/4 SW/4 and SE/4
Section 10: All
Section 11: All
Section 12: W/2 NW/4 and NW/4 SW/4
Section 14: W/2 NE/4 and NW/4
Section 15: NE/4 and N/2 NW/4

TOWNSHIP 24 SOUTH, RANGE 31 EAST, NMPM
Section 3: Lots 2 to 4 inclusive, SW/4 NE/4, S/2 NW/4, SW/4 and W/2 SE/4
Section 4: All
Section 5: Lots 1 to 4 inclusive, S/2 N/2, N/2 S/2 and SE/4 SE/4
Section 6: Lots 1 to 6 inclusive, S/2 NE/4, SE/4 NW/4, NE/4 SW/4 and N/2 SE/4
Section 9: E/2 and NW/4
Section 10: W/2 NE/4 and W/2
Section 35: Lots 1 to 4 inclusive, S/2 N/2 and N/2 S/2
Section 36: Lots 1 and 2, SW/4 NW/4 and N/2 SW/4

TOWNSHIP 25 SOUTH, RANGE 31 EAST, NMPM
Section 1: Lots 3 and 4 and S/2 NW/4
Section 2: Lots 1 to 4 inclusive and S/2 N/2

STATEMENT OF AGREEMENT BETWEEN
THE POTASH INDUSTRY AND OIL AND
GAS INDUSTRY ON CONCURRENT
OPERATIONS IN THE POTASH AREA
IN EDDY AND LEA COUNTIES, NEW MEXICO

Introduction

This Statement of Agreement sets forth the joint agreement of the Potash Industry and Oil and Gas Industry on important issues concerning the concurrent development of potash and oil and gas reserves in Eddy and Lea Counties, New Mexico. It represents the efforts of numerous representatives from each Industry over many months and is intended to resolve many of the disputes that have arisen as a result of concurrent oil and gas drilling activities in the vicinity of underground potash mining.

The parties recognize that this Agreement will not resolve all disputes or disagreements that may arise and that regulatory intervention may still be necessary in some instances. By entering into this Agreement, however, each industry recognizes the right of the other to develop its mineral resources in a safe and economical manner and acknowledges that concurrent development of multiple mineral resources places certain limits on each industry. Each also agrees that these limits can be better defined through good faith discussions among industry representatives familiar with industry technology and practices than repeated and prolonged litigation or administrative proceedings.

EXHIBIT "B"
CASE NO. 9316
ORDER NO. R-111-P

In attempting to accomplish this, each Industry has made concessions on issues considered critical to it in a good faith effort to obtain concessions from the other. For this reason, both Industries agree that the terms of this Statement of Agreement are subject to the following conditions:

1. Upon approval by representatives of each Industry, the terms of the Agreement will be submitted to and must be adopted without substantial change by the New Mexico Oil Conservation Commission ("OCC") in lieu of the current Order R-111A, as amended;

2. The terms of the Agreement will be submitted to and must be adopted without substantial change by the U. S. Department of Interior, Bureau of Land Management ("BLM") in lieu of Section III (E) of the Secretary of the Interior's Order of October 21, 1986 [51 Fed. Reg. 39425];

3. Each Industry will use its best efforts to secure approval of the terms of the Agreement from the OCC and BLM; and

4. In the event the terms in the Agreement are not adopted without substantial change by both the OCC and the BLM, this Statement of Agreement will become null and void and will not be referred to by any Industry representative on the Study Committee in any future proceeding before the OCC or BLM.

It is the intention of the parties to this Agreement that: (1) certain areas of potash deposits, called "life-of-mine-reserves" or "LMR's," be permanently protected from oil and gas drilling activities; and (2) to make available for oil and gas drilling activities, certain areas within the Potash Area. The area of potash deposits protected will be determined in accordance with this Agreement but, generally speaking, will encompass the yellow, orange and a major portion of the blue

areas shown on the BLM Potash Resources Map as it existed on October 1, 1984. Areas in the Potash Area that will be available for oil and gas drilling activities will be those areas outside the designated LMR's which, generally speaking, will be the red, green, grey and a minor portion of the blue areas shown on the BLM Potash Resources Map as it existed on October 1, 1984, less areas designated as buffer zones by this Agreement.

I. The Potash Area

A. The Area covered by this Agreement shall be known as the "Potash Area".

B. The "Potash Area" includes those tracts of land in Southeastern New Mexico, from the surface downward, which are designated as a "potash area" by the Secretary of the Department of Interior in Section V of the Order dated October 21, 1986 and published in the Federal Register on October 28, 1986 [51 Fed. Reg. 39426]. It shall also include any subsequent revisions to such designations. The terms "potash" and "commercial deposits of potash" shall have the same meaning as assigned by the U. S. Department of Interior.

C. It is the intent of the parties to this Agreement that the "Potash Area" designated by the State of New Mexico be identical to that designated by the U. S. Department of Interior. Accordingly, if the "potash area" designated in the Secretarial Order of October 21, 1986 [51 Fed. Reg. 39425] is revised, the OCC, on its own motion after notice and hearing as

provided by applicable laws and regulations, will adopt the same revision.

II. Designation of Mine Reserves

A. Within ninety (90) days following adoption of this Agreement by the OCC and BLM and annually thereafter by January 31 if revised, each potash lessee, without regard to whether the lease covers State or Federal lands, shall file with the District Manager, BLM, a designation of the potash deposits considered by the potash lessee to be its life-of-mine reserves ("LMR"). For purposes of this Agreement, "life-of-mine reserves" means those potash deposits within the Potash Area reasonably believed by the potash lessee to contain potash ore in sufficient thickness and grade to be mineable using current day mining methods, equipment and technology. Information used by the potash lessee in identifying its LMR shall be filed with the BLM but will be considered privileged and confidential "trade secrets and commercial . . . information" within the meaning of 43 C.F.R. §2.13(c)(4) (1986) and not subject to public disclosure.

B. An authorized officer of the BLM shall review the information submitted by each potash lessee in support of its LMR designation and verify, upon request, that the data used by the potash lessee in establishing the boundaries of its LMR is consistent with data available to the BLM. Any disputes between the BLM and potash lessee concerning the boundary of a designated LMR shall be resolved in accordance with the

Department of Interior's Hearings and Appeals Procedures, 43 C.F.R. Part 4 (1986).

C. A potash lessee may amend its designated LMR by filing a revised designation with the BLM accompanied by the information referred to in Section A above. Such amendments must be filed by January 31 next following the date the additional data becomes available.

D. An authorized officer of the BLM shall commit the designated LMR of each potash lessee to a map(s) of suitable scale and thereafter revise the map(s) as necessary to reflect the latest amendments to any designated LMRs. These maps shall be considered privileged and confidential and exempt from disclosure under 43 C.F.R. Part 2 and will be used only for the purposes set forth in this Agreement.

III. Drilling in the Potash Area

A. All oil and gas wells drilled in the Potash Area after approval of this Agreement by the OCC and BLM, including those currently pending before the OCC and/or BLM, shall be subject to the terms of this Agreement.

B. It is the policy of the OCC and BLM to approve or deny applications for permits to drill (APD's) in the Potash Area in accordance with the following:

1. LMR and Buffer Zone. No oil or gas well shall be allowed from a surface location: (a) within the LMR of any potash lessee; (b) within one-fourth (1/4) mile, or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, of the LMR of any potash lessee; or (c) where the well casing will pass within one-fourth (1/4) mile, or a distance equal to

the depth of the ore plus ten percent (10%), whichever is greater, of the LMR of any potash lessee.

2. Outside Buffer Zone But Within One-Half (1/2) mile of LMR. An APD for an oil or gas well at a location more than one-fourth (1/4) mile, or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, but less than one-half (1/2) mile from the LMR of any potash lessee may be approved only if: (a) the bottom hole location does not extend below the base of the Delaware Mountain Group, and (b) the well is drilled in accordance with the cementing and casing requirements set forth in Section V.

3. More Than One-Half Mile But Less Than One Mile From LMR. An APD for an oil or gas well at a location more than one-half (1/2) mile but less than one mile from the LMR of any potash lessee may be approved regardless of the depth of the bottom hole location provided: (a) wells with bottom hole locations below the base of the Delaware Mountain Group are drilled in accordance with the cementing and casing requirements set forth in Section V of this Agreement, and (b) wells to bottom hole locations above the base of the Delaware Mountain Group may be drilled without regard to the requirements in Section V of this Agreement but must be drilled in accordance with then current Industry safety standards.

4. More Than One Mile From LMR. An APD for an oil or gas well at a location more than one mile from the LMR of any potash lessee may be approved regardless of the depth of the bottom hole location and without regard to the requirements of Section V of this Agreement.

5. Open Mine Workings. No oil or gas well shall be allowed from any location where the well casing will pass within one-fourth (1/4) mile or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, of any open mine workings.

6. Abandoned Mine Workings. No oil or gas well shall be allowed from any location where the well casing will pass through or within one-fourth (1/4) of a mile or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, of any abandoned mine workings that are connected to an existing mine by an opening or barrier of one-hundred (100) feet or less unless the APD is accompanied by the sealing and safety plan and certification described in Paragraph G below.

7. An APD for a directionally drilled oil or gas well to a bottom hole location underlying the LMR of any potash lessee may be approved subject to the limitations and requirements set forth in Paragraphs 1 - 6 above. Directionally drilled holes shall be drilled vertically until they have completely penetrated Marker Bed No. 126 (U.S.G.S.) of the Salado Formation at which time they may be deviated.

C. An oil and gas operator desiring to drill a well to a bottom hole location that does not extend below the base of the Delaware Mountain Group from a surface location where the well casing will pass through or within one-fourth (1/4) of a mile or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, of abandoned mine workings that are connected to an existing mine by any opening or a barrier of one-hundred (100) feet or less shall prepare and submit to all affected potash lessees a plan and program for sealing off the area to be penetrated from other mine workings. Approval of any such plan shall be in the sole discretion of the affected potash lessees. Any approved plan shall be attached by the oil and gas operator to the APD for filing with the OCC, and/or BLM. The oil and gas operator shall also complete a certification in the form prescribed by the OCC and/or BLM that the drilling of such well will not create a safety hazard to affected potash lessees.

D. It is the belief of both parties that the provisions of this Agreement eliminate the need for drilling islands and three-year mining plans and, therefore, both agree that no drilling islands will be established in the Potash Area and the filing of three-year mining plans will be eliminated.

IV. Location of Wells and Notice to Potash Lessee

A. The BLM, upon request, will advise oil and gas lessees of the surface locations where wells will be allowed to develo the leases. Oil or gas leases covering areas designated a LMR by a potash lessee will be unitized to the extent possible with other areas where drilling is allowed.

B. An oil or gas operator desiring to drill an oil or gas well in the Potash Area or within one (1) mile of a potash lease shall prepare and file an APD with the OCC and/or BLM along with a map or plat showing the location of the proposed well. One copy of the APD and map or plat shall be served by registered mail, return receipt requested, on all potas leaseholders within one (1) mile of the proposed wel location. However, if the APD is for an oil or gas well that will penetrate abandoned mine workings, all potash leaseholder in the Potash Area shall be notified. Proof of such service shall be attached to the APD and filed with the OCC and/o BLM. Within twenty (20) days of service of an APD and requir documents, any potash leaseholder within one (1) mile of the proposed well location (or any affected potash lessee if t proposed well will penetrate abandoned mine workings) may fi an objection with the OCC to the proposed well. If the objections cannot be resolved by agreement of the parties, t matter shall be referred for hearing before the OCC.

C. The failure of a potash leaseholder to object to well location or its agreement to the drilling locatio

referred to in this Agreement shall not constitute a release of liability. Oil and gas leaseholders and those persons and/or entities involved in the development of the lease shall be responsible as provided by law for any damages caused by them to any person by the release of gases or liquids into the strata or atmosphere as a result of drilling activities.

V. Drilling and Casing Program

[Same as current R-111-A]

VI. Drilling Fluid for Salt Section

[Same as current R-111-A]

VII. Plugging and Abandonment of Wells

[Same as current R-111-A]

VIII. Filing of Well Surveys

The OCC may require an oil and gas operator to file a certified directional survey from the surface to a point below the lowest known potash bearing horizon on all wells drilled in the Potash Area. All encounters with flammable gases, including H_2S, shall be reported by the operator to the OCC.

IX. Additional Safety Requirements and Emergency Action

A. All oil and gas drilling activities within the Potash Area shall be performed using appropriate technology, equipment, and procedures to reduce the hazards of such activities to underground mines and miners and be conducted in accordance with the prudent operator standard.

B. Only the minimum number of wells necessary to develop an oil or gas lease will be allowed within the Potash Area.

C. In the event the increased oil and gas drilling activities allowed by this Agreement result in a safety hazard or if data developed in the course of such increased activities make it reasonably appear that such activities are or will become a hazard to underground miners or mining activities, the BLM and/or OCC will, upon request, initiate proceedings in accordance with NMSA 70-2-23 and/or other applicable laws and regulations to review such data and take whatever emergency steps are found necessary to eliminate such hazard. Potash lessees may, in addition, initiate actions for injunctive relief under NMSA 70-2-29. The taking or failure to take such action by the OCC or any potash lessee shall not relieve the oil and gas lessee from liability for any damages caused by its oil and gas activities.

AGREED TO AND APPROVED THIS 23rd DAY OF November, 1987, BY THE FOLLOWING REPRESENTATIVES OF EACH INDUSTRY COMPRISING THE POTASH-OIL AREA SPECIAL RULES STUDY COMMITTEE:

For the Oil and Gas Industry:	For the Potash Industry:
[signature]	[signature]
[signature]	W. S. Thayer
Robert F. [signature]	[signature]
	Donald Galbraith

1727L-7

areas shown on the BLM Potash Resources Map as it existed on October 1, 1984. Areas in the Potash Area that will be available for oil and gas drilling activities will be those areas outside the designated LMR's which, generally speaking, will be the red, green, grey and a minor portion of the blue areas shown on the BLM Potash Resources Map as it existed on October 1, 1984, less areas designated as buffer zones by this Agreement.

I. The Potash Area

A. The Area covered by this Agreement shall be known as the "Potash Area".

B. The "Potash Area" includes those tracts of land in Southeastern New Mexico, from the surface downward, which are designated as a "potash area" by the Secretary of the Department of Interior in Section V of the Order dated October 21, 1986 and published in the Federal Register on October 28, 1986 [51 Fed. Reg. 39426]. It shall also include any subsequent revisions to such designations. The terms "potash" and "commercial deposits of potash" shall have the same meaning as assigned by the U. S. Department of Interior.

C. It is the intent of the parties to this Agreement that the "Potash Area" designated by the State of New Mexico be identical to that designated by the U. S. Department of Interior. Accordingly, if the "potash area" designated in the Secretarial Order of October 21, 1986 [51 Fed. Reg. 39425] is revised, the OCC, on its own motion after notice and hearing as

provided by applicable laws and regulations, will adopt the same revision.

II. Designation of Mine Reserves

A. Within ninety (90) days following adoption of this Agreement by the OCC and BLM and annually thereafter by January 31 if revised, each potash lessee, without regard to whether the lease covers State or Federal lands, shall file with the District Manager, BLM, a designation of the potash deposits considered by the potash lessee to be its life-of-mine reserves ("LMR"). For purposes of this Agreement, "life-of-mine reserves" means those potash deposits within the Potash Area reasonably believed by the potash lessee to contain potash ore in sufficient thickness and grade to be mineable using current day mining methods, equipment and technology. Information used by the potash lessee in identifying its LMR shall be filed with the BLM but will be considered privileged and confidential "trade secrets and commercial . . . information" within the meaning of 43 C.F.R. §2.13(c)(4) (1986) and not subject to public disclosure.

B. An authorized officer of the BLM shall review the information submitted by each potash lessee in support of its LMR designation and verify, upon request, that the data used by the potash lessee in establishing the boundaries of its LMR is consistent with data available to the BLM. Any disputes between the BLM and potash lessee concerning the boundary of a designated LMR shall be resolved in accordance with the

Department of Interior's Hearings and Appeals Procedures, 43 C.F.R. Part 4 (1986).

C. A potash lessee may amend its designated LMR by filing a revised designation with the BLM accompanied by the information referred to in Section A above. Such amendments must be filed by January 31 next following the date the additional data becomes available.

D. An authorized officer of the BLM shall commit the designated LMR of each potash lessee to a map(s) of suitable scale and thereafter revise the map(s) as necessary to reflect the latest amendments to any designated LMRs. These maps shall be considered privileged and confidential and exempt from disclosure under 43 C.F.R. Part 2 and will be used only for the purposes set forth in this Agreement.

III. Drilling in the Potash Area

A. All oil and gas wells drilled in the Potash Area after approval of this Agreement by the OCC and BLM, including those currently pending before the OCC and/or BLM, shall be subject to the terms of this Agreement.

B. It is the policy of the OCC and BLM to approve or deny applications for permits to drill (APD's) in the Potash Area in accordance with the following:

1. LMR and Buffer Zone. No oil or gas well shall be allowed from a surface location: (a) within the LMR of any potash lessee; (b) within one-fourth (1/4) mile, or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, of the LMR of any potash lessee; or (c) where the well casing will pass within one-fourth (1/4) mile, or a distance equal to

the depth of the ore plus ten percent (10%), whichever is greater, of the LMR of any potash lessee.

2. Outside Buffer Zone But Within One-Half (1/2) mile of LMR. An APD for an oil or gas well at a location more than one-fourth (1/4) mile, or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, but less than one-half (1/2) mile from the LMR of any potash lessee may be approved only if: (a) the bottom hole location does not extend below the base of the Delaware Mountain Group, and (b) the well is drilled in accordance with the cementing and casing requirements set forth in Section V.

3. More Than One-Half Mile But Less Than One Mile From LMR. An APD for an oil or gas well at a location more than one-half (1/2) mile but less than one mile from the LMR of any potash lessee may be approved regardless of the depth of the bottom hole location provided: (a) wells with bottom hole locations below the base of the Delaware Mountain Group are drilled in accordance with the cementing and casing requirements set forth in Section V of this Agreement, and (b) wells to bottom hole locations above the base of the Delaware Mountain Group may be drilled without regard to the requirements in Section V of this Agreement but must be drilled in accordance with then current Industry safety standards.

4. More Than One Mile From LMR. An APD for an oil or gas well at a location more than one mile from the LMR of any potash lessee may be approved regardless of the depth of the bottom hole location and without regard to the requirements of Section V of this Agreement.

5. Open Mine Workings. No oil or gas well shall be allowed from any location where the well casing will pass within one-fourth (1/4) mile or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, of any open mine workings.

6. Abandoned Mine Workings. No oil or gas well shall be allowed from any location where the well casing will pass through or within one-fourth (1/4) of a mile or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, of any abandoned mine workings that are connected to an existing mine by an opening or barrier of one-hundred (100) feet or less unless the APD is accompanied by the sealing and safety plan and certification described in Paragraph C below.

7. An APD for a directionally drilled oil or gas well to a bottom hole location underlying the LMR of any potash lessee may be approved subject to the limitations and requirements set forth in Paragraphs 1 - 6 above. Directionally drilled holes shall be drilled vertically until they have completely penetrated Marker Bed No. 126 (U.S.G.S.) of the Salado Formation at which time they may be deviated.

C. An oil and gas operator desiring to drill a well to a bottom hole location that does not extend below the base of the Delaware Mountain Group from a surface location where the well casing will pass through or within one-fourth (1/4) of a mile or a distance equal to the depth of the ore plus ten percent (10%), whichever is greater, of abandoned mine workings that are connected to an existing mine by any opening or a barrier of one-hundred (100) feet or less shall prepare and submit to all affected potash lessees a plan and program for sealing off the area to be penetrated from other mine workings. Approval of any such plan shall be in the sole discretion of the affected potash lessees. Any approved plan shall be attached by the oil and gas operator to the APD for filing with the OCC, and/or BLM. The oil and gas operator shall also complete a certification in the form prescribed by the OCC and/or BLM that the drilling of such well will not create a safety hazard to affected potash lessees.

D. It is the belief of both parties that the provisions of this Agreement eliminate the need for drilling islands and three-year mining plans and, therefore, both agree that no drilling islands will be established in the Potash Area and the filing of three-year mining plans will be eliminated.

IV. Location of Wells and Notice to Potash Lessee

A. The BLM, upon request, will advise oil and gas lessees of the surface locations where wells will be allowed to develo the leases. Oil or gas leases covering areas designated a LMR by a potash lessee will be unitized to the extent possible with other areas where drilling is allowed.

B. An oil or gas operator desiring to drill an oil or gas well in the Potash Area or within one (1) mile of a potash lease shall prepare and file an APD with the OCC and/or BLM along with a map or plat showing the location of the proposed well. One copy of the APD and map or plat shall be served by registered mail, return receipt requested, on all potas leaseholders within one (1) mile of the proposed well location. However, if the APD is for an oil or gas well that will penetrate abandoned mine workings, all potash leaseholder in the Potash Area shall be notified. Proof of such service shall be attached to the APD and filed with the OCC and/o BLM. Within twenty (20) days of service of an APD and require documents, any potash leaseholder within one (1) mile of the proposed well location (or any affected potash lessee if th proposed well will penetrate abandoned mine workings) may fi an objection with the OCC to the proposed well. If the objections cannot be resolved by agreement of the parties, t matter shall be referred for hearing before the OCC.

C. The failure of a potash leaseholder to object to well location or its agreement to the drilling locatio

referred to in this Agreement shall not constitute a release of liability. Oil and gas leaseholders and those persons and/or entities involved in the development of the lease shall be responsible as provided by law for any damages caused by them to any person by the release of gases or liquids into the strata or atmosphere as a result of drilling activities.

V. Drilling and Casing Program

[Same as current R-111-A]

VI. Drilling Fluid for Salt Section

[Same as current R-111-A]

VII. Plugging and Abandonment of Wells

[Same as current R-111-A]

VIII. Filing of Well Surveys

The OCC may require an oil and gas operator to file a certified directional survey from the surface to a point below the lowest known potash bearing horizon on all wells drilled in the Potash Area. All encounters with flammable gases, including H_2S, shall be reported by the operator to the OCC.

IX. Additional Safety Requirements and Emergency Action

A. All oil and gas drilling activities within the Potash Area shall be performed using appropriate technology, equipment, and procedures to reduce the hazards of such activities to underground mines and miners and be conducted in accordance with the prudent operator standard.

B. Only the minimum number of wells necessary to develop an oil or gas lease will be allowed within the Potash Area.

C. In the event the increased oil and gas drilling activities allowed by this Agreement result in a safety hazard or if data developed in the course of such increased activities make it reasonably appear that such activities are or will become a hazard to underground miners or mining activities, the BLM and/or OCC will, upon request, initiate proceedings in accordance with NMSA 70-2-23 and/or other applicable laws and regulations to review such data and take whatever emergency steps are found necessary to eliminate such hazard. Potash lessees may, in addition, initiate actions for injunctive relief under NMSA 70-2-29. The taking or failure to take such action by the OCC or any potash lessee shall not relieve the oil and gas lessee from liability for any damages caused by its oil and gas activities.

AGREED TO AND APPROVED THIS 23rd DAY OF November, 1987, BY THE FOLLOWING REPRESENTATIVES OF EACH INDUSTRY COMPRISING THE POTASH-OIL AREA SPECIAL RULES STUDY COMMITTEE:

For the Oil and Gas Industry:

[signature]

[signature]

[signature]

For the Potash Industry:

[signature]

W. S. Thayer

[signature]

Donald Galbraith

1727L-7

NM OIL CONSERVATION COMMISSION
HEARING
February 18, 1988

Yates	OCD	Hinkle Law	Lundberg
Bass	BLM	Charles High	Western Ag
Exxon	SLO		NM Potash
Gas Co NM			IMC Fertilizer
Chevron			
Phillips			
Conoco			
Texaco			
Amoco			
Unocal			
Campbell & Black			
Talisman Energy			
Mesa Ltd. Ptnr			
Sun E&P			
Louisiana Land			
Hondo Oil			
Tenneco Oil			

COMPANIES REPRESENTED AT COMMITTEE MEETINGS

Heyco	Charles High	IMC Fertilizer
Yates Petroleum	Steelworkers	NM Potash
Talisman	OCD	Mississippi Chem
Bass	BLM	Western Ag
Texaco	Kellahin NMOGA	Lundberg
Exxon		Noranda Minerals
Anadarko Pet.		AMAX
Amoco		

MAILING LIST

Enron	Carlsbad Chamber of Commerce
Tenneco	W. Tom Kellahin
Kaiser-Francis Oil Co.	Robert Light, NM State Rep.
	James Ott
	NMOCD
	D. S. Nutter

POTASH STUDY COMMITTEE

Mailing List

NAME	REPRESENTING	ADDRESS
J. C. Allen	Amoco Production Co.	Box 3092, Houston Tx. 77253
George R. S. Buehler	Anadarko Petroleum Corp.	Box 2497, Midland, Tx. 79702
Frank Condon	Noranda Minerals	Box 159, Lithia, Fl. 33547
James L. Cromer	Exxon Drilling	Box 10488, Midland, Tx. 79702
Randall L. Foote	Mississippi Chemical Corp.	Box 101, Carlsbad, N.M. 88220
Joe Gant	Chamber of Commerce Government Affairs Comm.	P. O. Box 909, Carlsbad, N.M. 88220
Dan Girand	HEYCO	Box 1933, Roswell, N.M. 88201
Jimmy D. Hall	Steelworkers Local	804 Solana, Carlsbad, N.M. 88220
Jens Hansen	Bass Enterprises Prod. Co.	First City Bank Tower, 201 Main St., Ft. Worth, Tx. 76102
Charles C. High, Jr.	Attorney, pro se	Drawer 2800, El Paso, Tex. 79999
George Hover	Enron Oil & Gas	Box 2267, Midland, Tex. 79702
W. Tom Kellahin	Attorney N. M. Oil & Gas Attorney	Box 2265, Santa Fe, N.M. 87504
Robert E. Kirby	Amax Chemical Corp.	Box 279, Carlsbad, N.M. 88220
Robert N. Kreul	Lundberg Industries, Ltd.	Box 31, Carlsbad, N.M. 88220
Robert H. Lane	New Mexico Potash	Box 610, Hobbs, N.M. 88240
Robert S. Light	N.M. State Representative	Box 1658, Carlsbad, N.M. 88220
B. L. Midgley	Western AG-Minerals Co.	Box 511, Carlsbad, N.M. 88220
David L. Motlock	Tenneco Oil Co.	7990 IH 10 West, San Antonio, Tx. 78230
James Olsen	B.L.M. - NM 921	Box 1449, Santa Fe, N.M. 87504
James Otts	St. Representative	1015 N. Pate, Carlsbad, N.M. 88220
R. W. Parrish	International Minerals & Chem. Corp.	Box 71, Carlsbad, N.M. 88220

Oil - Potash Work Committee Meeting
July 23, 1987

Name	Representing	Location
V. T. Lyon	OCD	Santa Fe
RANDY FOOTE	M.C.C.	CARLSBAD
DAN GIRAND	HEYCO	Roswell
LARRY BROOKS	HEYCO	ROSWELL / ARTESIA
Herbert T. Rempe	Yates Pet. Corp.	Artesia, NM
JOHN M. WAID	TALISMAN	HOUSTON, TX
Jane Hamm	BASS Enterprises	Fort [illegible]
Dave Mari	B.L.M.	Roswell, NM
Walter Thayer	IMC	Carlsbad, N Mex
Charles C. High Jr	Potash Industry	El Paso
Erling A. Brostuen	N.M. M.M.D.	Santa Fe
ROBERT LANE	N.M. POTASH CORP	HOBBS

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NEW MEXICO OIL CONSERVATION COMMISSION

COMMISSION HEARING

SANTA FE , NEW MEXICO

Hearing Date FEBRUARY 18, 1988 Time: 9:00 A.M.

NAME	REPRESENTING	LOCATION
Norbert F. Rempe	Yates Pet. Corp.	Artesia, NM
Jem Hower	BASS	Fort Worth
Louis Wilpitz	Bass Enterprises Production Co	Fort Worth, Texas
Victor T. Lyon	OCD	Santa Fe
Jim Knauf	Self	Artesia, NM
Bill Duncan	Exxon	Midland, TX
Dean H. Mutti	Exxon	Midland, TX
Robert Grady	Exxon	Midland, TX
Fran Cherry	BLM	Roswell NM
W. Bruce	Hinkle Law Firm	Santa Fe
Ernest Szabo	SLO	Santa Fe
JM Otis	Gas Co. of NM	Albuq.
Carolyn Titus	Gas Co. of NM	Albuq.
W. Kellahin	Bass	Santa Fe
Robert M Krenl	Lundberg	Carlsbad
Mickey Cohlmia	Chevron	Hobbs
Guy Hollingsworth	Chevron	Hobbs
Larry Sanders	Phillips Petroleum Co.	Odessa, Texas
Hugh Ingram	Conoco	Hobbs
John Seeman	Texaco	Hobbs
Dennis Wehmeyer	Texaco	Hobbs
Jim Collier	Amoco	Houston
Dan Currens Engineer	Self	Midland

NEW MEXICO OIL CONSERVATION COMMISSION

COMMISSION HEARING

SANTA FE, NEW MEXICO

Hearing Date FEBRUARY 18, 1988 Time: 9:00 A.M.

NAME	REPRESENTING	LOCATION
H. René Moulinet	Unocal	Midland, TX.
R. Huber	Byram	Santa Fe
Scott Hall	Campbell & Black	SF
John Waid	Talisman Energy Corp	Houston, TX
John Dean	Mesa Ltd. Partnership	Amarillo, Tex.
Richard Paris / Mike Mozentalm	Sun E&P	Midland, TX
Alan Beers	Sun	Midland
Don Galbraith	Western Ag-Minerals	Carlsbad, N
Charles A Caughey	Louisiana Land & Expl Co.	Houston
Charles Snow	Hondo Oil & Gas Company	Roswell
R.H. Lane	New Mexico Potash Corp	Hobbs
John Purcell	IMC	Carlsbad
Armando Lopez	BLM	Roswell
Ray L. Graham	Self	Santa Fe
Dean Nyffel	BLM	Roswell
Charles C. High, Jr.	Potash Industry	El Paso
Walter D. Thaxton	IMC-Fert	Carlsbad
Joe Lara	BLM	Roswell
Paul F. Nielsen	Louisiana Land and Explor. Co	Houston, TX
Rex Bourland	Tenneco Oil Company	San Antonio, TX

Jim Pullig	Bass Enterprises Prod. Co.	Box 2760, Midland, Tx. 79702
L. John Seeman	Texaco USA	Box 728, Hobbs, N.M. 88240
Walter Thayer	International Minerals & Chem. Corp.	Box 71, Carlsbad, N.M. 88220
Al Springer	Yates Petroleum	207 S. Fourth, Artesia, N.M. 88210
Warren Traweek	Western AG-Minerals Co.	Box 511, Carlsbad, N.M. 88220
J. M. or J. B. Waid	Talisman Energy Corp.	2807 Buffalo Spdwy, Suite 319, Houston, Texas 77098
Jae J. Walker	Amax Chemical Corp.	Box 279, Carlsbad, N.M. 88220
Marvin Watts	N.M. State Senator	Box 56, Carlsbad, N.M. 88220
Victor T. Lyon	N.M.O.C.D.	Box 2088, Santa Fe, N.M. 87504
Les Clements	N.M.O.C.D.	Drawer DD, Artesia, N.M. 88210

Information and Mailing

D. S. Nutter	Consultant	105 E. Alicante, Santa Fe, N.M. 87501
James T. Wakefield	Kaiser-Francis Oil Co.	Box 21468, Tulsa, Ok. 71421
Jerry Sexton 88240	N.M.O.C.D.	P. O. Box 1980, Hobbs, New Mexico

OIL-POTASH STUDY COMMITTEE MEETING

March 19, 1987

Santa Fe, New Mexico

NAME	AFFILIATION	LOCATION	PHONE NO.
Vic Lyon	OCD	Santa Fe	505-827-5809
John Waid	Talisman Energy	Houston, Tx.	713-840-7000
Don Steinnerd	Texaco	Hobbs	505-393-7191
Rex Parrish	Steel Workers	Loving	505-745-3303
Donald Galbraith	Western Ag-Minerals	Carlsbad	505-887-3976
Robert Kreul	Lundberg Industries	Carlsbad	505-887-2844
Robert H. Lane	New Mexico Potash	Hobbs	505-397-3261
Norbert T.Rempe	Yates Petroleum Corp.	Artesia	505-748-1471
James L. Cromer	Exxon Co.	Midland, Tx.	915-686-4364
Jens Hansen	Bass Enterprises	Ft. Worth, Tx.	817-390-8568
J. B. Waid	Talisman Energy	Midland, Tx	
Dan Girand	Harvey E. Yates	Roswell	505-623-6601
A. J. Deans	Harvey E. Yates	Roswell	505-623-6601
John Purcell	IMCC	Carlsbad	505-887-2871
Dan Morehouse	IMCC	Carlsbad	505-887-2871
Clark H. McNaughton	IMCC	Carlsbad	505-887-2871
George R.S. Buehler	Anadarko Petroleum	Midland	915-682-1666
Randy Foote	Mississippi Chemical	Carlsbad	505-887-5591
Walter E. Thayer	IMCC	Carlsbad	505-887-2871
James Olsen	BLM	Santa Fe	
Bill LeMay	OCD	Santa Fe	
Charles C. High Jr.	Potash Industry	El Paso, Tx.	915-533-4424

Potash Oil Study Committee
Sept. 25, 1986

Name	Company	Location
Vic Lyon	N.M.OCD	Santa Fe
Charles C. High, Jr.	Kemp, ~~Smith~~	El Paso
Warren Traweek	Western Ag-Minerals Co.	Carlsbad
Walter E. Thayer	IMC	Carlsbad
John Waid	Talisman Energy Corp	Houston, TX
A.J. Deans	Harvey E. Yates Co.	Roswell
Dan Morehouse	IMC	Carlsbad
John Seeman	Texaco	Hobbs
Dan Girand	HEYCO	Roswell
James L. Cromer	Exxon Co USA	Midland
R.H. Lane	New Mex Potash	Hobbs
Robert S. Light	State Representative Dist 55 Eddy	Carlsbad
[illegible]	NMOGA	Santa Fe
[illegible]	Steelworker's 189-A	Carlsbad
Jens Hansen	Bass Enterprises	Fort Worth
Louie M. Lore	Bass Enterprises	Midland
Robert Bell	Harvey E. Yates Co.	Roswell
James A. Olsen	Bur. Land Mgmt	Santa Fe
William Darmitzel	N.M. Mining Assn.	Santa Fe
George Buehler	[illegible]	Midland TX
David Catanach	NMOCD	Santa Fe
Michael E. Stogner	NMOCD	Santa Fe, NM
Marvin Watts	State Senate	Carlsbad
James C. Allen	Amoco Production Co.	Houston
R E Kirby	Amax Chemical Corp	Carlsbad
Robert N. Kreul	Lundberg	Carlsbad
Bill Midgley	Western Ag-Minerals Co.	Carlsbad
Frank Condon	Noranda Minerals	Florida
Larry Brooks	Harvey E. Yates Co	Roswell NM
Norbert F. Rempe	Yates Petroleum Corp.	Artesia, NM
Al Springer	" "	" "
Darrell Moore	NMOCD	Artesia, N.M
Les Clements	NMOCD	Artesia, NM

STATE OF NEW MEXICO

ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT

OIL CONSERVATION DIVISION

GARREY CARRUTHERS
GOVERNOR

POST OFFICE BOX 2088
STATE LAND OFFICE BUILDING
SANTA FE, NEW MEXICO 87504
(505) 827-5800

M E M O R A N D U M

TO: Charles High, Attorney
Walt Thayer, IMC.
Robert Lane, N.M. Potash
Randy Foote, (Alternate), Miss. Chem.
Jens Hansen, Bass Enterprises
A. J. Deans, Heyco Inc.
John Waid, Talisman Energy
Norbert Rempe, (Alternate), Yates

FROM: Victor T. Lyon

SUBJECT: Potash-Oil Work Committee Meeting

DATE: November 12, 1987

A meeting of the committee is hereby called for November 23. We will convene at 9:00 a.m. in the conference room in Charlie High's law firm, Kemp, Smith, Duncan and Hammond, in M Bank Plaza, corner of Kansas and Mills Streets, downtown El Paso. We hope to finalize the agreement attached to Mr. High's letter dated October 15, 1987 to Jens Hansen.

cc: Erling Brosteun, MMD
Jim Olsen, BLM, Santa Fe
Fran Cherry, BLM, Roswell

VTL/ag

U.S. Department of the Interior • Bureau of Mines

MINERAL INDUSTRY SURVEYS

T S Ary, Director Washington, DC 20241

For information call:
James P. Searls (202) 501-9407

Annual, Preliminary

POTASH IN 1991

The attached 2 pages, reprinted from the Bureau of Mines Mineral Commodity Summaries--1992, provide the earliest estimates of 1991 data and activity highlights of Potash. Most of the estimates are based on 9 months data and are compared with final data from previous years.

Footnote 5 for Potash refers to reserve base definitions published in Mineral Commodity Summaries--1992 and in U.S.G.S. Circular 831, 1980.

Prepared by the Branch of Industrial Minerals and Branch of Data Collection and Coordination, January 1992.

POTASH

(Data in thousand metric tons of K_2O equivalent, unless noted)

1. **Domestic Production and Use:** In 1991 the production of marketable potash, f.o.b. mine was about $305 million. Potash production was centered in southwestern New Mexico, where five companies operated six mines by conventional underground mining of bedded deposits; this potash was beneficiated mostly by flotation, but also by heavy media separation, dissolution-recrystalization, and washing, providing 85% of the U.S. total. In Utah, one company was able to bring underground bedded potash to the surface by solution mining. The potash was recovered from the brine by solar evaporation and flotation. Another company collected subsurface brines from an interior basin for solar evaporation and flotation. A third company used solar evaporation to concentrate the brines of the North Arm of the Great Salt Lake. In California, one company recovered potash, coproducts borax pentahydrate, and saltcake from subsurface brines from an interior basin using mechanical evaporation. In Michigan, a company continued experimental work concerning solution mining and recovery by mechanical evaporation. The fertilizer industry used close to 95% of the U.S. potash sales and the chemical industry used about 5%. About 75% of the potash was produced as potassium chloride (muriate of potash). Potassium sulfate (sulfate of potash) and potassium magnesium sulfate (sulfate of potash-magnesia), required by certain crops and soils, composed about 20% of potash production. Potash was transported by train, truck, and barges to warehouses, wholesalers, and retailers with some potash being sold from barges used as temporary warehouses. Retailers sold potash and potash blended with other fertilizers in dry or liquid form for distribution over fields in both spring and fall.

2. **Salient Statistics—United States:**

	1987	1988	1989	1990	1991[e]
Production, marketable	1,262	1,521	1,595	1,713	1,770
Imports for consumption	4,073	4,217	[1]3,410	4,164	4,200
Exports	470	380	446	470	650
Consumption, apparent	5,088	5,264	[2]4,500	5,453	5,343
Price, dollars per metric ton of K_2O, average, muriate, f.o.b. mine[3]	93	132	137	130	131
Stocks, producer, yearend	155	248	307	303	290
Employment: Mine	720	855	890	1,011	1,011
Mill	791	745	930	960	990
Net import reliance[4] as a percent of apparent consumption	75	71	65	68	67

3. **Recycling:** None.

4. **Import Sources (1987-90):** Canada, 90%; Israel, 5%; U.S.S.R., 2%; Federal Republic of Germany, Eastern states, 2%; and other, 1%.

5. **Tariff:**

Item	Number	Most favored nation (MFN) 1/1/92	Non-MFN 1/1/92
Crude salts, sylvinite, etc.	3104.10	Free	Free.
Potassium chloride	3104.20	Free	Free.
Potassium sulfate	3104.3	Free	Free.
Potassium nitrate	2834.21	Free	Free.
Potassium-sodium nitrate mixtures	3105.90001	Free	Free.

6. **Depletion Allowance:** 14% (Domestic), 14% (Foreign)

[e]Estimated.
[1]Source: U.S. Bureau of the Census. The Potash & Phosphate Institute (PPI) reported 4,050,000 tons in 1989.
[2]Based on the U.S. Bureau of the Census reports of imports from Canada. An alternative calculation of apparent consumption using the PPI report of imports from Canada would be 5,150,000 tons.
[3]Average prices based on actual sales; excludes soluble and chemical muriates.
[4]Defined as imports – exports + adjustments for Government and industry stock changes.
[5]See page 200 for definitions.
[6]Total reserve base in the Dead Sea is equally divided between Israel and Jordan.
[7]A reserve of 22,300,000 was reported by I. D. Sokolov in Basic Tasks of the Potash Industry up to the Year 2000, Zhurnal Vsesoyuznogo Khimicheskogo Obshchestva Im. D. I. Mendeleyeva, v. 32, No. 4, July–Aug. 1987, pp. 383–387.

Prepared by **James P. Searls, (202) 501-9407.**

POTASH

7. **Government Stockpile:** None.

8. **Events, Trends, and Issues:** The world's potash producers stayed in over-capacity but several producers operated at partial capacity to maintain prices. The Canadian potash industry operated at about 60% capacity for the year. In the United States the Corn Belt and Lake States received about the same amount of potash as the 1989 and 1990 spring seasons even though it was a wet spring through May. Abundant world supplies of soybeans and corn did not encourage heavy planting. After spring planting season, the crop conditions in the U.S.S.R., and the anticipation of exports to the U.S.S.R., encouraged a stronger fall use of potash in anticipation of 1992. The U.S. Department of Agriculture also reduced the corn Acreage Reduction Program to 5%, which increased the application of potash in the fall. One Carlsbad, NM, potash mine is currently for sale.

   It is estimated that in 1992 domestic mine production will be 1.8 million tons and that the U.S. apparent consumption will be 5.4 million tons.

9. **World Mine Production, Reserves, and Reserve Base:**

	Mine production		Reserves[5]	Reserve base[5]
	1990	1991[e]		
United States	1,713	1,770	85,000	290,000
Brazil	60	30	50,000	600,000
Canada	7,372	7,500	4,400,000	9,700,000
Chile	25	25	10,000	50,000
China	40	60	320,000	320,000
France	1,300	1,250	16,000	35,000
Germany, Federal Republic of				
Eastern states	2,700	2,000	300,000	350,000
Western states	2,200	2,300	500,000	600,000
Israel	1,350	1,350	53,000	[6]600,000
Italy	60	100	20,000	40,000
Jordan	790	790	54,000	[6]600,000
Spain	690	670	28,000	45,000
Thailand	—	—	—	100,000
U.S.S.R.	9,500	8,800	3,600,000	[7]3,800,000
United Kingdom	490	500	25,000	30,000
World total (may be rounded)	28,290	27,145	9,460,000	17,200,000

10. **World Resources:** Estimated domestic potash resources total about 6 billion tons. Most of this lies at depths between 6,000 and 10,000 feet in a 1,200-square-mile area of Montana and North Dakota as an extension of the Williston Basin deposits in Saskatchewan, Canada. The Paradox Basin in Utah contains approximately 2 billion tons, mostly at depths of more than 4,000 feet. An unknown, but apparently large, quantity of potash resources lies about 7,000 feet under central Michigan. The U.S. reserve figure above contains 25 million tons of reserves in central Michigan. Estimated world resources total about 250 billion tons. The potash deposits in the U.S.S.R. contain large amounts of carnallite; it is not clear if this can be mined in a free market, competitive economy. Large resources, about 10 billion tons and mostly carnallite, occur in Thailand.

11. **Substitutes:** There are no substitutes for potassium as an essential plant nutrient and essential requirement for animals and humans. Manure and glauconite are low-potassium-content sources that can be transported short distances to the crop fields.

GEOLOGY OF THE CARLSBAD
POTASH MINING DISTRICT

(With Emphasis on Brine and Inert Gases

Adjacent to or Within the Ore Beds)

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March 9, 1982

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HISTORY OF DISCOVERY AND DEVELOPMENT

OF CARLSBAD POTASH DISTRICT

The denial of access to German sources of potash fertilizers during World War I was sufficient incentive to cause a nationwide search for a domestic source in our known bedded salt deposits such as in the Michigan, Paradox, Williston and Permian Basins. Early investigations by the U.S. Geological Survey favored the Permian Basin because the mineral polyhalite had been recognized over wide areas of southeast New Mexico and west Texas from cuttings recovered from holes drilled for oil, Hoots, 1925. The desire to find domestic sources was demonstrated by the enactment of Public Law 424 in 1926 which authorized a 5-year exploration program, including core-drilling, by the U.S. Geological Survey and U.S. Bureau of Mines. The government drilled a total of 24 widely spaced holes between 1927 and 1931, 13 in New Mexico, 10 in Texas and 1 in Utah. Simultaneously, private industry joined into the search, with geologists carefully examining cuttings from holes drilled for oil but penetrating salt on the way down. Fortunately, most of the drilling still was done with cable tools during the late 1920s which insured a saturated brine would build-up in the hole and thus retard dissolving soluble potash minerals.

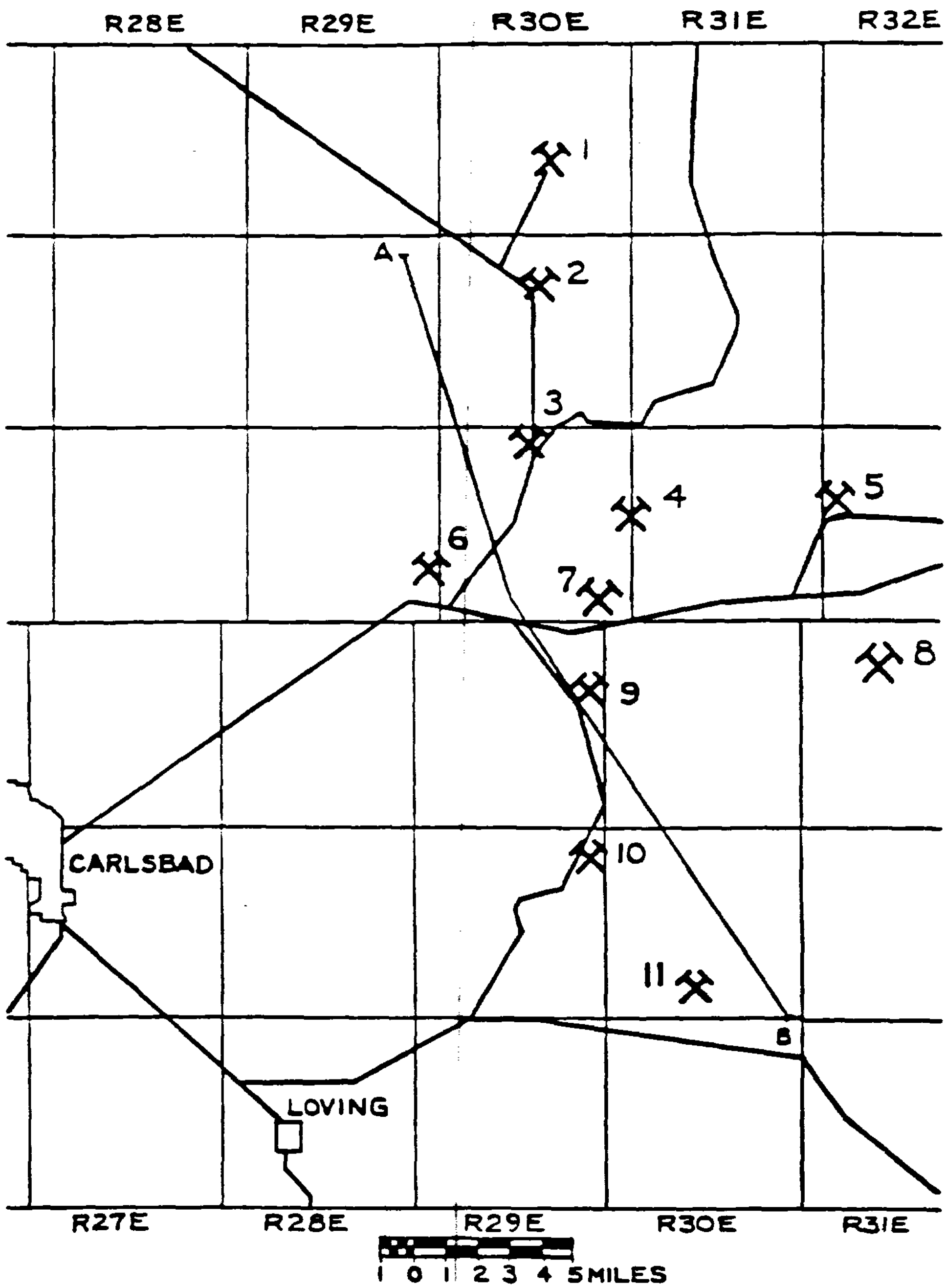
Although it was the U.S. Geological Survey who initiated the potash exploration program, serendipity played its usual role in the discovery. Drill cuttings from the Snowden-McSweeney No. 1 McNutt wildcat provided the first evidence of commercial amounts of sylvite. The well was spudded on July 5, 1925, and reached its eventual total depth of 4416 feet on March 20, 1926. V.H. McNutt is credited with the identification of several significant intercepts of sylvite by examination of the cuttings. That serendipity played its role rests on these eventual revelations: 1) the hole was drilled for oil of which none was found, 2) the hole location was almost at the exact "center of gravity" of the numerous ore bodies now known in the district, 3) potassium mineralization was present in all 11 of the now accepted ore horizons, but 4) no potash mining has been done in the immediate vicinity of the hole because of the low grade in comparison with surrounding areas.

The American Potash Company was formed initially as a subsidiary of the Snowden-McSweeney Oil Company. A core-drilling program was commenced which immediately proved up reserves of sufficient size and grade to justify mine development a short distance west of the initial discovery. The holdings of the American Potash were transferred and reorganized into the U.S. Potash Company which in turn was a subsidiary of U.S. Borax. Mining commenced in 1931. The Potash Company of America opened a second mine in 1934. The capacities of these mines were steadily increased and still other companies opened new mines until there are now six companies working in the district (Fig. 1 and 2).

At present 3000 persons are directly employed by the Carlsbad potash industry with an annual payroll of $60 million. While the potash industry is affected by national economic trends and faces stiff foreign competition, it has been one of the most stable industries in New Mexico.

STRATIGRAPHY

The Carlsbad district is located within a classical marine evaporite basin. The total thickness of evaporites ranges from 1000 feet in the



1- DUVAL (WILLS-WEAVER)*
2- AMAX
3- PCA
4- MISSISSIPPI (NORTH)*
5- NATIONAL (LEA)*
6- NATIONAL (EDDY)*
7- DUVAL (SAUNDERS)*
8- KERR McGEE
9- MISSISSIPPI
10- INTERNATIONAL MINERALS
11- DUVAL NASH DRAW
* CLOSED

FIGURE 1
LOCATION MAP

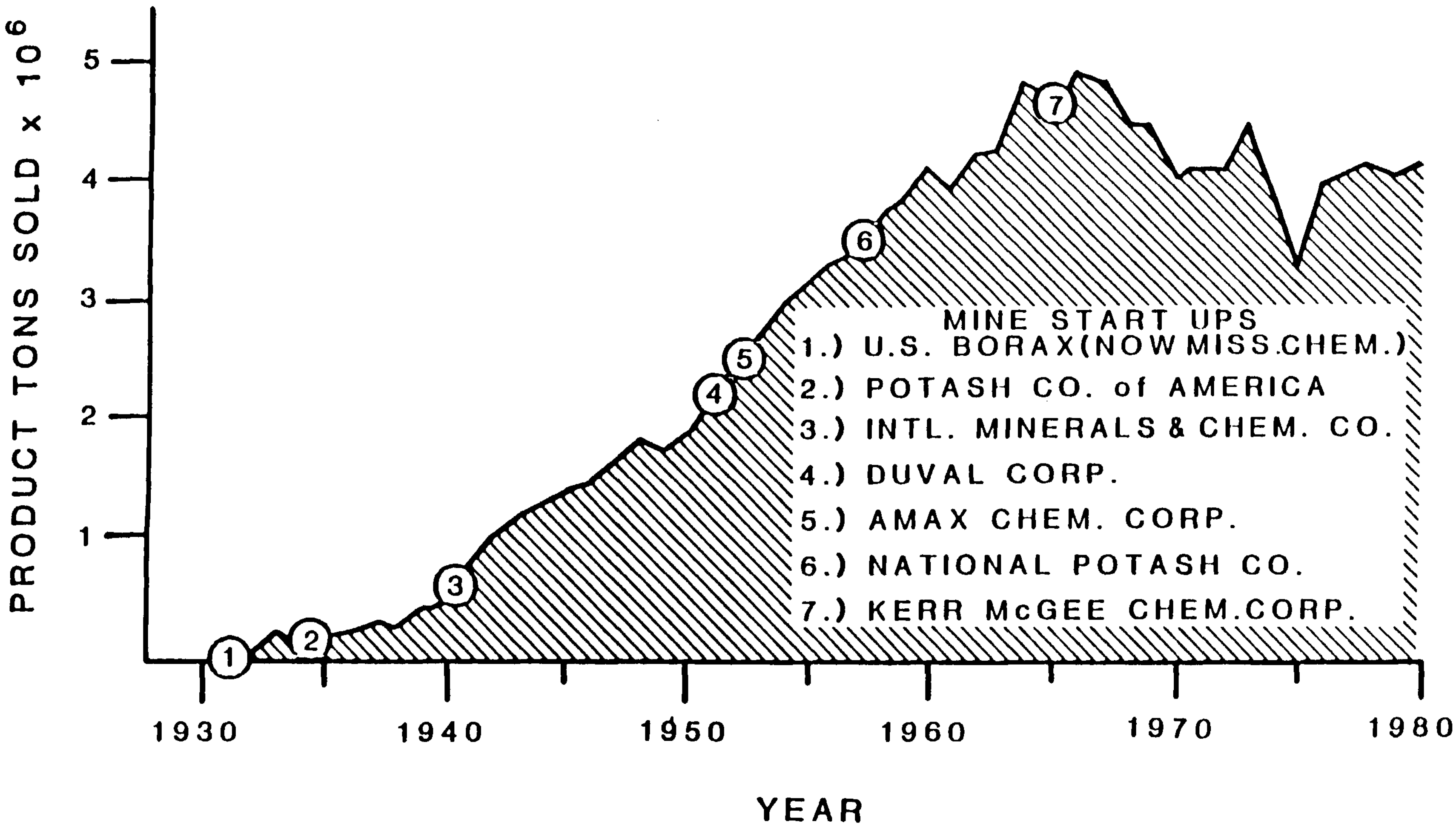


Figure 2. Potash production. Includes all potassium salts (sylvite, langbeinite and K_2SO_4).

northern mines to as much as 3000 feet in the south. The potash deposits are restricted to thin lenses (4 to 8 feet) within this thick sequence of salt and anhydrite beds. The potash mining horizons occur in the upper portion of the evaporites; thus an "insulating" blanket of salt and anhydrite separates the potash mining levels from underlying sandstone and porous carbonate beds that contain oil and gas. The thickness of this insulating blanket is never less than 400 feet and may be as thick as 2500 feet. What will now follow is a more detailed description of the character and method of deposition of these evaporites that will fully explain the reason that potash mining horizons are completely isolated from entry of gases from underlying oil-gas reservoirs.

The potash deposits lie within a large Permian aged structural feature known as the Southern Permian Basin. The basin is of large areal extent, covering most of southeast New Mexico and west Texas. This basin, along with its ancestral structures, contains one of the most complete stratigraphic sections of the Permian to be found anywhere within the continental U.S. A generalized stratigraphic cross-section is presented in Figure 3. The entire section is in the order of 16,500 feet thick, two-thirds of which is of Permian age. The Permian is divisable into four series: Wolfcampian, Leonardian, Guadalupian, and Ochoan.

Note the postion reefs and carbonate banks on Figure 3. Throughout Guadalupian time a large reef commenced to grow which separated deep marine sedimentation on the south from shallow lagoonal deposition to the north. The back reef environment was ideal for the eventual formation of oil reservoirs.

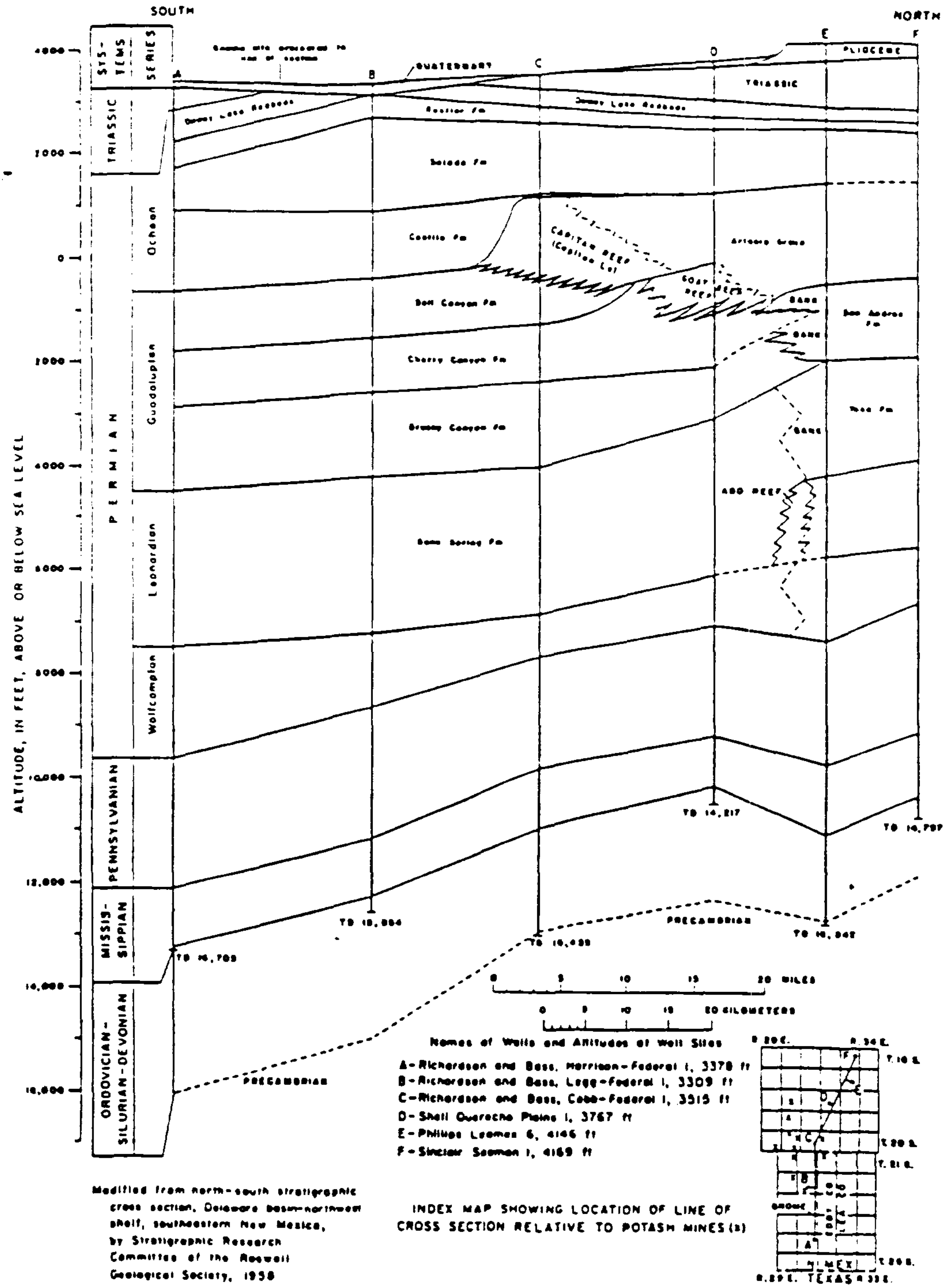


Figure 3. Generalized geologic cross section from south to north through the vicinity of the Gnome site and the potash mines, Eddy and Lea Counties, New Mexico.

By the close of Guadalupian time the Capitan Reef had reached a thickness of 1000 feet and formed a complete oval shaped barrier that cut off what is now called the Delaware Basin from the main Permian seas to the south. This barrier set the stage for formation of the Ochoan evaporites by a simple ocean drying process. Sediments could no longer pass through the reef into the basin, and pure beds of anhydrite and salt formed in a deep water environment. These deep water evaporites are called the given name of Castile Formation. Shales and carbonates continued to form behind the reef, but the environment rapidly became highly saline and organic life could no longer be sustained either in front of, over, or behind the reef.

Marine waters invaded again after the close of Castile time. The conditions continued to be quite arid and halite and anhydrite precipitation continued, represented by the Salado Formation. The bed characteristics are such to indicate that this deposition was in shallow evaporating pans. The Salado evaporites are extensive; they cover most of the Permian Basin. At certain times, evaporation of marine waters continued to the extreme end point where all calcium and sodium had precipitated to form gypsum and halite. The residual bitterns became highly enriched in potassium and magnesium. These bitterns accumulated in restricted basins to be eventually precipitated as potash mineral deposits.

The Rustler Formation overlies the Salado. These beds contain dolomite, anhydrite and salt at the base which grade upward into clay and silt deposits. This sequence of deposition is interpreted as representing an initial transgression of marine waters, followed by evaporation. Then a final regression of the sea occurred that allowed fluvial sediments (clay and silt) to cover and preserve the underlying evaporites. The fluvial beds are called the Dewey Lake Formation and represent the close of Permian time in this part of New Mexico.

The Triassic is represented by red bed type deposits of sandstone, siltstone and conglomerate of the Santa Rosa Formation. These deposits rest on the Dewey Lake with only a moderate unconformity. The stratigraphic history is missing from the Triassic to the Late Tertiary Cretaceous rocks may have been present but if so, they were removed by erosion. The oldest beds now overlying the Santa Rosa are the gravel deposits of the Ogallala Formation. The Ogallala has been stripped in the eastern portion of the district by erosion associated with the present Pecos River drainage.

STRUCTURE

While major structures exist to the west (Guadalupe Mountain Uplift), the structural setting within the potash mining district is monotonously flat. Figure 4 is a north-south cross-section through the district. The undulations of the beds is due to the extreme vertical exaggeration used to compile the cross-section. The most prominent subsurface feature is the Capitan Reef, which separates the Delaware Basin from the Northern Shelf. Note that the deep marine evaporites of the Castile thin rapidly from the basin as they pass over the reef. On the other hand, the Salado is of fairly uniform thickness from basin onto the shelf. Therefore, the effect of the reef on sedimentation was limited to the period of time from its growth during the Guadalupian until the basin was filled

Figure 4. Geologic cross-section through the Potash Mining District

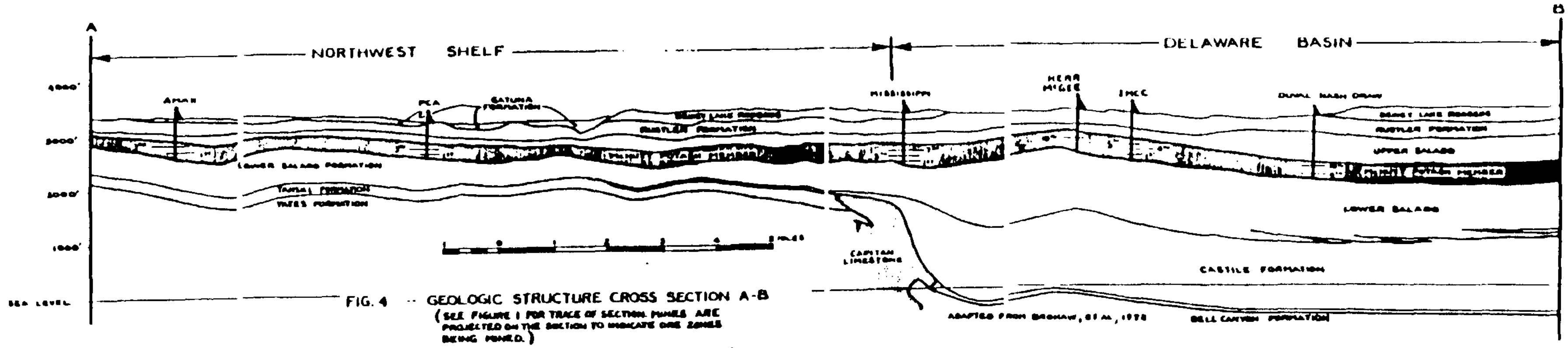


FIG. 4 -- GEOLOGIC STRUCTURE CROSS SECTION A-B
(SEE FIGURE 1 FOR TRACE OF SECTION. MINES ARE PROJECTED ON THE SECTION TO INDICATE ORE ZONES BEING MINED.)

by the earlier Ochoan Castile Formation. The Salado, Rustler and Dewey Lake Formation appear to have been deposited in a broad and shallow tidal basin environment that has been little disturbed since, except for a gentle tilting to the east.

Two additional structures need to be mentioned. A Tertiary aged basaltic dike transects the mining district. The general trend of the dike is N. 50° E. The dike has been encountered in the IMCC Mine in the southwest and in the Ker-McGee Mine in the northwest. No offset of beds has been noticed, it is thin (2 to 6 feet), there are no associated fluids, and it has presented no difficulty to mining. The other type structures are solution collapsed chimneys. The origin is thought to be due to groundwaters within the underlying Capitan Reef having dissolved salt from the base of the Salado or due to collapse of caverns within the reef itself. One of these collapsed chimneys has been encountered in the Mississippi Mine, but it presented no obstacle to mining, other than destroying the ore bed within the actual breccia.

DETAILED STRATIGRAPHY OF THE OCHOAN EVAPORITES

The Ochoan is divided into four formations; see Table 1. Figure 5 is a general stratigraphic column of the entire Ochoan along with an expanded section of the McNutt Member of the Salado Formation. The cyclical nature of deposition, commencing with mudstone at the base followed by anhydrite and finally salt, is much in evidence throughout the Salado. These rhythmic cycles, averaging 4 feet thick but may be as thick as 20 feet and as thin as less than one foot, are thought to be due to periodic

Table 1. Description of Ochoan Rock

		TRIASSIC
Dewey Lake 200-300 ft.		Red siltstone, sandstone and mudstone. Thin lamination and small-scale cross lamination common.
Rustler 200-500 ft.		Mostly anhydrite with some salt. Contains two dolomite layers, a basal sandstone, and several thin layers of clastics. The two dolomite layers are normally aquifers in most of the eastern part of the district, and halite has been removed from the section and original anhydrite converted to gypsum.
Salado	Upper 500 ft.	Halite with regular but thin beds of anhydrite and polyhalite. Clay seems common at the base of the anhydrite-polyhalite seams. Suberosion by groundwaters has removed much of this member in the eastern part of the district.
	McNutt 300-500 ft.	The overall character is identical to the Upper and Lower Members. The important exception is that sylvite and Langbeinite occur as thin (1 to 10 feet) beds within this unit.
	Lower 400-1500 ft.	Identical in lithology to the Upper Member except that halite units are thicker and purer.
Castile	0-1500 ft.	This formation is present only in the Delaware Basin, i.e. south of the Capitan Reef. Near the reef the section is almost totally anhydrite. South of the reef it consists of equal portions of salt and anhydrite in thick beds. The halite is very pure. The anhydrite is "banded" with thin alternating layers of anhydrite and dolomite.
		GUADALUPIAN

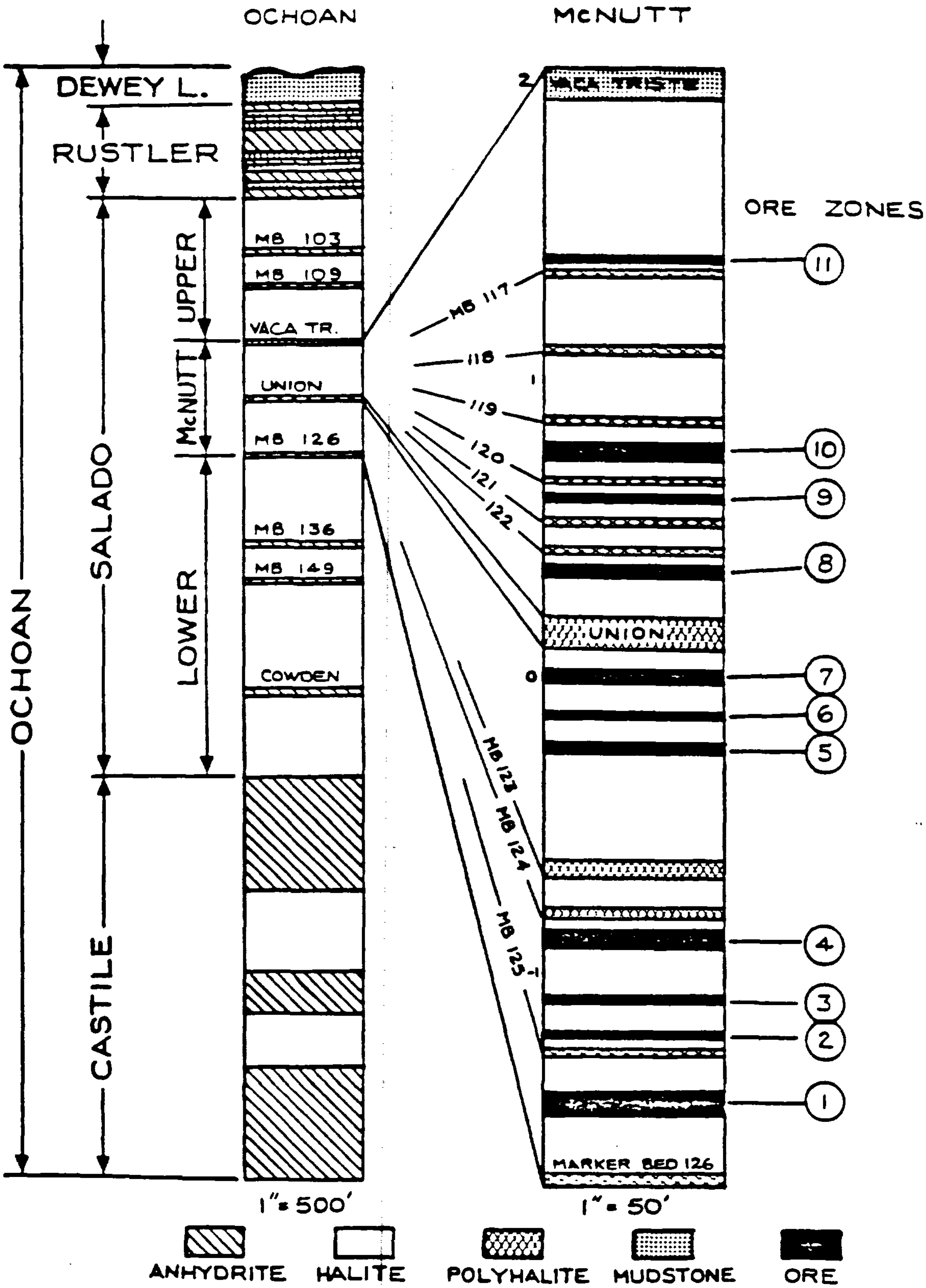


FIGURE 5

STRATIGRAPHIC COLUMN OF THE OCHOAN

ADAPTED FROM GRISWOLD, 1982

climatic changes. The anhydrite beds are easily recognizable on certain geophysical logs and are amazingly consistent laterally throughout most the mining district.

A uniform stratigraphic code has been developed by the U.S. Geological Survey to describe the Salado. (Smith, 1938, and Jones, et al., 1960). The code designates 43 "marker bed" horizons commencing with 100 at the top down to 143 which lies just above the Cowden Anhydrite. The Cowden and two other beds (Vaca Triste and Union) retain formal names to agree with prior usage in southeast New Mexico. The base of the Salado is normally picked at the top of the first massive banded anhydrite in the Castile. Marker beds consist of a thin seam of mudstone at the base followed by a variable thickness of anhydrite. Frequently the anhydrite has been either partially or completely replaced by polyhalite.

Commercial quantities of potash are limited to the McNutt Member of the Salado. The McNutt being defined as the interval from Marker Bed 126 up to the Vaca Triste, a mudstone-sandstone bed. Eleven ore horizons normally are recognized within the McNutt commencing with the First Ore Zone which occurs between Marker Beds 126 and 125 up to Eleventh located immediately above Marker Bed 117. Thus Marker Beds are numbered sequentially downward, and Ore Zones are numbered sequentially upward. Two other potash rich beds are known that occur above the McNutt, but commercial amounts of potash mineralization are not known in them.

The eleven ore zones are consistent in their stratigraphic relationship between marker beds; however, the thickness and mineralogy is quite variable. Mineral suites and ore zone characteristics are given in Tables 2 and 3.

Table 2. Evaporite minerals of the Carlsbad district. Only sylvite and lanbeinite are ore minerals at the present time. The hydrated potassium minerals are not amenable to existing concentration methods.

Mineral	Formula	Equivalent Percent			
		(K)	(KCl)	(K_2O)	(K_2SO_4)
*Anhydrite	$CaSO_4$	--	--	--	--
Arcanite	K_2SO_4	44.88	--	54.06	100.00
Bischofite	$MgCl_2 \cdot 6H_2O$	--	--	--	--
Bloedite	$Na_2SO_4 \cdot MgSO_4 \cdot 4H_2O$	--	--	--	--
*Carnallite	$KCl \cdot MgCl_2 \cdot 6H_2O$	14.07	26.83	16.95	--
Erytrosiderite	$2KCl \cdot FeCl_3 \cdot H_2O$	23.75	45.28	28.61	--
Glaserite	$K_3Na(SO_4)_2$	35.29	--	42.51	78.63
Glauberite	$Na_2SO_4 \cdot CaSO_4$	--	--	--	--
*Gypsum	$CaSO4 \cdot 2H_2O$	--	--	--	--
*Halite	NaCl	--	--	--	--
Hydrophilite	$KCl \cdot CaCl_2 \cdot 6H_2O$	13.32	25.39	16.04	--
*Kainite	$MgSO_4 \cdot KCl \cdot 3H_2O$	15.71	29.94	18.92	--
*Kierserite	$MgSO_4 \cdot H_2O$	--	--	--	--
*Langbeinite	$K_2SO_4 \cdot 2MgSO_4$	18.84	--	22.70	41.99
*Leonite	$K_2SO_4 \cdot MgSO_4 \cdot 4H_2O$	21.33	--	25.69	47.52
Loeweite	$6Na_2SO_4 \cdot MgSO_4 \cdot 15H_2O$	--	--	--	--
Mirabilite	$Na_2SO_4 \cdot 10H_2O$	--	--	--	--
*Polyhalite	$K_2SO_4 \cdot MgSO_4 \cdot 2CaSO_4 \cdot 2H_2O$	12.97	--	15.62	28.90
Schoenite	$K_2SO_4 \cdot MgSO_4 \cdot 6H_2O$	19.42	--	23.39	43.27
*Sylvite	KCl	52.44	100.00	63.17	--
Syngenite	$K_2SO_4 \cdot CaSO_4 \cdot H_2O$	23.81	--	28.68	53.06
Tachyhydrite	$CaCl_2 \cdot 2MgCl_2 \cdot 12H_2O$	--	--	--	--
Thenordite	Na_2SO_4	--	--	--	--
Vanthoffite	$3Na_2SO_4 \cdot MgSO_4$	--	--	--	--

*Common

TABLE 3. Mineralogy and mineability of ore zone

Ore zone	Marker Bed Nearest Base	Mineralogy	Mineability
Eleventh	MB 117	Mostly carnallite, minor sylvite and leonite	Not commercial to date
Tenth	MB 120	Sylvite	Second best in the district
Ninth	MB 121	Carnallite, kier-serite, minor sylvite	Not commercial to date
Eighth	Union	Sylvite	Moderate reserves, important in future
Seventh	----	Sylvite	Moderate reserves
Sixth	----	Carnallite, kierserite, etc.	Not Commercial to date
Fifth	MB 123	Sylvite and langbeinite	Moderate reserves
Fourth	----	Langbeinite and sylvite	Principal source of langbeinite
Third	----	Sylvite	Ranks 3rd in production of sylvite
Second	MB 125	Carnallite, kierserite, etc.	Not Commercial to date
First	MB 126	Sylvite	Was the major sylvite pro-ducing zone

Ore zones exhibit considerable effects of diagenetic processes. Jones (1954) divided potassic mineral occurrences as:

(1) Accessory minerals

(2) Stratified deposits in sulfate strata

(3) Bedded deposits in mixed halite-clastic strata

(4) Veins or lens deposits that have replaced or displaced the strata

The accessory minerals category includes widespread but very low grade occurrences of soluble potassium minerals in halite beds. The stratified deposits in sulfate strata are those original anhydrite marker beds which have been at least partially replaced by polyhalite. The bedded deposits are what constitute the true ore zones of the Carlsbad district. The spacial relationship between the ore zones and the more widely distributed polyhalite and accessory mineral occurrences of potash mineralization is observed in Figure 5. The polyhalite and accessory mineral occurrences can be considered as halos. Veins or lens of pure or mixed assemblages of potassium minerals occur, but in and adjacent to ore their contribution to minable reserves is quite small.

While ore zones remain in consistent stratigraphic positions, the original sedimentary features of the beds is mostly obliterated by authigenesis and recrystallization processes that followed original deposition. While these processes caused the formation of commercial deposits in some localities, it is also apparent that late moving fluids, unsaturated in potassium, destroyed what would have constituted ore.

SOURCE OF LIQUIDS AND GASES IN THE EVAPORITES

It is well established that liquids (as saturated brine) and gas (mostly nitrogen with minor amounts of methane) are associated with the Salado Formation. These fluids occur in three forms.

Negative Crystals in Halite

A negative crystal is simply a void within a halite crystal. The voids are most commonly entirely filled with liquid but occassionally include a gas bubble. The term fluid inclusion is also used to describe negative crystals. Negative crystals are common to essentially all halite deposits, i.e., they are not unique to the Salado. The size of the fluid inclusions range from microscopic up to a centimeter across. The normal shape is cubic but rounded shapes are also present. In the Salado the average size is less than 5 microns for the cubic crystals up to 100 microns for the rounded ones. Brine within negative crystals account for 0.5% by weight of typical halite. Gases associated with the brine is almost insignificant, accounting for only about 1% of the brine or 0.005% of halite.

Brine Absorbed in Clay Within Halite

Some of the halite or mixed halite-sylvite beds contain several percent clay. These clays can normally be expected to contain around 25% moisture. Some of the ores mined contain as much as 5% clay; therefore, such high clay ore will contain about 1% salt saturated water. Some gas may be occluded on the clay, but the amount must be small because none has been measured to date.

Brine and Gas Associated with Clay Seams at the Base of Marker Beds

This is by far the most common occurrence of liquids and gases in the Salado. The brines are saturated in potassium, magnesium and sodium. The prevalent anions are chloride and sulfate. This chemistry is indicative of residual bittern fluid associated with the original formation of the potash deposits. The gas components are nitrogen along with minor amounts of methane. The source of the gas is from original atmospheric air that was either in solution with the original seawater or was trapped under salt-anhydrite crusts formed on the surface of the evaporation pans. That oxygen is totally absent is easily explained by the high activity of that gas -- it would react with other elements to form stable oxide minerals such as hematite.

GEOLOGIC REASONS THAT BRINE AND GAS WITHIN THE SALADO ARE ISOLATED FROM FLUIDS EITHER ABOVE OR BELOW

Halite has the well known behavior of behaving plastically under pressure. Petrofabric analysis along with modern day observation of halite being deposited in evaporation basins indicate that loosely packed crystals form within saturated brine pools. Continued burial forces the brine upward so that closer packing is achieved. On continued burial the halite crystals become completely plastic and all brine is ejected. The only exception being those fluids trapped in negative crystals at the time of crystallization. Thus halite becomes a true solid and possesses no porosity (except for brine filled negative crystals) and therefore no permeability. Permeability tests performed on salt cores either yield results that are beneath the measurement capability of the test apparatus or if measureable can be accounted for by fractures induced into the sample.

Other evidence of impermeability of halite lies in the fact that brine and gases trapped in the clay seams at the base of the marker beds have remained in position since deposition. The approximate age of the Ochoan evaporites is 230 million years. That the brine and gas remain in position is due to the halite immediately under and overlying the fluid bearing strata.

The McNutt Member is underlain by 400 to as much as 1500 feet of halite of the Lower Member of the Salado. Thus, the potash mining horizons are protected not only by halite immediately above and below the mining horizons but by an extra 400 to 1500 feet of halite provides additional impermeable barrier between the mining levels and any oil-gas horizons located in Guadalupian strata below. Evidence that these lower halites are impermeable is proven by the fact the brine and gas, which are under high pressure, remain in position and have not escaped upward to be vented to the atmosphere. They have been prevented from doing so by the overlying Upper Member of the Salado. The thickness of the Upper Member ranges from 100 to 500 feet over most of the mining district, i.e. less than what is below.

PROBABLE SOURCE OF HYDROCARBONS IN THE SALADO

Hydrocarbons, mostly as simple methane, are present in trace amounts in the Salado Formation. Methane has been detected in both the gases from the clay seams at the base of the marker beds and in fluid inclusions within halite. The richest concentrations are in the clay seam gas where it reaches as high as 6.37% methane. In all cases, the balance of the gas mixture is inert, consisting of nitrogen in the mud seams and carbon dioxide and nitrogen in fluid inclusions. Oxygen is not present; therefore the methane can not be considered as explosive. It must be remembered that gases released from drill holes diffuse into the mine atmosphere. The methane content thus decreases and never enriches. To do otherwise is contrary to the laws of gas dynamics.

We have argued that the halite beds that separate the potash mining zones from underlying oil-gas reservoirs are impermeable. Therefore, we must now explain the presence of methane in marine evaporites which were deposited from highly saline solutions which supposedly would not support any form of life. The answer lies in the cyclical nature of deposition of the evaporites. As previously described the cycle commences with a thin layer of clay covered by a thicker but still thin sheath of anhydrite followed by a much thicker bed of halite. The lower portion of the halite is normally purer (freer of clay) than the upper portion. This depositional cycle is interpreted as follows: (1) the clay seamlet represents an original drying and erosional surface at the top of the underlying halite. Clay minerals tend to concentrate at the surface. (2) Seawater re-entered the area causing additional solution of the underlying halite. Clay build up continues by settling of fine particles carried in by the seawater. (3) Evaporation recommences with first aragonite ($CaCO_3$) and then gypsum ($CaSO_4 \cdot H_2O$) being deposited. The former will eventually be converted to dolomite ($Mg,CaCO_3$) and the latter to anhydrite ($CaSO_4$) by diagenitic processes. Some of the thicker marker beds are banded representing several cyclets of aragonite and gypsum deposition. These are interpreted as refreshing of the seawater in some sort of periodic manner, perhaps seasonal. (4) Halite commences to crystallize. The original seawater becomes highly concentrated by evaporation. All of the calcium has been removed by the formation of aragonite and gypsum. (5) Drying continues with the formation of additional halite. The surface must be quite dry at this stage and blowing winds and occasional rainfalls on nearby above tidal surface deposits tend to add more detrital material to the evaporation pan. Therefore, more clay begins to be deposited along with the halite. (6) The evaporation cycle is complete setting the stage for the next cycle.

A reasonable estimate is that a quarter of a thousand of these cycles occurred during the deposition of the Salado Formation. The thickest of these cycles produced the several inch to several feet thickness of anhydrite which constitute the 45 marker beds now used to map stratigraphic position within the Salado Formation.

Marine organic life could exist at one period of time during the depositional cycle. That is during stage (2). Marine waters are assumed to reenter the area, albeit much more saline than the open sea. Algal and other microscopic organisms could exist. The modern analogy is algal "mats" observed in sabkha environments. Higher order organisms could not be present because no recognizable fossils have been identified in the Salado. The algae is the probable source of methane. Organic acids, the primodial form of heavier hydrocarbons, could be produced from other microorganisms. The assumption that this organic material existed under aerobic conditions is verified by the fact that the gases now present in the Salado are nitrogen rich. Atmospheric oxygen was either consumed by the organisms themselves or later reacted with metallic ions to form stable oxides.

The gases associated with the fluid inclusions is probably similar except that conditions may have been anaerobic. Oxygen deficiency is indicated because trace amounts of H_2S are present and organic matter appears as organic acids rather than as methane. Inert gases, nitrogen and CO_2, are by far the most common constituents of gases within the fluid inclusions. The combined percentage of N_2 and CO_2 is never less than 90% and the highest methane analysis of samples tested did not exceed 0.5%. (Such a mixture is not explosive.) The gas composition of fluid inclusions in halite is considered to be in agreement with crystal formation under shallow subaqueous conditions. The high preponderance of nitrogen and carbon dioxide is explained by the soluability of those gases in brine. H_2S, methane and organic acid in trace amounts is attributed to the decay of organic matter that was either able to survive under highly saline conditions or that was transported in by wave action or winds. The total amount of gas present in fluid inclusions is minute, accounting for only few tens parts per million by weight of the halite. Methane accounts for only 0.5% of these gases; or less than 1 ppm in halite.

GEOCHEMICAL SAMPLE EVIDENCE THAT SUPPORT THE CONCLUSIONS THAT BRINE AND GASES CONTAINED IN THE SALADO ARE INDIGENOUS TO THE FORMATION

We have collected gas samples from relief holes drilled in the roof at 5 of the 6 active mines in the district. Twelve gas samples were collected in all. For reliability, seven samples were analyzed in a commercial laboratory in Hobbs and five were analyzed by a State supported research laboratory. Not only did these two laboratory produce compatible results but overall results are in excellent agreement with results obtained by the U.S. Bureau of Mines which sampled the same mines in 1964. A summary of results is shown in Table 4.

Emphasis needs to be placed on the fact that our 12 samples and the 14 samples taken by the U.S. Bureau of Mines were all taken several feet up into relief holes. Therefore, the sample results are representative of the composition of the gas in situ and before being diluted with mine atmosphere. We took the normal precaution of using hand held methanometers to monitor the mine atmosphere while samples were being collected. In no case was a measurable amount of methane detected eventhough we were in the immediate vicinity of blowing holes.

The sample results indicate a consistent relationship. The gases associated with the base of the marker beds are nitrogen rich. The only other constitutents are methane along with even lesser amounts heavier hydrocarbon gases such as ethane.

The gases associated with fluid inclusions were also sampled. This was done by collecting run of the mine ore from all six of the active mines. To our knowledge this is the first time this has been done for Carlsbad potash ore. The only other fluid inclusion geochemical study that has been done is that by Sandia National Laboratories on core samples taken from the lower Salado and Castile Formation at the Waste Isolation Pilot Plant site south of the mining district, Powers, et al., 1978.

TABLE 4. GAS SAMPLE ANALYSIS

(Samples Taken from Within Relief Holes)

	CH_4	CnHn+2	N_2	Ratio CH_4/CnHn+2
New-Tex Lab (7 Samples)				
Highest	6.37	0.11	93.52	57
Average	1.58	0.04	98.38	35
Lowest	0.0	0.0	100.00	0
N.M. Petroleum Recovery Research Center (5 Samples)				
Highest	4.97	0.12	94.91	40
Average	1.59	0.04	98.37	43
Lowest	0.07	0.0	99.93	0
U.S. Bureau of Mines† (14 Samples)				
Highest	4.7	*	91.2	*
Average	1.8	*	96.0	*
Lowest	0.06	*	97.3	*

*Not Reported

†From Rutledge, et al., 1964

The samples we took were analyzed by Dr. David Norman at N.M. Institute of Mining and Technology. The procedure he used is quite experimental but well suited for the specific task. The samples were first crushed with a clean hammer and 2 to 4 mm grains of ore were hand-picked. About 5 grams of sample were then placed in a cleaned quartz tube. The tube was then placed on a vacuum line and heated to 125°C. The purpose of this was to drive off all water of hydration. The temperature was then raised to 350°C. At this higher temperature the fluid inclusions ruptured, liberating both the enclosed brine (converted to water vapor) and gases. These gases were then passed through a mass spectrograph for analysis.

The results of six ore sample analysis are given in the table below.

Table 5. Gas Sample Analysis of Ores

Ore Zone	CO_2	N_2	CH_4	CxHy	H_2S	Other
1	81.3	13.6	0.1	3.4	0.5	1.6
1	31.9	64.0	0.0	3.4	0.7	0.0
3	73.6	18.8	0.1	6.6	0.0	0.9
4	45.4	44.8	0.0	8.6	0.9	0.3
5	86.4	6.1	0.0	3.4	3.9	0.2
10	73.9	9.1	1.2	15.3	0.5	0.0
Average	65.4	26.3	0.02	6.8	1.1	0.4

The results are comparable with gases associated with clays seams at the base of marker beds with these exceptions.

1. Inert gases consist of both CO_2 and N_2 in contrast to simply N_2 in clay seams. CO_2 is normally dominant. The average total of inert gases (CO_2 + N_2) = 91.7%.
2. Methane is present only in trace amounts. Heavier hydrocarbons, mostly as organic acids, averages about 6.8%. These hydrocarbons may represent original organic matter that has only been partially decomposed.

3. H_2S is present which is indicative of an anaerobic condition at the time of formation of the fluid inclusions.
4. The total weight percentage of fluid inclusions amounts to only 10 to 100 ppm of the ore. A ton of ore that was totally crushed would liberate only about one cubic feet of gas of which >90% would be inert.

The principal difference between the gases associated with fluid inclusions in contrast to those associated with clay seams is substitution of high molecular weight hydrocarbons and H_2S for simple methane and the partial substitution of CO_2 for N_2. We tentatively conclude that conditions were anaerobic at the time of formation of the fluid inclusions. Atmospheric oxygen was totally used in partial conversion of organic matter to CO_2. The important similarity is that the bulk of both gases are inert, consisting of either just N_2 or a mixture of N_2 and CO_2. These gases were probably derived for the earths atmosphere.

In Figure 5 we compare the compositions of the clay seam and fluid inclusion gases with natural gases associated with known oil-gas producing areas near the potash mines. For this comparison we have used a three component diagram because the gases can be considered as a mixture of methane, heavier hydrocarbons and inert gas. The inert constitutent can be nitrogen or a mixture of nitrogen plus carbon dioxide. In order to more fully explain a three component diagram consider a gas that contains equal proportions of all three gases, e.g. 1/3 methane, 1/3 heavier hydrocarbons and 1/3 nitrogen. Such a gas would plot in the exact center of the triangle. On the other hand a gas that contains 100% methane would plot at the CH_4 apex.

Note that the compositions are distinctly different. The Guadalupian oil-gas reservoirs contain a mixture of methane and heavier gases such as ethane. Pennsylvanian gas reservoirs are mostly simple methane. In contrast, the clay seam and fluid inclusion gases are mostly inert. Trace amounts of methane are present in the clay seams. The balance is N_2. The fluid inclusion gas is mostly a mixture of CO_2 and N_2. H_2S is present in trace amounts and probably represents the only other gas phase. Heavier hydrocarbons are present in minor amounts but not in the form of light gases such as methane, ethane, etc.

We have also collected samples of brine that issue from relief holes drilled above the potash mining horizons. These waters are completely saturated in K, Mg and Na salts and sulfates. We believe that these brines are representative of original bitterns associated with the deposition of the McNutt Member of the Salado. The composition of these waters is presented in Figure 6. A three component diagram of $Mg\text{-}K_2\text{-}SO_4$ is used because all Permian waters have a common constituent of halite (NaCl). There are two principal aquifers near the potash mines, the Rustler above an the Capitan Reef below. Average composition of these aquifer waters is also shown on the $Mg\text{-}K_2\text{-}SO_4$ plot to illustrate the distinctive characteristics of the saturated brines associated with clay seams.

In conclusion, the results of geochemical sample analysis indicate that the gases associated with clay seams at the base of marker beds near the ore beds and the gases contained within fluid inclusions in the actual ore beds consist of inert gases with only trace amounts of methane and H_2S. The composition is compatible with original

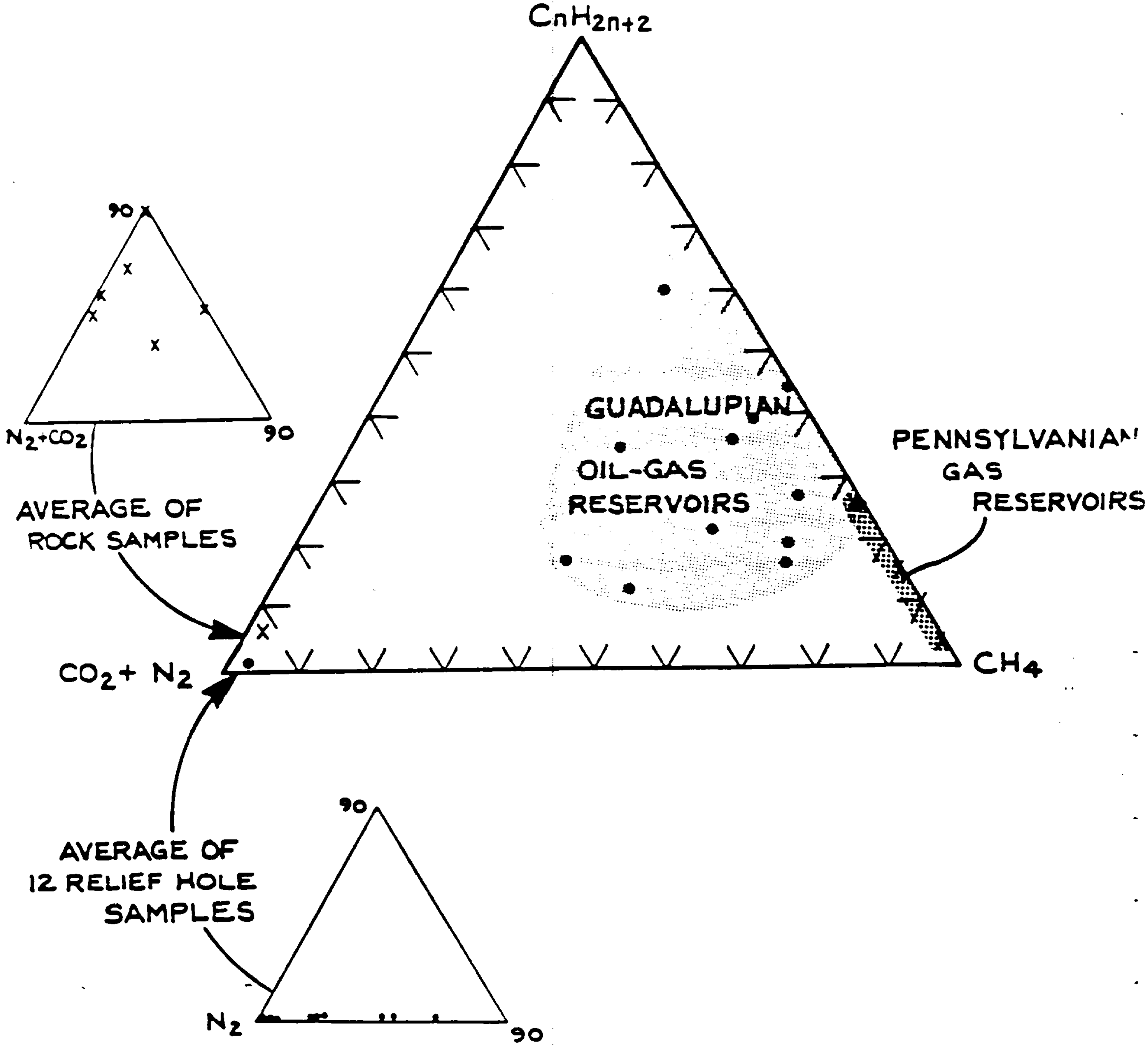


FIGURE 6
COMPARISON OF GAS SAMPLE ANALYSIS

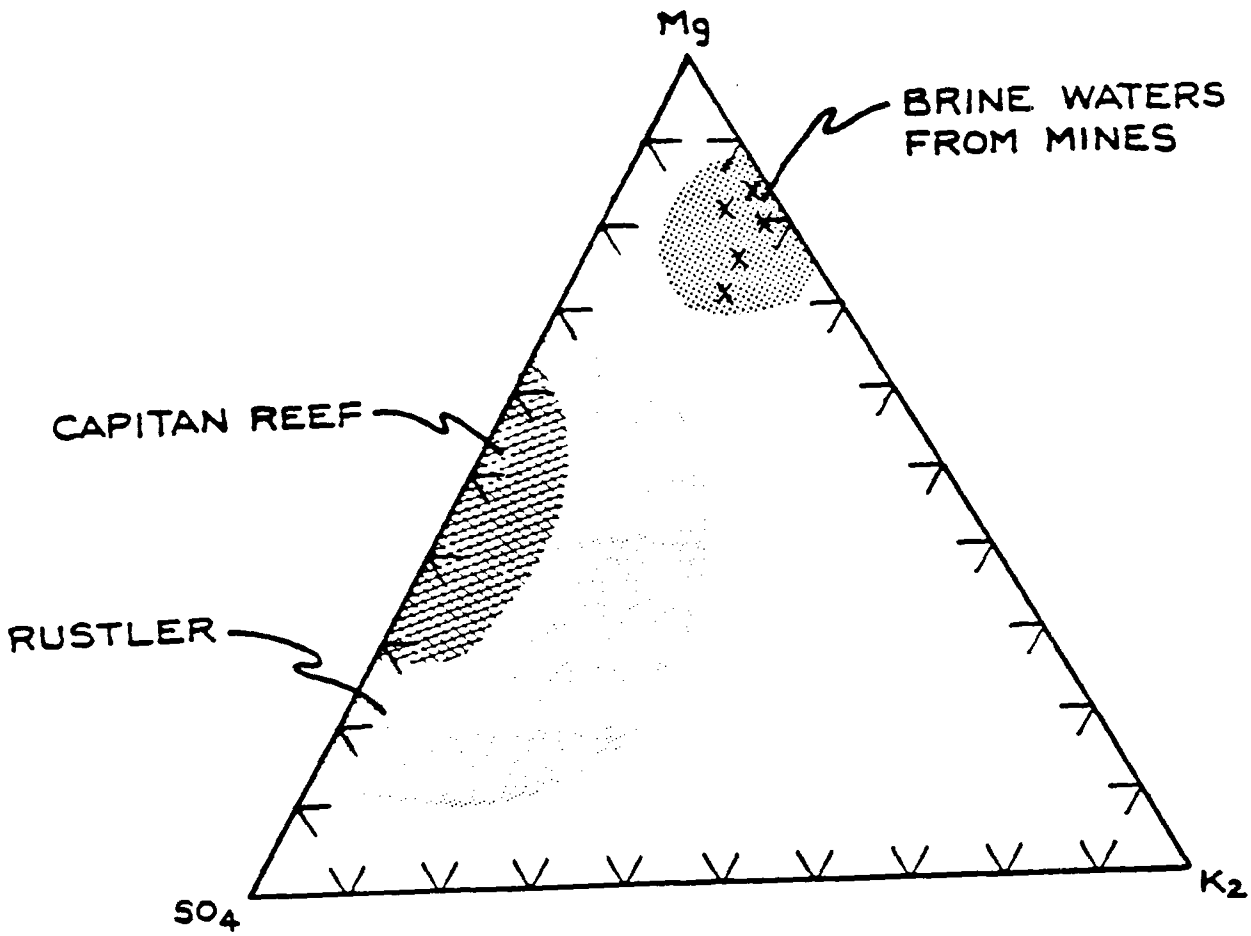


FIGURE 7
COMPARISON OF WATER SAMPLE ANALYSIS

atmospheric air being trapped into the evaporites at the time of their formation. That these gases have remained trapped in position since their original formation more than 200 million years ago is proof that the beds over and underlying the potash beds are impermeable. In addition, the brine waters associated with the clay seams is typical of bittern waters to be expected adjacent to potash deposits.

COMPARISON OF THE CARLSBAD POTASH DISTRICT WITH OTHER DISTRICTS WHICH MINE EVAPORITE MINERALS

The Carlsbad Potash Mining District is distinctive from other evaporite mining districts in several aspects. First, the structural setting is simple. Beds dip no more than 2 degrees. While small faults have been observed they are few and limited to minor slippage due to local salt flowage. Anticlinal structures are absent. Sudden thickening or thinning of halite beds between markers beds has not been observed anywhere in the district. Salt flowage has been detected in the Castile Formation which underlies the Salado. Where observed these structures reduce to broad but low aptitude flextures in the Salado.

Second, the potash ore beds are contained in the middle of a thick section of rock salt. Ore is limited to the McNutt Member of the Salado. The Lower Member of the Salado provides from 400 to 1,500 feet of impermeable salt between the deepest mining levels and the shallowest oil-gas reservoirs. No evidence of explosive amounts of methane gas has been detected in the course of drilling thousands of pressure relief holes in the Carlsbad District.

While we do not claim to be expert on other mining districts we can make the following comparisons.

Salt Domes of the Gulf Coast

Salt domes are diapiric structures. The underlying Louanne Salt has pierced upward through weakly consolidated sandstones and shales. Oil and gas deposits are common to the flanks of these domes. It is only to be expected that methane gas can become entrained in the salt during its upward movement. These gases are methane rich in contrast to the inert gases associated with the Salado Formation.

Trona Deposits in Wyoming

Evaporites of the Green River Formation are lacustrine rather than marine. Oil shale beds are intercalated with the trona. The environment during deposition was one that supported abundant aquatic life in contrast to marine evaporties.

Potash at Cane Creek, Utah

The potash deposits are contained in marine evaporites similar to those of Carlsbad. However, there are two important differences. First, the individual evaporite beds are thinner. Marine black shales are present at regular intervals throughout the salt formations. These shale beds contain oil and gas reservoirs. Second, the potash deposits are highly deformed due to a large salt anticline. Thus the potash deposits at Cane Creek are somewhat analogous to the salt diapirs on the Gulf Coast. Methane gas is common and analysis has shown that the in situ concentration is 51.4% CH_4, 21.2% ethane-pentane, and only 27.4% nitrogen-carbon dioxide. Such gas is defintely explosive when mixed with normal air. The gases in the Salado never contain more to 6.37% hydrocarbon gases and can never be considered explosive when mixed with normal air.

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We list the following pertinent references on the geology of the Carlsbad District for those interested in additional details. We have drawn on these and many others in preparation of this treatise.

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EEG-25

HEALTH ENVIRONMENT department

OCCURRENCE OF GASES IN THE SALADO FORMATION

Lokesh Chaturvedi

Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
State of New Mexico

March 1984

AIR RELIEF RECORD

Size		Crew ______________________	
small pop	☐	Shift ______________________	
Bang & blow	☐	Date ______________________	
Rock Moved		Time ______________________	
Less than one cu. ft.	☐	Area ______________________	
Between 1 $ft.^3$ and 4 cu. yd.	☐		
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

OCCURRENCE OF GASES IN THE SALADO FORMATION

Lokesh Chaturvedi

Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
P. O. Box 968
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March 1984

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.

The project is funded entirely by the U.S. Department of Energy through Contract DE-AC04-79AL10752 with the New Mexico Health and Environment Department.

Robert H Neill

Robert H. Neill
Director

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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

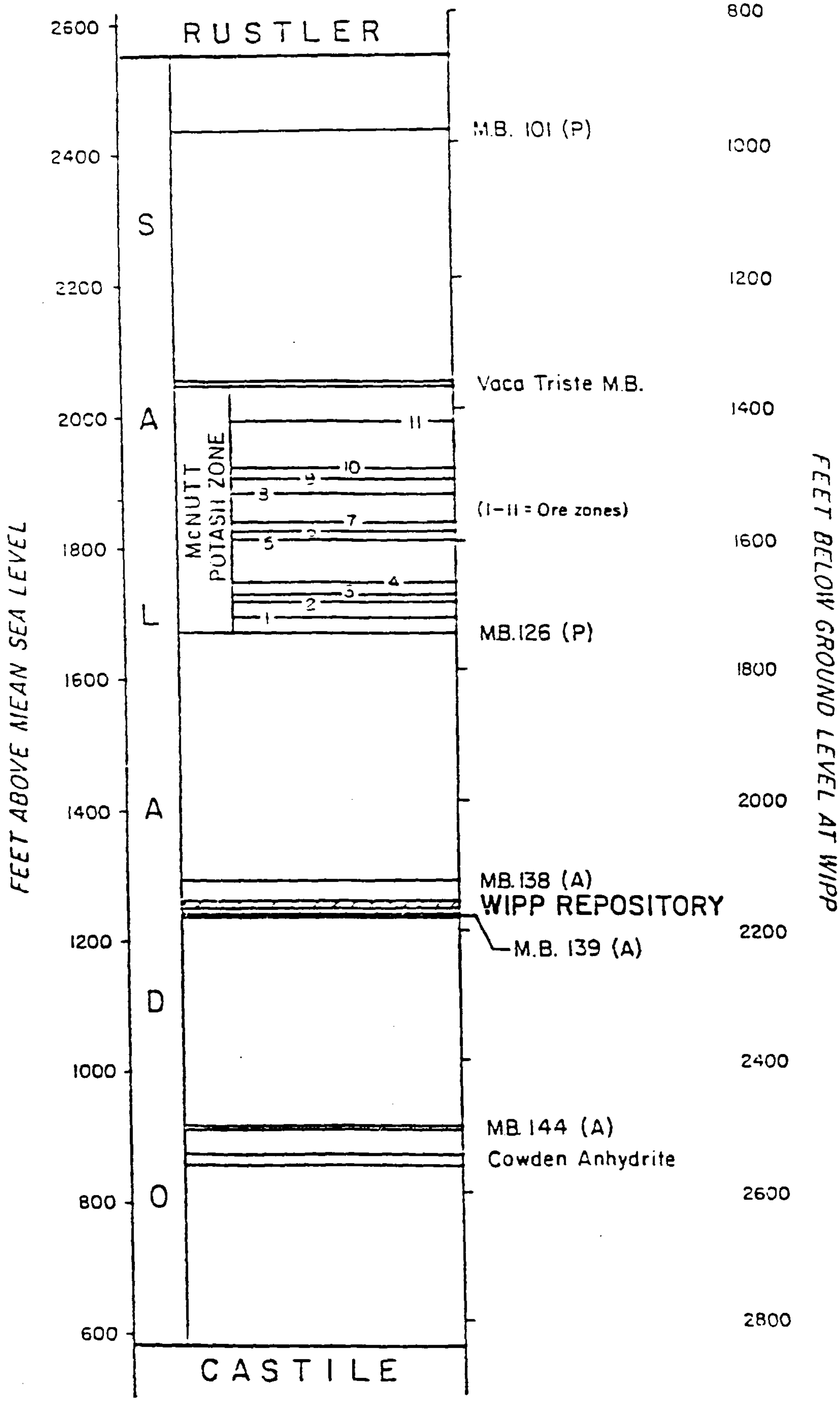

Figure 1. Details of the stratigraphy of the Salado Formation showing the locations of the marker beds, ore zones and the WIPP repository. P = Polyhalite, A = Anhydrite

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.

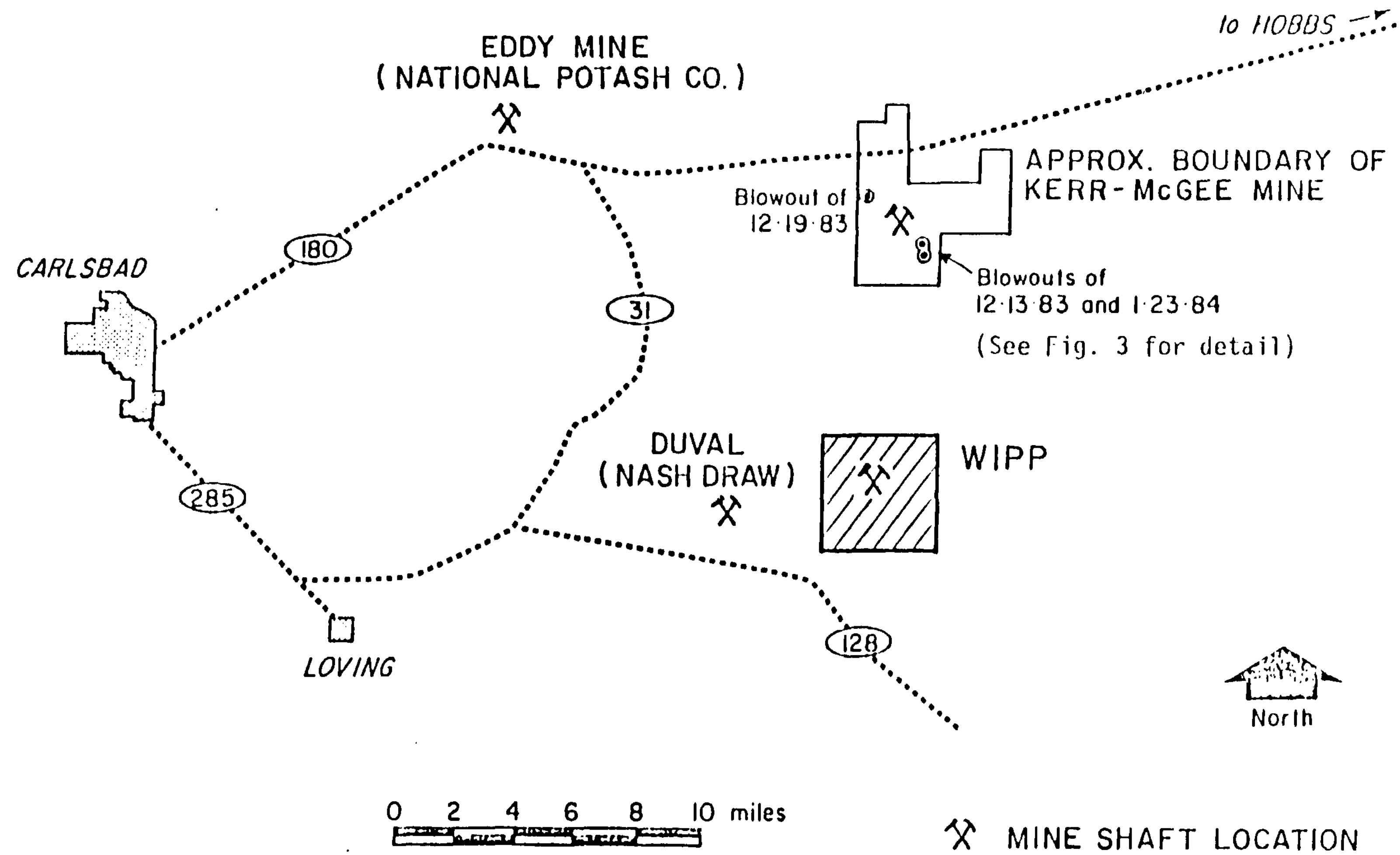

Figure 2. Location of the WIPP site and potash mines where gas blowouts have been documented.

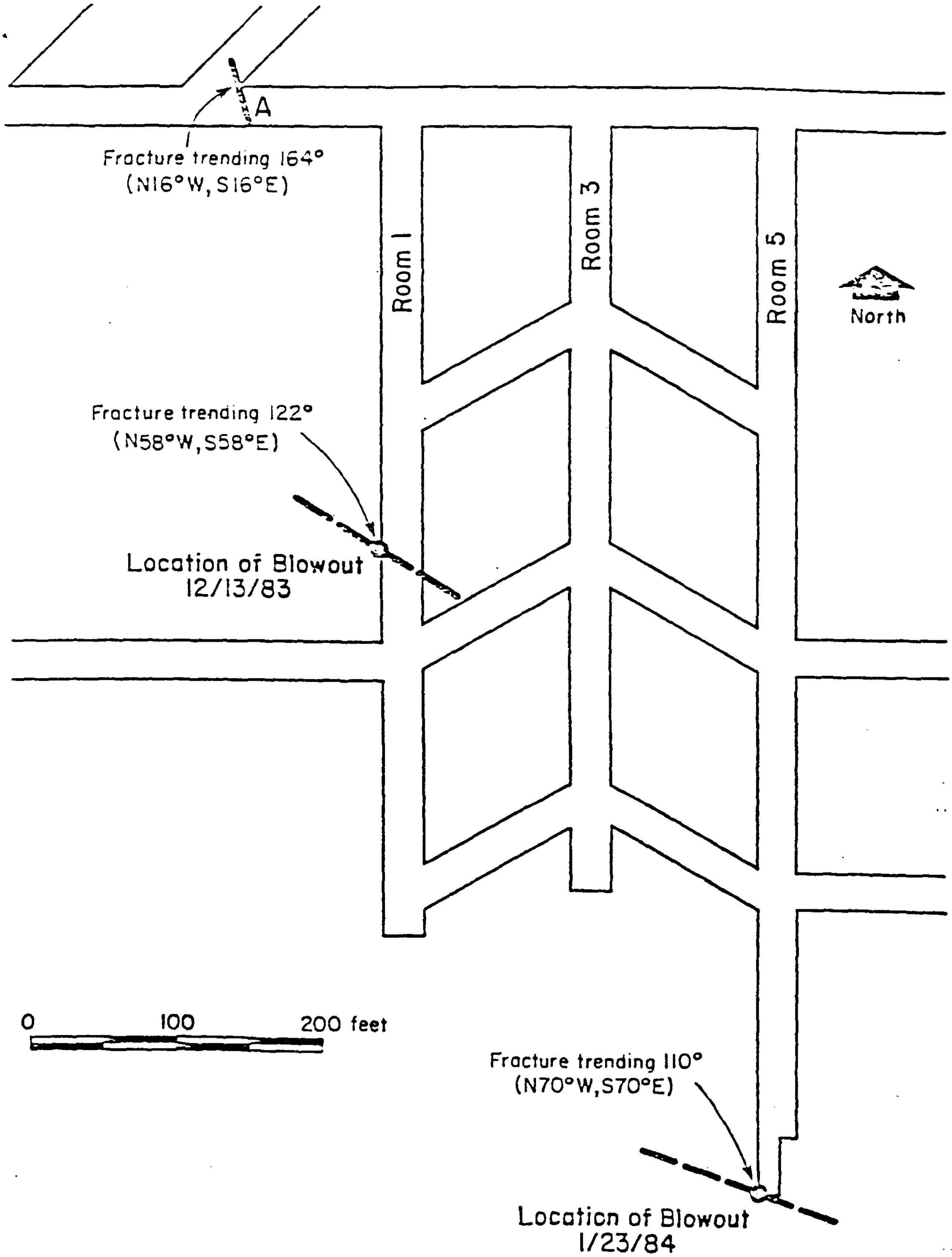

Figure 3. Detailed layout of Area 169 at the Kerr-McGee mine where the gas blowouts of 12·13·1983 and 1·23·1984 occurred. The orientation of fractures is shown. The fracture at **A** resulted from a previous blowout. (See Fig. 2 for location within the mine)

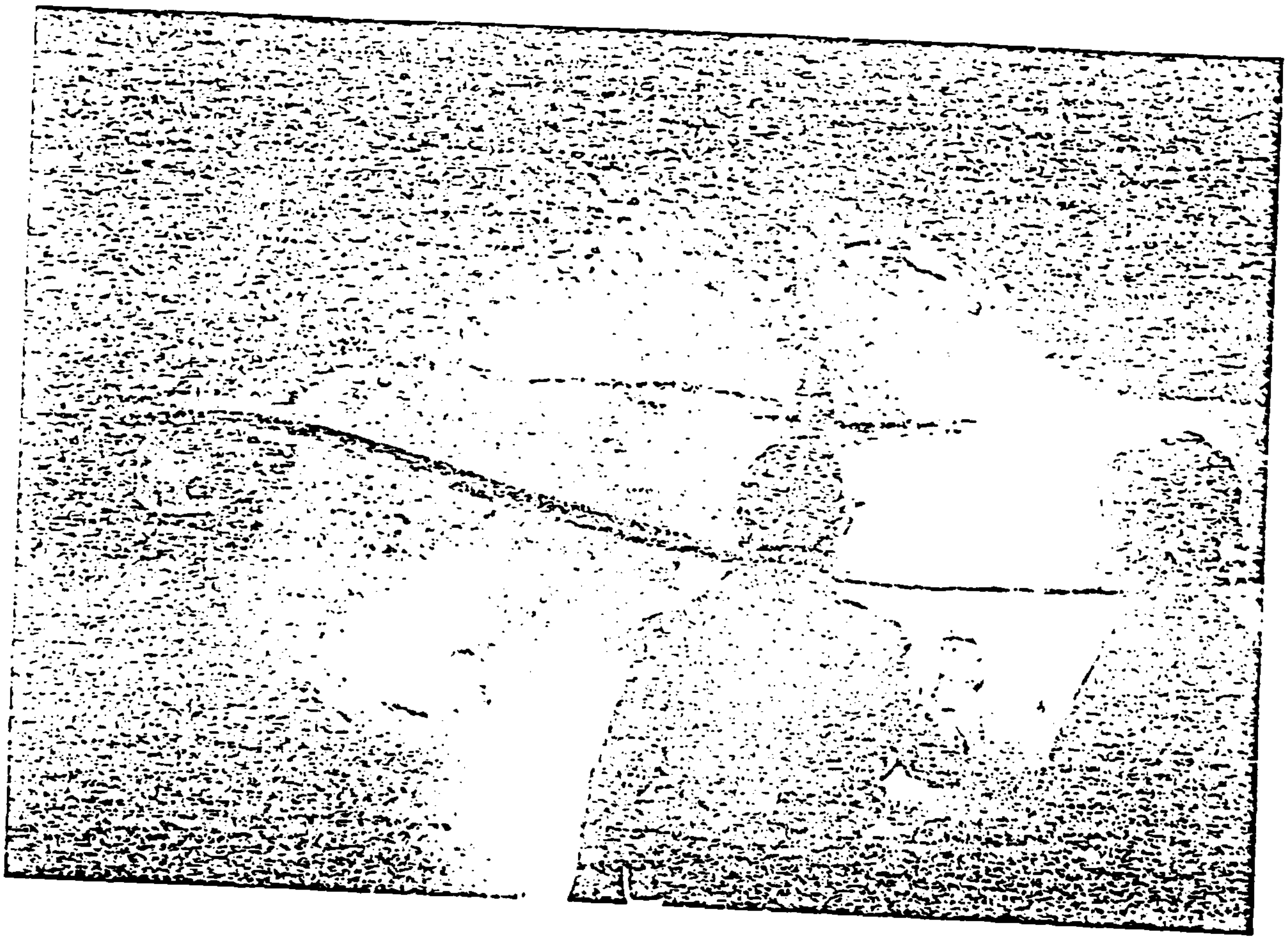

Figure 4. The location of 12·13·1983 blowout showing the cavity (9ft x 5ft x 2.5ft) formed and the vertical fracture trending 122° in Room 1, Area 169, Kerr-McGee mine (See Fig. 3 for location).

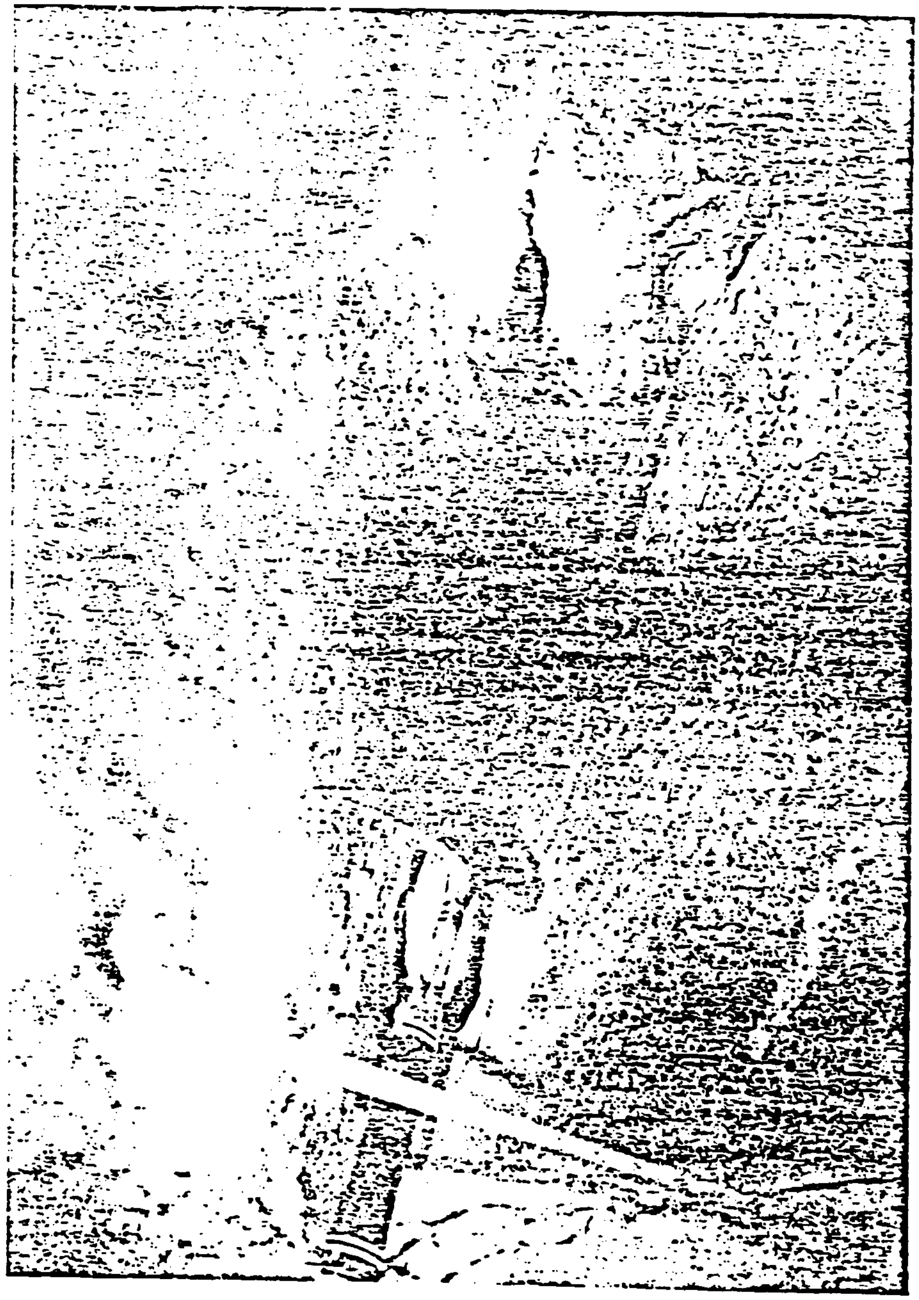

Figure 5. Close up of the fractures at the location of 12•13•1983 gas blowout in area 169 of the Kerr-McGee mine (See Fig. 3 for location).

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.

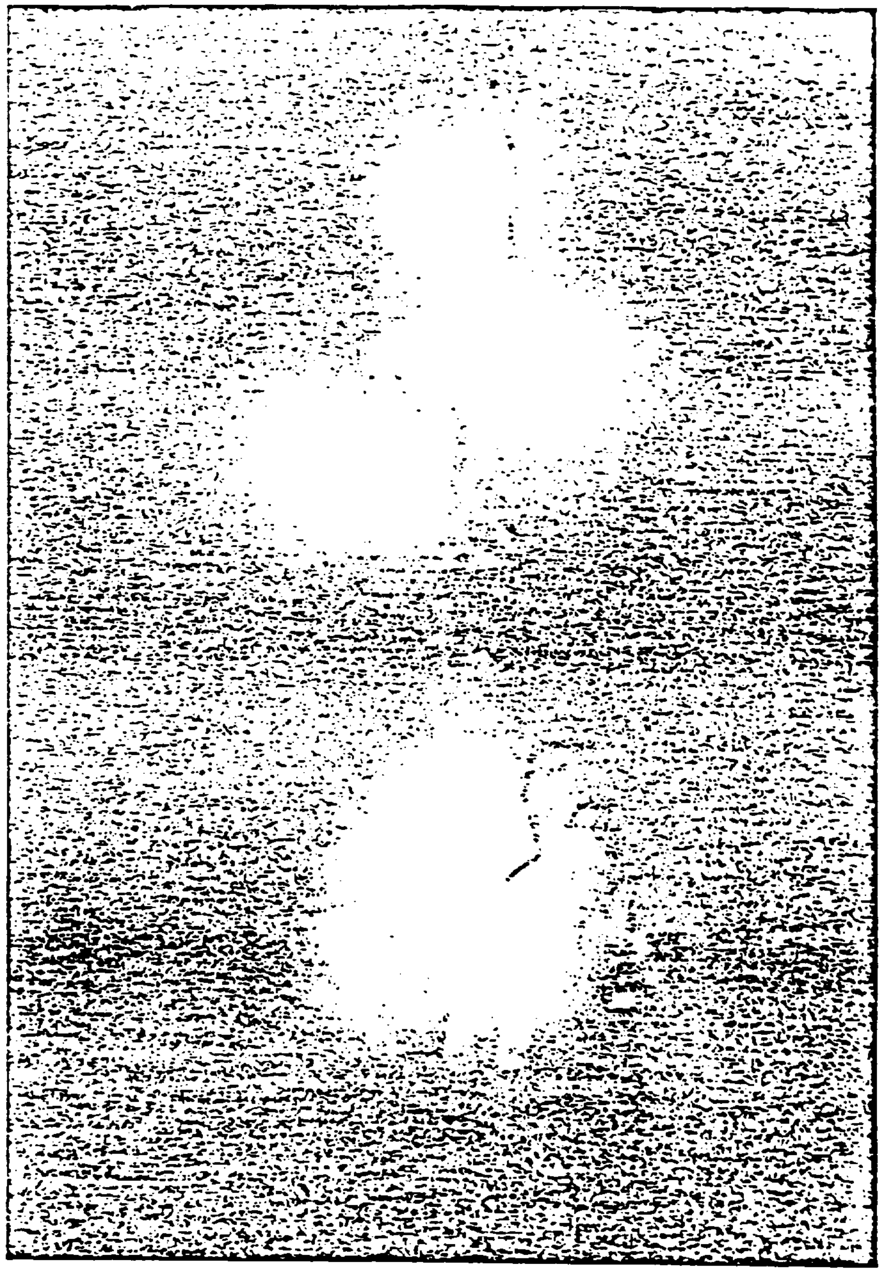

Figure 7. Vertical fracture, trending 125° (N65°W - S65°E) laterally displaced along a clay seam at the location of 12·19·1983 gas blowout in area 160 of the Kerr-McGee mine (See Fig. 2 for location).

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).

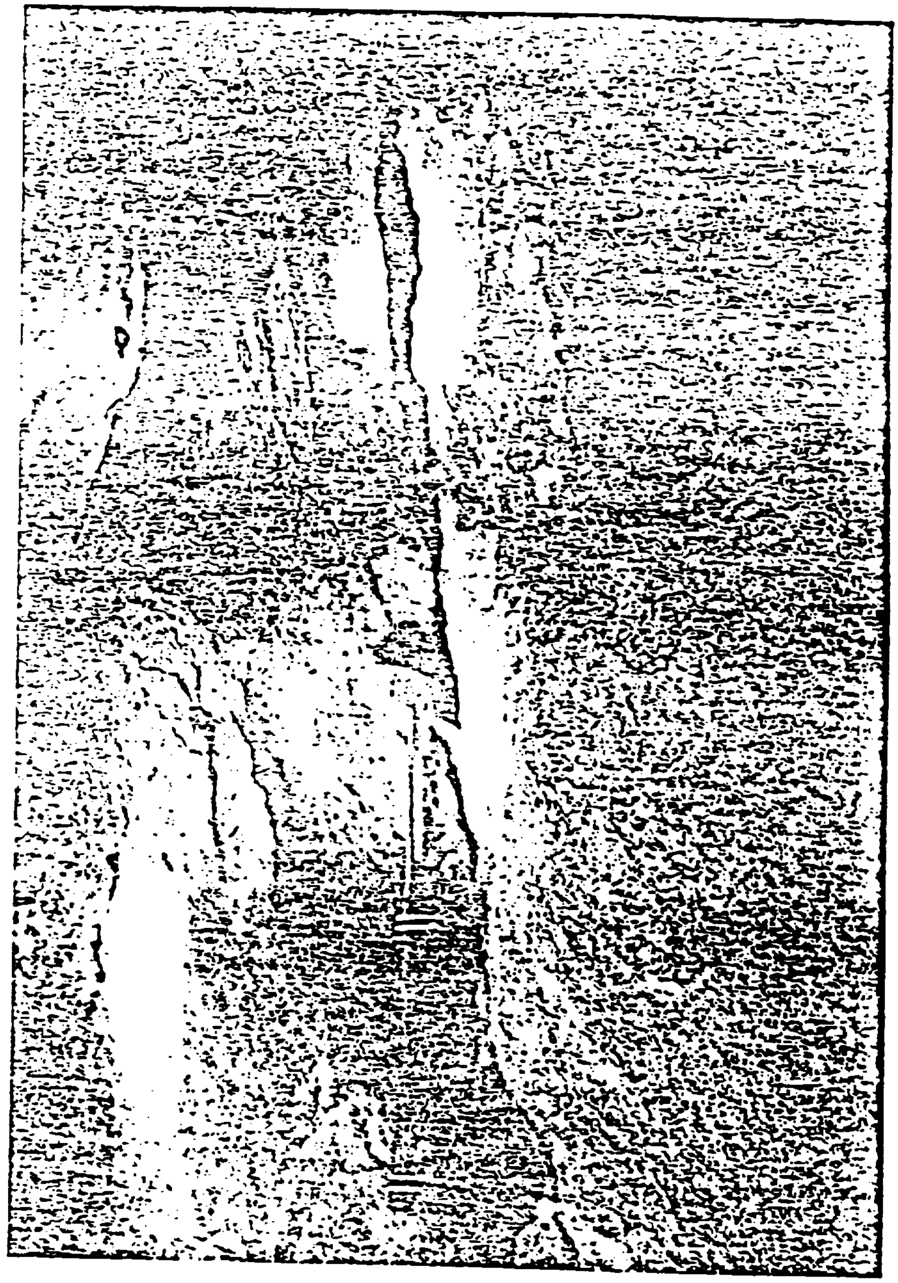

Figure 9. Near vertical open fracture trending 110° at the location of 1·23·1984 gas blowout in Room 5, Area 169 of Kerr-McGee mine (See Fig. 3 for location).

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 qses 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.

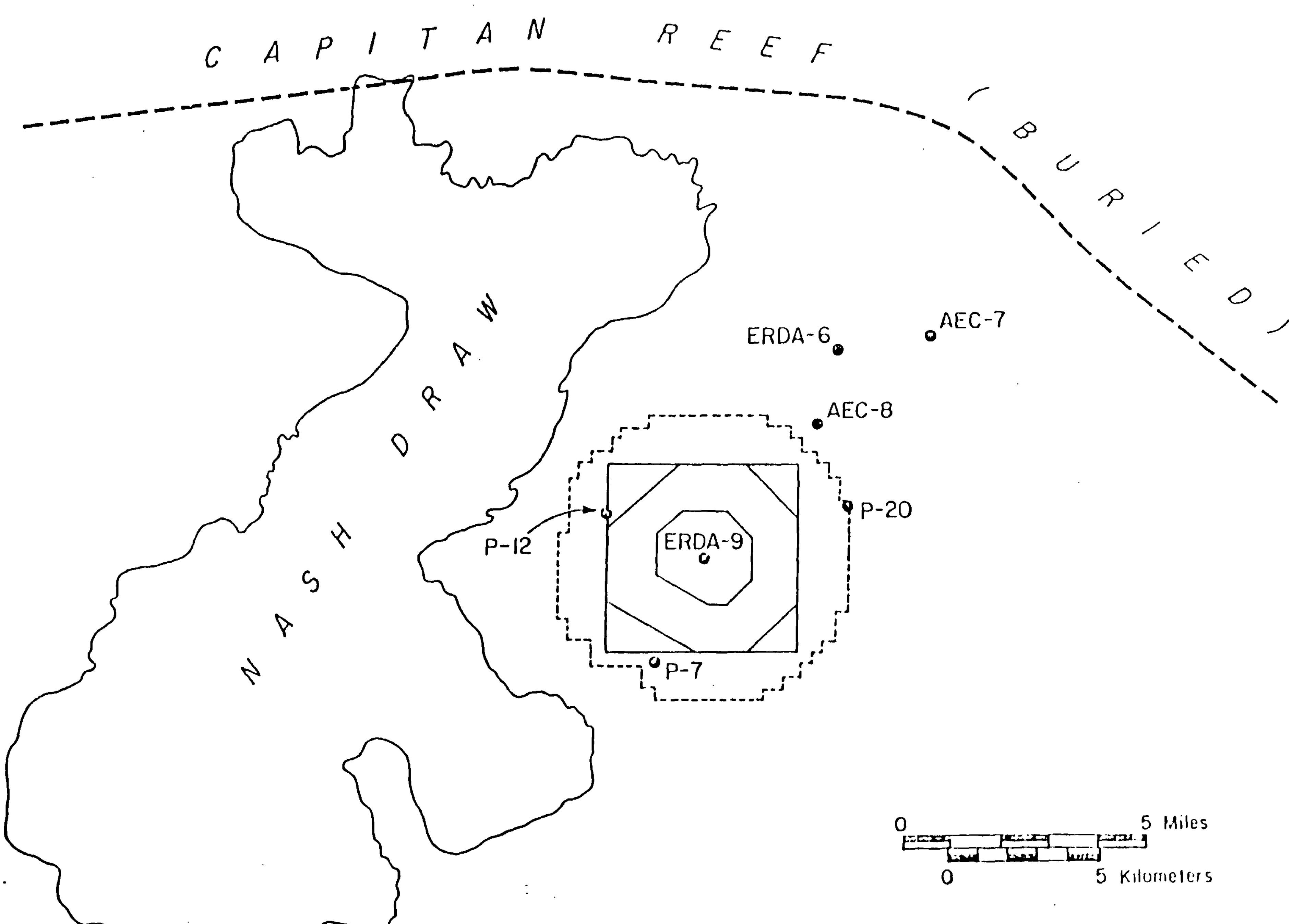

Figure 10. The location of WIPP boreholes where gases were

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, 350 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)

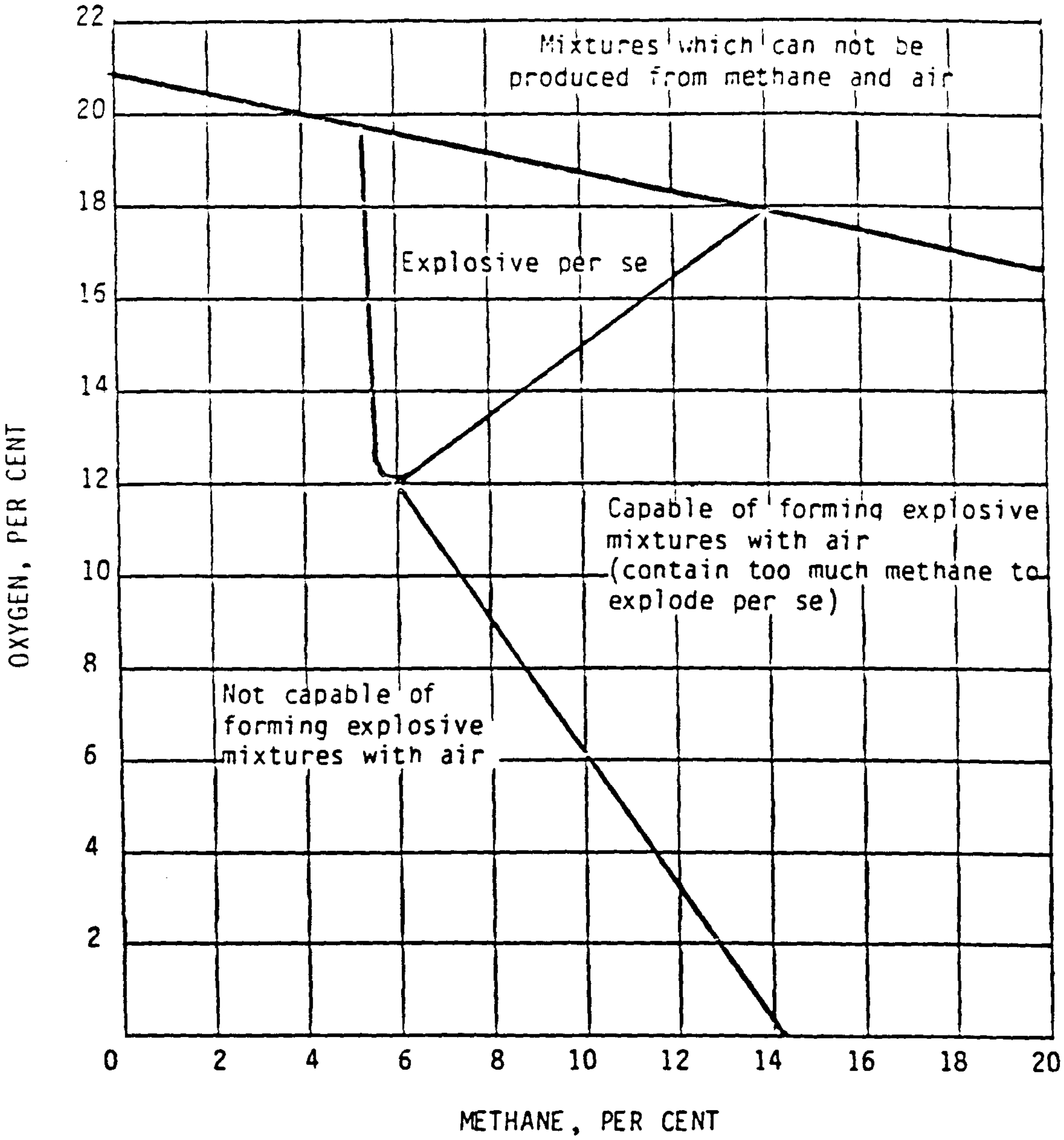

Figure 11. Relationship between the composition and the explosibility of mixtures of methane, oxygen and nitrogen (From Coward and Jones, 1952).

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

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

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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 833 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.

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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 intersecti 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 driv 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 interbedded salt and mud, and the polyhalite seam was composed of interbedded 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 large 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 year prior to this investigation, and gas pressure was not found in these mud sea

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 intersection

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 result

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-1568 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" class as approaching medium had velocities in excess of 9,000 feet per minute.

---

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 Explosib of Mine Atmospheres, Bureau of Mines Information Circular 7901, 1959, 11 p.

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 consistant 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 information 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,

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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 Strat[a]
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	Comment
416	Light	7'6"	30 psi	Reached 10 min. after packer was
425	Light	9'6"	50 psi	Reached 20 min. after packer was
429	Light	9'6"	60 psi	Reached 5 m after packe was set.

APPENDIX 5

Gas Analysis Results

SAMPLE #	X351	X352	X367	X368	X349	X350	X358
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	1.20%	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 ☐

Bang & blow ☐

Rock Moved

Less than one cu. ft. ☐

Between 1 $ft.^3$ and 4 cu. yd. ☐

More than 4 cu. yd. ☐

Crew__________

Shift__________

Date__________

Time__________

Area__________

Floor ☐

Middle Mud ☐

Top Mud ☐

Salt ☐

Full Pass ☐

Half Pass ☐

Face ☐

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

Environmental Evaluation Group
Reports

(Continued)

EEG-12 Little, Marshall S. Potential Release Scenario and Radiological Consequence Evaluation of Mineral Resources at WIPP, May 1982.

EEG-13 Spiegler, Peter. Analysis of the Potential Formation of a Breccia Chimney beneath the WIPP Repository, May, 1982.

EEG-15 Bard, Stephen T. Estimated Radiation Doses Resulting if an Exploratory Borehole Penetrates a Pressurized Brine Reservoir Assumed to Exist Below the WIPP Repository Horizon, March 1982.

EEG-16 Radionuclide Release, Transport and Consequence Modeling for WIPP. A Report of a Workshop Held on September 16-17, 1981, February 1982.

EEG-17 Spiegler, Peter. Hydrologic Analyses of Two Brine Encounters in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, December 1982.

EEG-18 Spiegler, Peter. The Origin of the Brines from ERDA-6 and WIPP-12 Stable Isotopes of Hydrogen and Oxygen, March 1983.

EEG-19 Channell, James K. Review Comments on Environmental Analysis Cost Reduction Proposals (WIPP/DOE-136) July 1982, November 1982.

EEG-20 Baca, Thomas E. An Evaluation of the Non-radiological Environmental Problems Relating to the WIPP, February 1983.

EEG-21 Faith, Stuart, et al., The Geochemistry of Two Pressurized Brines From the Castile Formation in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, April 1983.

EEG-22 EEG Review Comments on the Geotechnical Reports Provided by DOE to EEG Under the Stipulated Agreement Through March 1, 1983, April 1983.

EEG-23 Neill, Robert H., et al., Evaluation of the Suitability of the WIPP Site, May 1983.

EEG-24 Neill, Robert H. and James K. Channell, Potential Problems From Shipment of High-Curie Content Contact-Handled Transuranic (CH-TRU) Waste to WIPP, August 1983.

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UNDERGROUND MOVEMENT AND SUBSIDENCE OVER UNITED STATES POTASH COMPANY MINE

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This paper is to be presented at the Annual Meeting of the American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, February 16-[illegible], [illegible]. Permission is hereby given to publish with appropriate acknowledgments, excerpts or summaries not to exceed one-fourth of the entire text of the paper. Permission to print in more extended form subsequent to publication by the Institute must be obtained from the Secretary of the Society of Mining Engineers of A.I.M.E.

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open but occasionally it is necessary to blast down a slab and remove it.

It is thought that roof slabbing and floor heaving are caused by the vertical pressure and certain resulting forces. The vertical pressure through a punching action causes the tendency for the floor to rise in the entry and the back to sag. The other resulting forces are thought to be the movement of clay in the clay seams from above and below the pillars out into the floor and back in the entries. It is also thought that "end pressure" exerted on the floor and roof slabs from the expanding pillars helps to cause the initial separation of the slabs.

The second type of mining in our operations is in the continuous miner sections. Also five years ago we commenced the use of continuous miners, and in this operation a different ty[illegible] pillar was necessary due to the limitations of the machine. The general mining pattern with this method leaves pillars one hundred feet long and thirty-five feet wide after first mining. In final mining, these pillars are reduced to such size that from ninety-five to ninety-eight percent extraction is being obtained. The back stands well immediately after mining but with such a large percentage of extraction, subsidence is relatively rapid.

In graphically plotting subsidence, the major amount of movement underground is estimated to be approximately twelve feet, while the major subsidence on the surface is approximately eight and one-half feet. This would appear to indicate that very little breaking [illegible] in the strata above the mined-out area and that the overlying beds are more or less [illegible] uniformly.

In plotting the movement of one particular station on the surface and underground in [illegible] final mined area, it was found that for approximately thirty days subsidence was extremel[illegible] The total height of the mined-out area was originally 12.75 feet. For the first thirty days [illegible] final mining, there was apparently little movement; but between thirty and sixty days, the underground workings at this point had subsided 3.25 feet, while the point above on the surfac[illegible] had dropped 0.75 feet. At the end of one hundred days, the back had come down a total of six feet, while subsidence on the surface measured 2.20 feet. After one hundred and forty days, the station underground had dropped a total of seven and one-half feet, while the point on the surface had moved down three and one-half feet. Due to the bad conditions of the back underground at this time, observations were discontinued. On the surface, however, the point continued downward, measuring six feet total drop after two hundred days. It was at approxima[illegible] this point that the sharp rate of subsidence changedabruptly. At the end of one thousand days the surface station had subsided a total of 7.50 feet, an increase of 1.50 feet in the last ei[illegible] hundred days.

In graphing the movement of this station, it was found that the line was not continuously downward but indicated that subsidence, both underground and on the surface, came in waves or intervals, and in some cases the ground actually rose from the previous month's reading. From our closest observation in a single instance, it appeared that surface subsidence became measurable approximately thirty-five days after subsidence was noted underground.

In the first study of subsidence movement, a grid was set over the area to be mined with stations on five-hundred foot spacing, both east-west and north-south. These stations were triangulated in each month and a record of their movement was noted. From this data an approxi[illegible]mate limiting angle of 51 degrees - 30 degrees has been calculated, the limiting angle, of cou[illegible] being measured from a line drawn vertically up from the edge of advance and a second line draw[illegible] upward from the edge of advance to the outermost point where subsidence was observed on the surface. This limiting angle is important in determining where surface structures will be affected by subsidence. There are many factors which contribute to the degree of the angle. Those principally responsible are:

(1) The overlying strata through which subsidence takes place, this angle being relative[illegible] small for strong rocks and relatively large for weaker members, the total limiting angle, of course, being the sum of the various limiting angles up through the differentstrata.

(2) It has been observed that the limiting angle is greater in areas where final mining opera[illegible]tions are bordered by first mining operations. Strictly speaking, this is not a true limiting angle because extraction outside the area effects an increase of the angle. However, from the practical point of view, it is quite necessary to take this influence under consideration. We have observed in some cases a limiting angle as large as 51 to 30 degrees. It may be when the

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UNDERGROUND MOVEMENT AND SUBSIDENCE OVER UNITED STATES POTASH COMPANY MINE

By

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The United States Potash Company was the original discoverer and first producer of underground mined potash ore in North America and commenced active production of potash in 1931. In July 1956, the company merged with United States Borax & Chemical Corporation and is now a Division of that corporation.

The mine is located twenty-two miles east of the city of Carlsbad and the refinery is located sixteen miles south of the mine. The mine was placed where the ore was found and the refinery placed where there was sufficient water for a dissolving and re-crystallization plant.

For twenty-three of the last twenty-six years, the potash ore was mined with the room and pillar method, taking approximately sixty percent extraction and leaving forty percent in pillars. These pillars are generally fifty-eight feet by fifty-eight feet square. Three years ago, it was decided that removal of as large an extraction as possible from these pillars should be commenced.

The first visible evidence of subsidence on the surface is by small hairline cracks which rapidly develop into openings measuring up to approximately one inch wide and one hundred feet long. As the face retreats underground, these tension cracks disappear. About the boundaries of the final mined area which have been unworked for any length of time, these cracks appear and become larger. With continual strain and erosional effects, some of the cracks develop into [illegible]able openings measuring six inches to two feet wide and with an unknown depth. With continued erosion, the walls of the cracks fall into the bottom, thus widening and filling the openings.

In the present stage after two years, some of the openings appear as slump holes measuring some six to eight feet across, ten to thirty feet long, and five to fifteen feet deep. The geologic structure through which these forces are transmitted is rather typical of bedded [illegible] deposits in the area. The buff dolomite section at approximately four hundred feet below the surface is a water zone of considerable magnitude over quite an extensive area. The fact that both the salt and potash are highly soluble makes it imperative that the section between this buff dolomite and the underground salt and potash beds below must not be ruptured. The potash bed, which varies from five to fifteen feet in height and lies more or less horizontal, is approximately one thousand feet below the surface and is normally overlain by a salt section some five hundred feet thick. The shale and clay strata below the water zone and above the salt section form the impervious layer which protects the salt section from the water above.

The effects of subsidence over the surface area are much larger than the actual final mined area underground. In those places where final mining has been carried to the limits of the ore body, subsidence effects have been observed some seven hundred feet beyond the limits on the surface. In those places where final mining stopped in a first mined area, subsidence has been noted for distances as great as one thousand two hundred feet beyond the limits of final mining. Principally for this reason, a large zone about the hoisting shafts has been prohibited to final mining activities until all other mining is completed.

In present operations, there are two types of mining in use. The first is known as conventional mining which utilizes undercutters, drills and blasting, after which the ore is moved from the face with loaders and shuttle cars. The other method is with continuous mining machines using extensible and mainline haulage belts. In both of these operations, final mining is being carried on. The conventional final mining system is used generally in high ore in which it would be uneconomical to use a continuous mining machine.

In cases where a mud seam or zone of weakness occurs in a pillar, it will, of course, crush and fail at this point. Frequently when the mud seam is just above the back or just under the floor, the pillar will punch through into the weak zone. Additional effects caused by the mud seam just above or just below an entry are frequent sags and falls of roof slabs and heaving of the floor.

Even in the event that roof slabs begin to fail over haulage ways, an attempt is made to control their subsidence until the haulage way is abandoned. In controlling roof slabs, cribbing, stulls and roof bolts are often used. These measures usually suffice to keep the haulage way ground completely stabilizes that this angle will become somewhat greater.

The limiting angle, of course, can only be measured well after final mining has been completed and the ground has more or less become stabilized. Up until that point there is a definite lag of subsidence behind final mining operations.

Recently a line of stations on one-hundred foot centers was placed over the center of an area which was to be final mined. In addition to giving much closer control on subsidence data, we can determine the amount of strain (elongation and compression) between these points. This method of computing will give a more accurate limiting angle and an angle of repose which is the complement of the limiting angle, and the angle of break. The angle of break is of considerable interest as it is the line through which the greatest force of shear is exerted. This angle is measured from the horizontal to a line which is drawn from the edge of advance of the retreating face underground up to a point of maximum tension strain, as plotted from the field data.

It is expected that with continued study, more detailed information on the characteristics of ground movement, as applied to salt-bedded deposits in the Carlsbad district, will become available.

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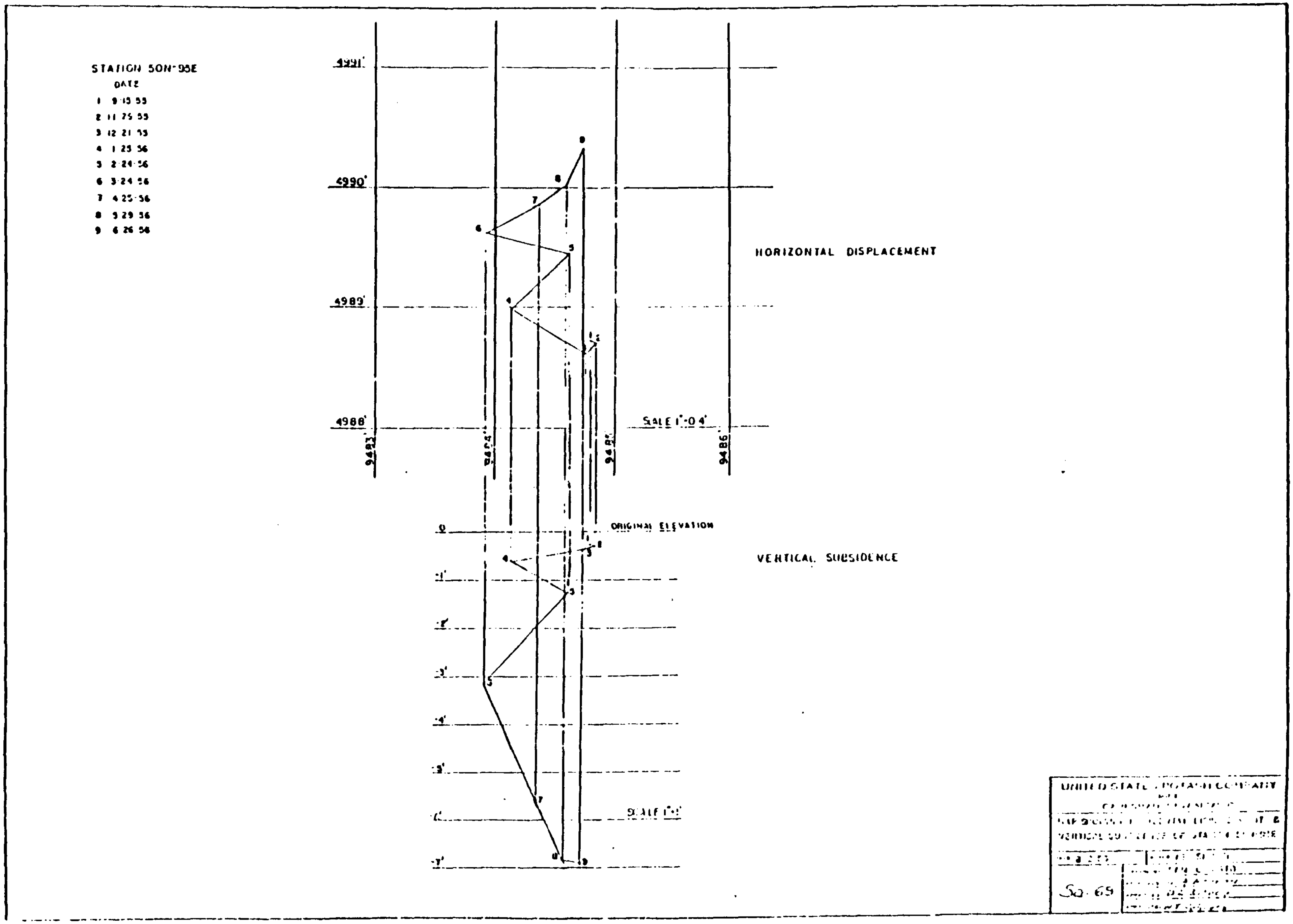
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2 11-25-55
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5 2-24-56
6 3-24-56
7 4-25-56
8 5-29-56
9 6-26-56
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HORIZONTAL DISPLACEMENT
SCALE 1"-0.4'
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ORIGINAL ELEVATION
VERTICAL SUBSIDENCE
-1'
-2'
-3'
-4'
-5'
-6'
-7'
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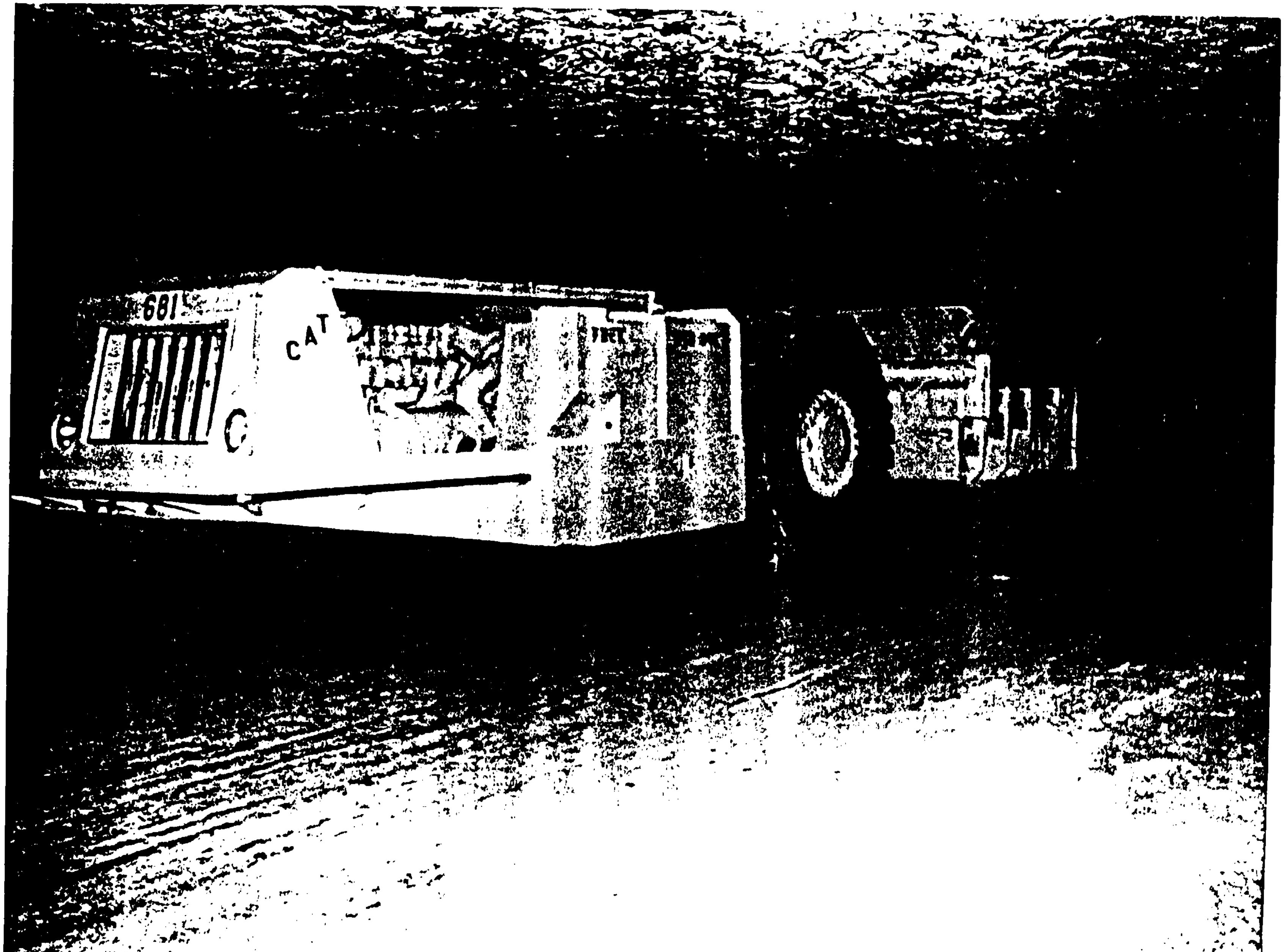
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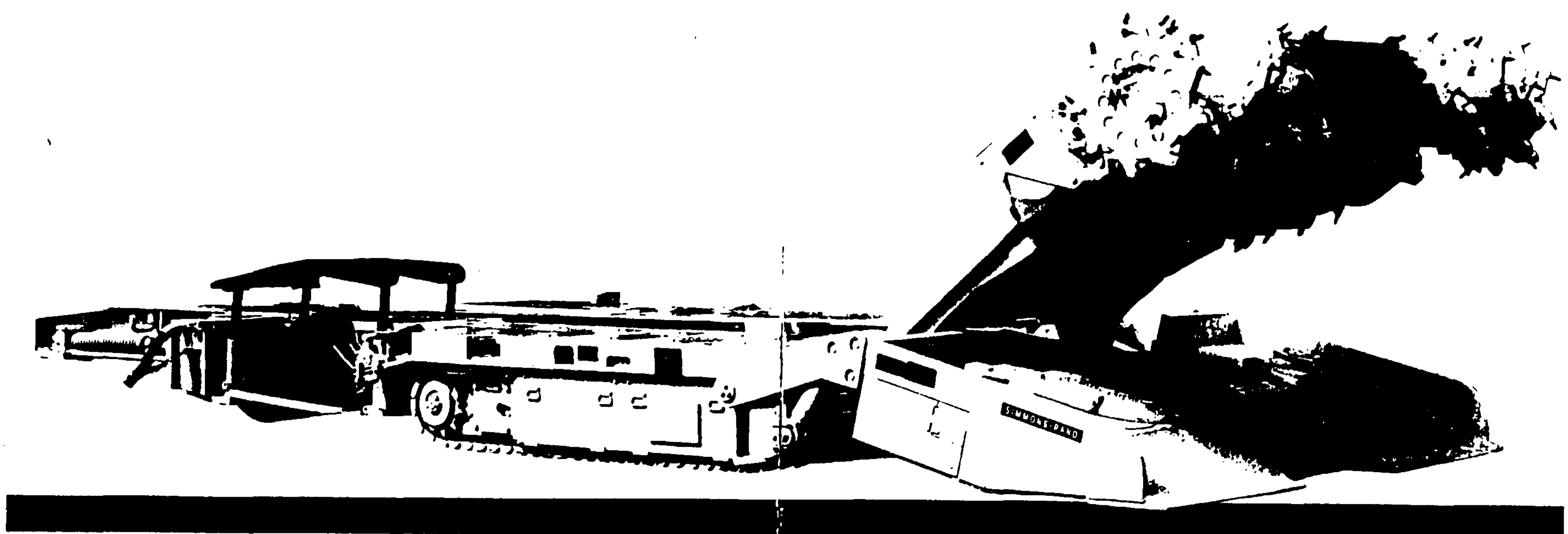
SIMMONS-RAND

Mr. President, critics of S. 717 have claimed that the imposition of civil penalties is a punitive measure, that it is an attempt to punish operators who do not comply with the act's requirements. Well, in my mind this is merely a question of attitude. I prefer to think of the civil penalty as a means of encouraging compliance, not as a means of punishing disobedience.

We have seen, in recent years, a much greater improvement in the rates of fatalities and serious injuries in the mining of coal, than we have seen in noncoal mining. I believe that the civil penalty system under the Coal Act is a major factor contributing to this improvement in what we are really getting at—the safety and health of our Nation's miners.

S. 717 provides a streamlined procedure for the collection of these penalties while insuring fairness to the parties. The bill provides a procedure which enables the questions arising out of civil penalties to be litigated quickly and with finality.

Under this procedure, an independent administrative tribunal assesses the penalties, and review of penalty assessments is based on a substantial evidence test, the prevalent test for court review of administrative determinations under our system.

We know, however, that there is a hard core group of operators for whom civil penalties provide little encouragement to comply with the requirements of the law. These operators apparently find it easier, and perhaps cheaper, to simply pay penalties rather than do what they must to get their mines in shape and provide true and lasting protection for their workers.

That was the situation the committee's investigators found at Scotia—a pattern of habitual violations of the act's requirements which would be cited by the inspector and abated by the operator. But the operator would then permit the mine to lapse back into violation, exposing miners to these risks all over again. This was repeated.

At Scotia there were 62 ventilation violations in the 2 years prior to the explosion. It is likely that it was just this improper ventilation which was instrumental in an explosion of accumulated methane gas.

This bill provides two new enforcement procedures addressed to these situations. One is a new closure order sequence, which is triggered by the finding that a pattern of violations exists in a mine which could substantially and significantly affect the health and safety of miners.

This new mechanism permits the Secretary to issue an order closing all or the affected portion of a mine every time another such violation is found, until an inspection of the entire mine indicates that there are no more violations of the type which established the pattern.

The other new sanction available in such situations permits the Secretary to ask a Federal district court to fashion appropriate relief in cases of chronic and habitual violations of the act by operators.

Mr. President, I think these new enforcement tools are true responses to the inadequacies of enforcement in our present law which the Scotia tragedy so clearly demonstrated.

S. 717 addresses the inadequate enforcement of our mine safety laws in another way. It transfers responsibility for the enforcement of this program to the Department of Labor.

In the committee's judgment, the responsibility for insuring workers' health and safety logically belongs with the Department which has as its overall duty the responsibility of safeguarding workers' rights. Yet the committee recognizes that miner health and safety calls for particular expertise and a special expenditure of effort. It is for that reason that S. 717 insures that the mining enforcement agency will maintain its independence within the Labor Department.

Further, in order to insure that the mine safety and health program will not be denied the technical mining expertise of the Bureau of Mines, the safety research and training functions which are integrally related to this technical expertise are retained in the Interior Department. Under this arrangement, the Secretary of Labor will be able to determine his safety research and training needs, and arrange to have the appropriate research and training done by the Interior Department. The considerable skill and experience of the Bureau of Mines will thus continue to be directed toward furthering the health and safety of our Nation's miners.

Mr. President, there will be charges that this attempt to improve the health and safety of our Nation's miners will be costly to the mining industry and that the cost to the consumer of energy and mineral products will increase. Possibly that is the case.

Mr. President, we must consider the cost we now pay in human suffering. One death and sixty-six disabling injuries every working day is a cost which no civilized society should permit itself to pay for extracting minerals.

Our country is now turning to address our natural energy shortage. The President has already sent to us a comprehensive plan to increase the development and exploitation of our energy and mineral reserves. I believe that an effective mine safety and health program must be put in place first—and must be the firm foundation upon which we will build our national energy program. Otherwise, we will continue to pay for our energy and minerals with the dreadful currency of human lives and limbs.

Our national energy needs should not be met at the expense of our Nation's miners and their families. With the possibility of greatly increased mineral extraction on the near horizon, the time has come for reform of our inadequate mine safety and health program. Our miners should have to wait no longer. Our Nation should want to wait no longer.

Mr. President, this bill has the support of the President and his administration.

The Secretary of the Interior and the Assistant Secretary of Labor have told the Labor Subcommittee that President Carter considers the changes to our mine safety and health program made by S. 717 to be essential, and of a high priority.

Mr. President, the Committee on Human Resources has felt this urgency for a long time.

S. 717 has been carefully drafted and considered by the committee, and I am glad that it is on schedule now for the Senate to make its determination.

Mr. President, I am happy to see that the ranking member of our committee, the Senator from New York (Mr. JAVITS), who has been one of the leading architects of all of our safety laws, is now ready to advance another necessary cause, S. 717, before the Senate now.

Mr. JAVITS. Mr. President, we have before us today a bill, S. 717—the Federal Mine Safety and Health Amendments of 1977, which was unanimously reported to the Senate last month by the Human Resources Committee. I am pleased once again to join the chairman of the committee, Mr. WILLIAMS, in urging the adoption of a measure to bring about a marked advance in the safety and health of our Nation's working men and women.

This bill is intended to strike a new balance in the longstanding antagonistic goals of maximizing production of energy and mineral resources on the one hand, and, on the other hand, affording the maximum safety and health protection for the workers who extract those resources in what all recognize is inherently a highly hazardous occupation.

With greatly increased emphasis on coal production to meet our future energy needs, we must be sure that accelerated production is accompanied by an improvement in the rate of fatalities and disabling injuries among miners. To this end, the bill makes a number of improvements in the standard setting and enforcement provisions of the Federal Coal Mine Health and Safety Act of 1969.

S. 717 will at last also bring about a balance in worker protection between coal miners and other miners who have been inadequately protected under the far less comprehensive and stringent provisions of thee Federal Metal and Non-Metallic Mine Safety Act of 1966. With the enactment of this bill, all miners, whether coal or noncoal, whether underground or surface, will be afforded equal protection against the hazards of their common occupation. To this end, the bill repeals the Metal Act and vests all authority in the Secretary of Labor under one new statute, which nevertheless leaves intact the appropriate differences in standards between the coal and noncoal operators in the mining industry.

This bill is a product of extensive oversight activities on the part of the Human Resources Committee that have continued over the past 7 years. The committee has investigated several of the terrible disasters that have taken the lives of miners during this period. The Human Resources Committee has also received a series of critical reports from the General Accounting Office on the state of the present mine health and safety program.

After all of this careful examination,

Bulletin 503
BUREAU OF MINES

LIMITS OF FLAMMABILITY OF GASES AND VAPORS

BY H. F. COWARD AND G. W. JONES

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1952

flammability; in a third (222) the flame speeds in a series of flammable mixtures of methane and air were extrapolated to zero speed, the corresponding composition being taken as the limit of flammability—an error, because a "limit" mixture has a flame speed that is far from zero. Many of the older figures are omitted because they are but rough approximations compared with more recent results, with which, however, they are not at variance.

A recent series of experiments in narrow tubes has, however, given some anomalous results, not yet explained. In a 2-cm.-diameter tube 60 cm. long, the limits were normally 5.40 and 13.72 percent; but, after the tube had been cleaned with chromic acid, washed, dried, and evacuated to 0.001 mm., the limits observed were 4.70 and 12.36 percent. An extended series of experiments was then made with a "natural gas" containing 94 percent of methane and 0.5 percent of "various hydrocarbons." Tubes 2.5, 2.0, 1.5, and 1.0 cm. in diameter were used, and both limits were determined for upward and downward propagation of flame. The "clean-tube" limits were always lower than the corresponding "normal-tube" limits, the difference being independent of tube diameter for both limits (downward propagation) and for the higher limit (upward propagation). It is difficult to explain a "wall effect" that is independent of tube diameter (254).

Upward Propagation in Small Vessels.—Table 11 shows the limits with upward propagation of flame in mixtures of methane and air in the smaller vessels. It is evident that the limits found in wide vessels open behind the flame—5.3 and 13.87 for gases saturated with water vapor—are not appreciably narrower in open tubes 5 cm. in diameter. In closed tubes, however, the higher limit is greater than in open tubes of equal diameter. This is explained by the observation that increase of pressure raises the higher limit; enough pressure to affect the limit is developed in closed tubes in the earlier stages of propagation, while the flame is still assisted by the initial impulse from the source of ignition. This explanation is confirmed by a comparison of two experiments in tubes of the same diameter (5 cm.) but of very different lengths. The shorter tube gave a greater higher-limit figure than the longer tube, because the pressure must rise faster and to a greater quantity in the shorter tube.

TABLE 11.—*Limits of flammability of methane in air, with upward propagation of flame in tubes*

Dimensions of tube, cm.		Firing end	Limits, percent		Content of aqueous vapor	Reference No.
Diameter	Length		Lower	Higher		
10.2	96	Closed	5.00	15.00	Dry	[illegible]
7.5	150	do	5.35	14.85	Half-saturated	[illegible]
6.2	33	Open	5.45	13.5	Saturated	[illegible]
6.0	200	Closed	5.40	14.3	Small	[illegible]
5.3	150	Open	5.28	14.2	Dry	[illegible]
5.0	50	Closed		15.11		[illegible]
5.0	150	Open	5.40	14.25	Half-saturated	[illegible]
5.0	180	do	5.24	14.02	Dry	[illegible]
5.0	180	do	5.33	13.80	Saturated	[illegible]
4.7	100	do	5.3	14.3	Small	[illegible]
4.0	100	Closed	5.5	14.1		[illegible]
2.7		Open	5.28		Dry	[illegible]
2.5	150	do	5.5		Saturated	[illegible]
2.5	150	Closed	5.50	13.20	Half-saturated	[illegible]
2.25	125	Open	5.48		Nearly dry	[illegible]

Horizontal Propagation in Small Vessels.—Table 12 shows the limits with horizontal propagation in the smaller vessels. The limits for closed tubes are narrowed appreciably by reducing the diameter of the tube to 2.5 cm. In open tubes the limits meet when the diameter of the tube is reduced to 0.45 cm. Flame is not propagated, except for a short distance from the source of ignition, along a tube 0.36 cm. in diameter.

Downward Propagation in Small Vessels.—Table 13 shows the limits with downward propagation of flame in the smaller vessels. The limits throughout are somewhat narrower than those found in the largest vessel for the same direction of propagation.

Propagation in Spherical Vessels.—Table 14 shows the limits for propagation of flame throughout mixtures of methane and air in closed spherical vessels of various sizes. The

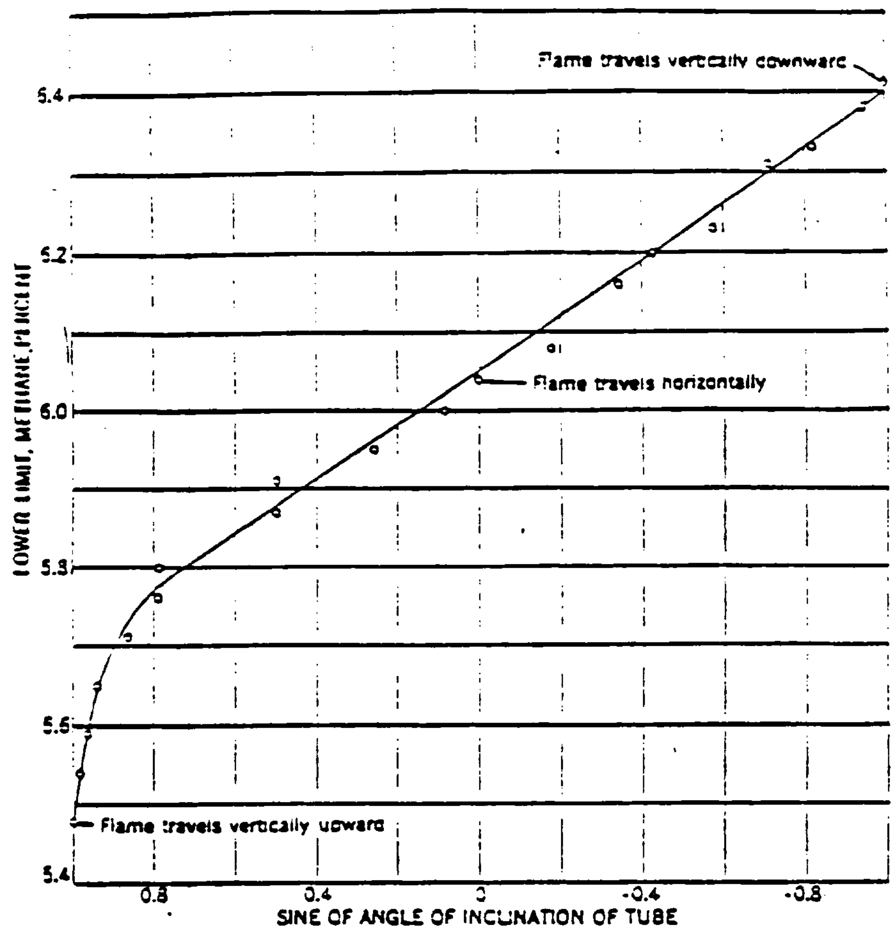

FIGURE 15.—Lower Limit of Methane for Various Directions of Propagation of Flame in a Tube 2.25 Cm. in Diameter.

Influence of Turbulence and Streaming Movement on Limits of Flammability.—When a small fan was rotated rapidly enough but not too rapidly in methane-air mixtures contained in a 4-liter globe, the lower limit of methane was 5.0 percent compared with 5.6 percent observed for quiescent mixtures in the same vessel. If the turbulence was too violent, however, even a 5.6-percent mixture did not propagate more than a short tongue of flame (*33, 350*).

A streaming movement of the gas mixture produces similar effects on the lower limit. At a speed of 35 to 65 cm. a second (69 to 128 feet a minute) flame was propagated in a 5.02-percent methane-air mixture but not at any speed in a 5.00-percent mixture (*286*). Hence, under appropriate conditions of movement of the gas mixture, the lower limit of methane is 5.0 percent. The same figure was obtained when movement of the mixture was produced by expansion caused by its own combustion in experiments on the propagation of flame from closed to open end of a large vessel (p. 137).

Reference may be made to observations of the effect of turbulence, in somewhat different circumstances, on the lower limit of natural gas in air (p. 115).

Influence of Pressure.—No measurable change in the limits of methane in air could be discovered, either when the pressure was varied between 753 and 794 mm. (*225*) or, in the lower limit for upward propagation of flame, when the pressure was varied from 1 to 2.9 atmospheres in a vessel of 11.3 liters capacity (*211*).

An interesting comparison has been made of the effect of change in pressure from 1 to 6 atmospheres on the limits with downward and horizontal propagation in tubes 2 cm. in diameter (*225, 277*). With downward propagation, the limits change steadily from 6.00 and 13.00 percent at 1 atmosphere to 6.40 and 14.05 percent at about 6 atmospheres. With horizontal propagation, the lower limit remained nearly constant (5.6 percent) over this range of pressure; the higher limit rose steadily from 13.31 percent at 1 atmosphere to 16.12 percent at about 6.3 atmospheres. In these experiments, therefore, the lower limit with horizontal propagation was unchanged, but that with downward propagation increased

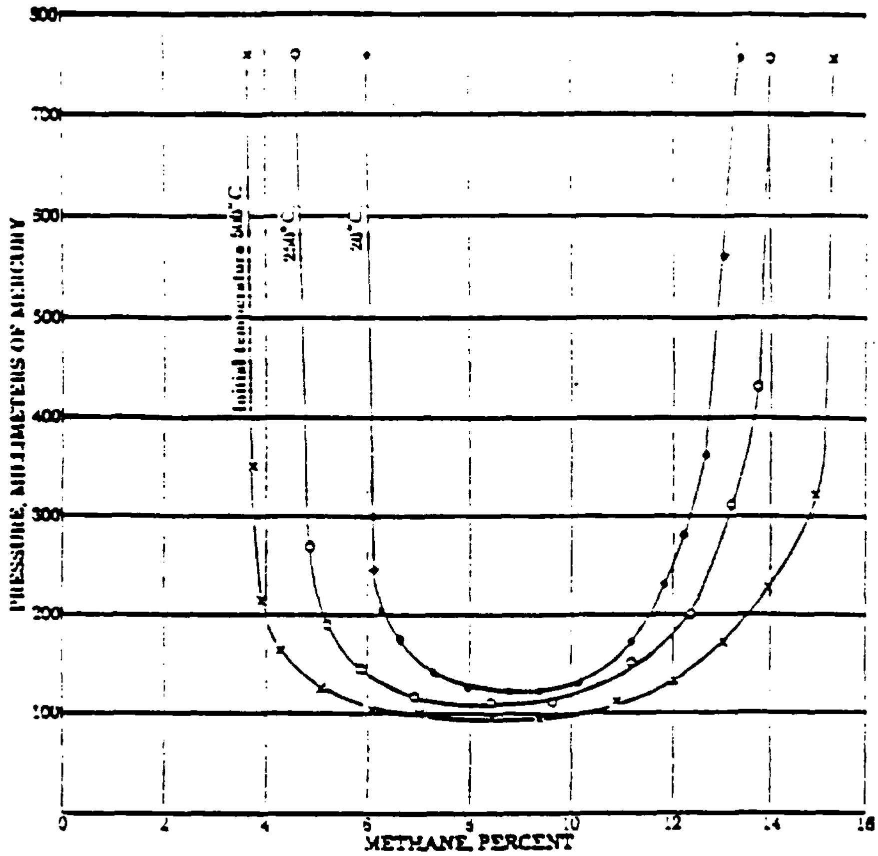

FIGURE 17.—Limits of Flammability of Methane in Air (Downward Propagation), Showing Influence of Pressure (Below Normal) and Temperature.

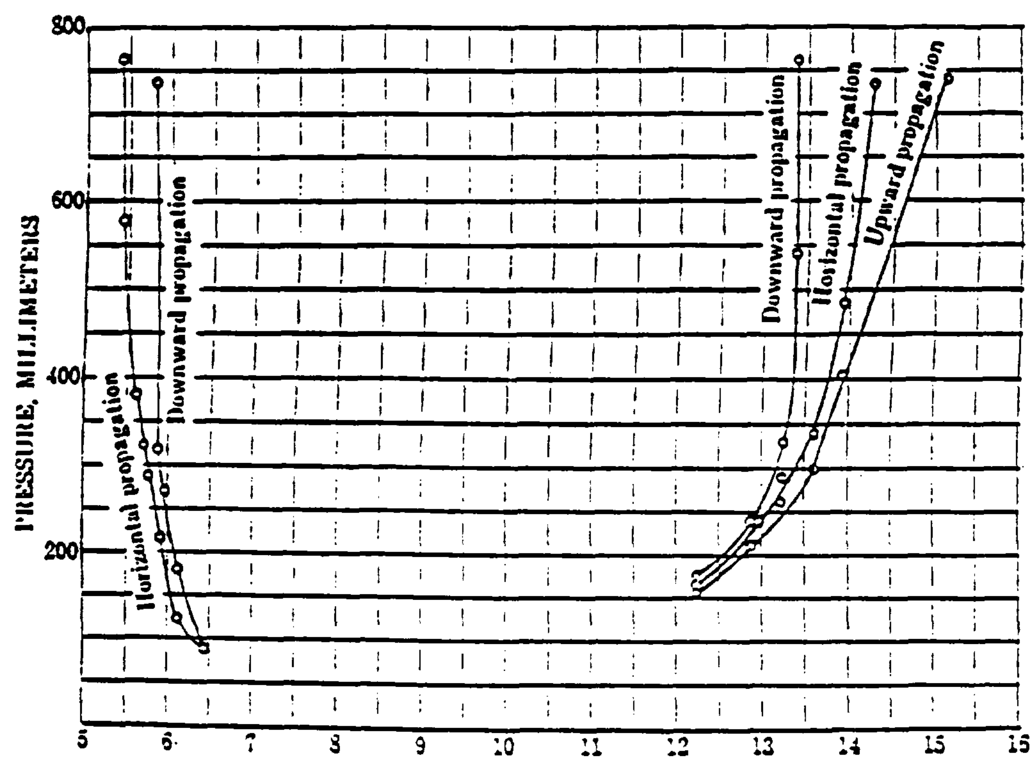

FIGURE 18.—Limits of Flammability of Methane in Air, Showing Influence of Pressure and of Direction of Propagation of Flame.

the same circumstances, but at room temperature, the limit is 6.1 percent.

Influence of Pressure at Various Temperatures.—The curves of figure 17 show the limits of flammability of methane-air mixtures at 20°, 250°, and 500° C. at all pressures below atmospheric. The limits were observed in a closed tube 2 cm. in diameter and 50 cm. in length (*285*).

A mixture of 2.1 percent methane in air was ignited by sudden compression to 80 atmospheres pressure, which produced a temperature of 705° C., and a mixture of 55 percent methane at 118 atmospheres and 540° C. (*57*).

Influence of Impurities.—The lower limit of methane in air, with downward propagation of flame, was raised about 1.3 percent by iron carbonyl (0.03 cc. liquid vaporized per liter). The higher limit was reduced from 13.0 to 10.5 percent by the same quantity of iron carbonyl (*325*).

METHANE IN OXYGEN

The limits of methane in oxygen, with upward propagation of flame in a 2-inch-diameter tube open at its lower end, are 5.15 and 60.5 percent (*138*).

Table 15 gives other determinations of the observed limits of methane in oxygen.

TABLE 15.—*Summary of other determinations of limits of flammability of methane in oxygen*

Dimensions of tube, cm.		Firing end	Limits, percent		Reference No.
Diameter	Length		Lower	Higher	
Upward Propagation of Flame					
2.5	150	Open	5.4		277
Horizontal Propagation of Flame					
2.5	150	Open	5.7; 5.5	59.2	277
Downward Propagation of Flame					
2.5	150	Open	6.3		271
2.0–2.2		Closed		54	313
1.9		do	6.4		95
1.9		do	6.45		328
1.7		do	5.0	57.1	325
		do		56	326
Propagation of Flame in Globe or Bomb					
2.5 liters capacity		Closed	6.0		267
35 cc. capacity		do		57.0	297
50 cc. capacity		do		54.5	53

Influence of Pressure.—The limits of methane in oxygen were not appreciably narrowed until the pressure was reduced below 150 mm. A moderately strong igniting spark was used (*65*). With a stronger spark the limits did not coincide until the pressure was reduced to 10 mm. (*50*). A curve has been obtained for results in a burette (*86*).

The higher limit is increased by an increase of pressure above atmospheric. One observation (*330*), incidental to other work, is that, at 10 atmospheres pressure, a mixture containing 71 percent methane slowly propagated flame. In a small bomb (*53*) the higher limit rose rapidly from 58.4 percent at 1 atmosphere to 81.7 percent at 60 atmospheres, then slowly to 84 percent at about 145 atmospheres; however, the mixtures contained about 4.5 percent nitrogen, and the limits would be somewhat higher in pure oxygen. Combustion was far from complete in such mixtures under moderately high pressure.

Influence of Temperature.—In a 35-cc. closed bulb the limits were 6.2 and 57.1 at 15° C. and 5.1 and 57.8 at 300° C. (*297*).

Influence of Temperature at High Pressures.—As the temperature is raised, the pressure required to make certain mixtures of methane and oxygen flammable decreases. For example, the pressure limit of a mixture containing 81.7 percent methane at atmospheric temperature was 60 atmospheres, but at 332° C. it was only about 21 atmospheres (*53*). Curves that show the higher limit at elevated temperatures and pressures are given in the original paper.

METHANE IN OTHER ATMOSPHERES

Atmospheres of Composition Between Air and Pure Oxygen.—The limits of methane in mixtures of nitrogen and oxygen richer in oxygen than ordinary air have been found as follows: (1) In a closed globe 2.5 liters in capacity the lower limit rose regularly from 5.8 percent in air to 6.0 percent in oxygen (*267*); (2) in a horizontal glass tube 2.5 cm. in diameter, open at the firing end, the lower limit fell from 5.3 percent in air to 5.7 percent in oxygen, and the higher limit rose linearly from 13.3 in air to 59.2 in oxygen (*189*); (3) in a closed tube 1.9 cm. in diameter the lower limit with downward propagation of flame rose regularly from 6.15 percent in air to 6.45 percent in oxygen. The higher limit rose from 12 percent in air to 38 percent in a 62-percent oxygen mixture and 52 percent in a 95-percent oxygen mixture (*328*).

Atmospheres of Air and Nitrogen (Air Deficient in Oxygen).—Large-scale experiments with mixtures of methane, air, and nitrogen have been made in a tube 7 feet in length and 10 inches in diameter, with upward propagation of flame from the open end of the tube; the mixtures throughout were at atmospheric pressure and were saturated with water vapor. The range of observations shown in figure 20 cannot form an explosive mixture with air, whatever the proportions used, whereas the mixture

	Percent
Methane	9
Oxygen	12
Nitrogen	79

although not itself explosive, may form a series of explosive mixtures with air. Figure 22 gives this information at a glance.

Explanation of Figure 23.—Figure 23 explains figure 22. The straight line *AD* (fig. 23) represents the composition of all mixtures of methane and pure air that contain up to 20 percent methane. No mixture of methane and air can fall above this line, and all mixtures of methane, air, and nitrogen must fall below it. The line *BE* is the line of lower limits of flammability of methane and *CE* the line of higher limits. As the oxygen content falls, *BE* and *CE* approach each other until they meet at *E*. No mixture which contains less oxygen than that corresponding with *E* is explosive *per se*, but all mixtures in the area *BEC* are within the limits of flammability and are therefore explosive.

Next consider any mixture to the right of the line *CEF*; for example, the mixture represented by the point *G*. Join *GA*. Then *GA* represents the mixtures formed, in succession, as *G* is diluted with air. Because *GA* passes through the area *BEC* the mixture, as it is diluted with air, becomes explosive and remains so as long

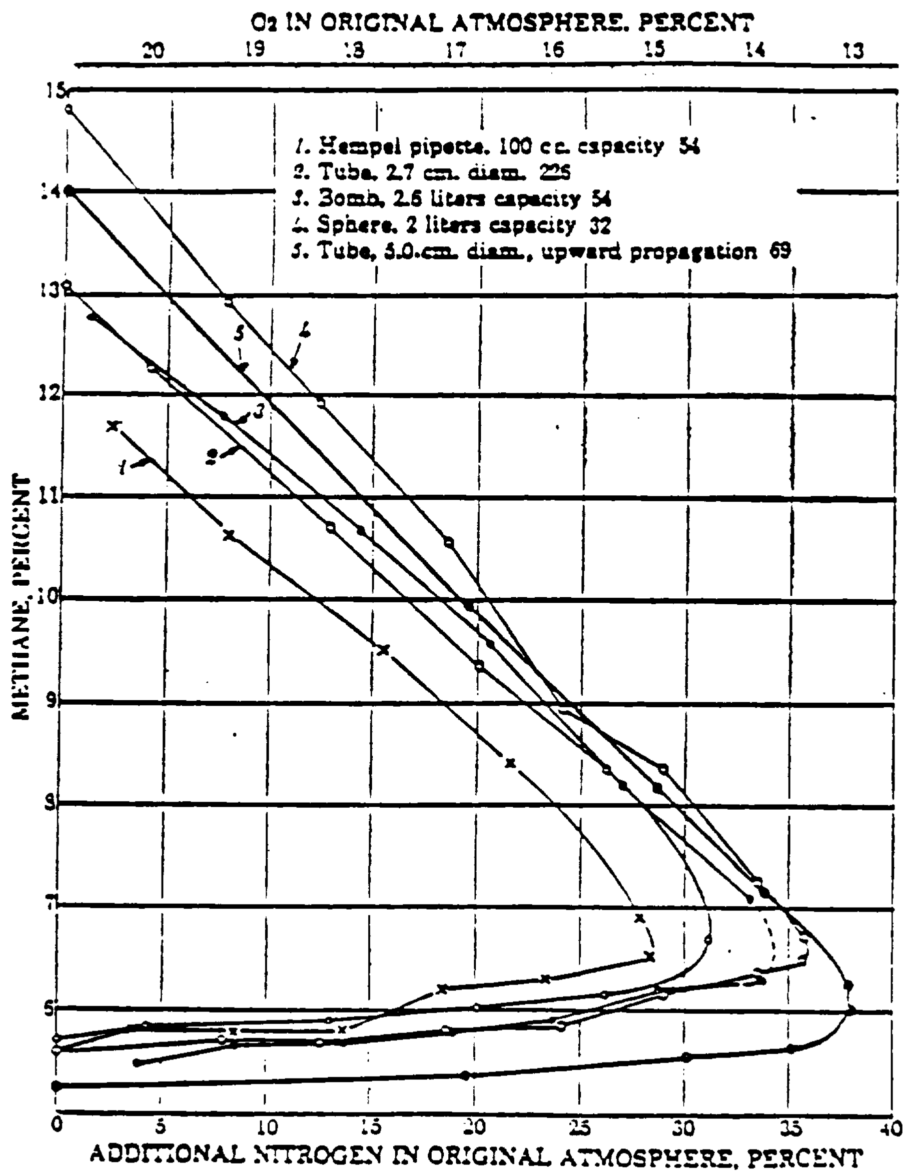

FIGURE 21.—Limits of Flammability of Methane in Mixtures of Air and Nitrogen; Comparison of Results Obtained in Smaller Vessels.

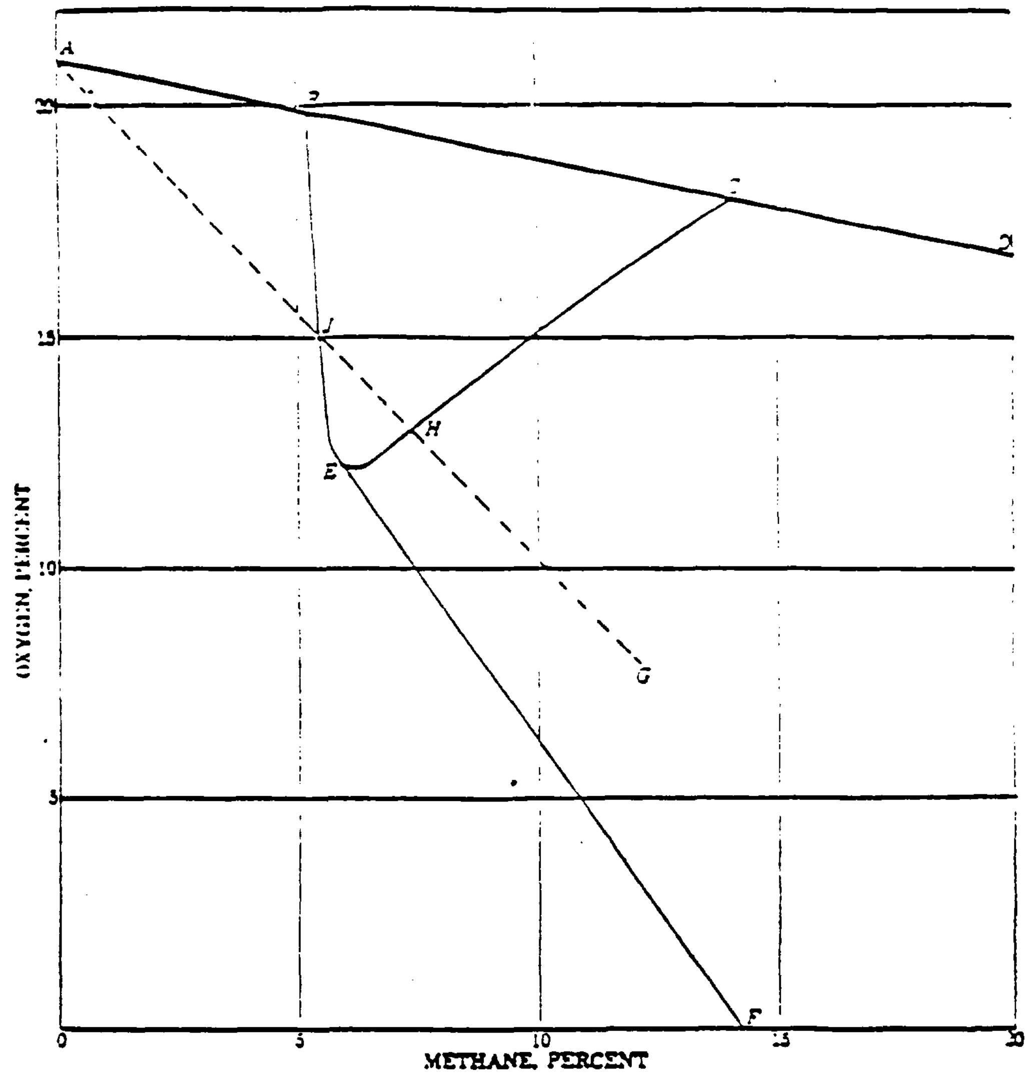

FIGURE 23.—Explanation of figure 22.

All Atmospheres of Oxygen and Nitrogen.—Limits of methane in these atmospheres have been determined with downward propagation of flame in a 1.7-cm.-diameter tube (*345*).

Atmospheres of Air and Water Vapor.—Observations that show the small difference in the limits of methane in dry air and in air saturated with water vapor at laboratory temperatures are quoted under Effect of Small Changes in Atmospheric Composition (p. 3).

The effect of large amounts of water vapor on the limits of methane in air is shown in figure 24. The determinations were made in a tube 3 feet in length and 2 inches in diameter, with upward propagation of flame at atmospheric pressure during propagation (*67*). For each experiment the tube was heated to the temperature necessary to maintain the required amount of water vapor. Hence, most of the observations were made at temperatures above normal. Had it been possible to experiment at normal temperature, the curve probably would have been a little to the right of the carbon dioxide curve over the lower-limit range and at the nose, but the two curves would have coincided over most of the higher-limit range.

Similar experiments have been made in a closed 350-cc. spherical vessel with a "natural gas" containing 97 percent methane, 3 percent ethane. Similar results were obtained, with somewhat smaller limits, which met at about 6.3 percent gas in a mixture containing about 30 percent of water vapor (*368*).

Atmospheres of Air and Carbon Dioxide.—Figure 25 shows the limits of methane in mixtures of air and carbon dioxide saturated with water vapor. The tests were made in a tube 7 feet in length and 10 inches in diameter, with

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary

BUREAU OF MINES
J. J. Forbes, Director

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Miners' Circular 33

Bureau of Mines

MINE GASES AND METHODS FOR DETECTING THEM

(Revised March 1954)

By J. J. Forbes and G. W. Grove

UNITED STATES GOVERNMENT PRINTING OFFICE
WASHINGTON : 1954

Colo., and Tintic and Park City, Utah, districts, as well as in numerous other metal-mining regions.[25] [26] [27] Carbon dioxide is a constituent of blackdamp, and traces of it (0.03 percent) are always present in normal air.

One-half of 1 percent (0.5 percent) of carbon dioxide in normal air causes a slight increase in the lung ventilation; a man exposed to this percentage of carbon dioxide will breathe a little deeper and a little faster than when in pure air. If the air contains 2 percent of carbon dioxide, the lung ventilation will be increased about 50 percent: if 3 percent, about 100 percent; if 5 percent, about 300 percent, and the breathing is laborious: and 10 percent cannot be endured for more than a few minutes.[28] Carbon dioxide in air has these effects when the oxygen content remains about normal and the subject is at rest. Moving around or working would naturally increase the symptoms, and they would be much more dangerous than when a man is resting.

Solid (dry ice) or liquid carbon dioxide sublimes or vaporizes at 109.3° F. below zero.[29] Liquid carbon dioxide is employed in a special permissible cartridge for blasting coal,[30] and dry ice has been used as a source of inert gas in fighting mine fires.

METHANE (CH_4)

Methane, also known as marsh gas, is one of the chief constituents of firedamp. It is colorless, odorless, tasteless, nonpoisonous, and flammable. As stated, methane is odorless; but, because it may be accompanied by other gases that are odorous, the mixture may have a distinct odor. Its common occurrence in the old workings of mines, where the air may be musty from decaying timbers and other impurities, has caused many mining men to believe that methane has an odor. The specific gravity of methane is 0.5545,[31] and its weight per cubic foot at sea-level pressure and 70° F. is 0.042 pound. Methane is found in almost all coal mines and occasionally in metal and other types of mines and in tunneling operations. In coal mines it may issue from the cleats or cracks of the coal, from "blowers" or "feeders," or from overlying or underlying strata and often is released in large amounts from the coal when irregularities, such as clay veins, "horsebacks," or faults, are encountered. In metal mines and in tunnel driving, methane frequently is found when carbonaceous shales are penetrated and occasionally is present by infiltration into metal mines at contacts or near carbonaceous rocks. Methane may be generated by the action of certain bacteria on organic matter, such as mine timber, and explosions have been caused by accumulated methane from this source while flooded mines were being unwatered. The liberation of methane from

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[25] Sayers, R. R., and others, Mine Rescue Standards: Bureau of Mines Tech. Paper 334, 1923, 44 pp.

[26] McElroy, G. E., Rock-Strata Gases in Mines of the East Tintic Mining District, Utah: Bureau of Mines Rept. of Investigations 2275, 1921, 3 pp.

[27] Denny, E. H., Marshall, K. L., and Fieldner, A. C., Rock-Strata Gases of the Cripple Creek District and Their Effect on Mining: Bureau of Mines Rept. of Investigations 2865, 1928, 24 pp.

[28] See footnote 25.

[29] International Critical Tables, vols. 1 and 3, 1928.

[30] Tiffany, J. E., A New Permissible Blasting Device: Bureau of Mines Rept. of Investigations 2920, 1929, 8 pp.

[31] Burrell, G. A., and Seibert, F. M. (revised by G. W. Jones), Sampling and Examination of Mine Gases and Natural Gas: Bureau of Mines Bull. 197, 1926, 108 pp.

the strata in mines may be a steady flow or a sudden outburst. When present, it is usually found near the mine roof or in high places; but, after becoming thoroughly mixed with air, it will be found uniformly distributed across any cross section of a moving air current and will not separate or stratify from still air. Methane may be detected with a flame safety lamp (preferably of the permissible type) and by various other approved detecting devices. Methane has no specific physiological effect upon man, but enough may accumulate in mine workings to dilute the oxygen of the air and produce atmospheres deficient in oxygen. Deaths from asphyxiation have resulted from men unknowingly entering high concentrations of methane.

The common occurrence of methane and its explosibility when mixed with air are directly responsible for numerous mine disasters. Air that contains 5 to 15 percent of the methane [32] and 12.1 percent or more oxygen will explode if ignited.[33]

Methane is not the only cause of mine explosions. Dry coal dust, except anthracite, suspended in air is explosive, but coal-dust explosions are propagated more rapidly and more readily when methane is present, even in percentages much below the lower explosive limit. Tests conducted in the Experimental mine of the Bureau of Mines show that, under the most favorable conditions as to diffusion of gas, point of ignition, and placement of coal dust, a uniform gas-air mixture of 146 cubic feet, containing approximately 13 cubic feet of methane (about 9 percent of the mixture), if ignited, is sufficient to initiate a general explosion.[34] Although the conditions under which these tests were conducted are rarely found in commercial coal mines, these experiments clearly indicate the danger of igniting even a small quantity of methane in the presence of coal dust.

Bureau of Mines engineers believe that 200 cubic feet, or possibly less, of an explosive methane-air mixture can precipitate a general explosion under conditions usually found in mines, if the mixture is ignited in the presence of coal dust. The concentration of methane, therefore, should be kept as low as possible by proper ventilation. It has been recommended that the safest practice is to prevent the accumulation of explosive mixtures and to keep the methane content of every air current below 0.5 percent at all times.[35]

CLASSIFICATION OF COAL MINES IN RESPECT TO METHANE LIBERATION

The Bureau of Mines believes that all coal mines are potentially gassy, but for purposes of administration in respect to prevention of explosions and fires the Federal Mine Safety Code (article V, sec. 10a) contains the following:

If and when a mine, subject to Title II of the Federal Coal Mine Safety Act, is classified as a gassy mine under the provisions of Title II of the Act, such

[32] Values such as these (5 to 15 percent in the case of methane) are said to represent the explosive or flammable limits of a combustible gas in air, and percentages between these limits are said to be within the explosive or flammable range of the particular gas in question. Gas-air mixtures containing the combustible gas in concentrations below or above the explosive limits will not propagate an explosion. Temperature, pressure, and the presence of inert diluents, such as carbon dioxide or nitrogen, affect the explosive limits of any combustible gas, and a limiting value exists for oxygen content of the mixture below which an explosion is impossible, regardless of the percentage of combustible gas present.

[33] Coward, H. F., and Jones, G. W., Limits of Flammability of Gases and Vapors: Bureau of Mines Bull. 503, 1952, 144 pp.

[34] Rice, G. S., Greenwald, H. P., and Howarth, H. C., Explosion Tests of Pittsburgh Coal Dust in the Experimental Mine: Bureau of Mines Bull. 369, 1933, 44 pp.

[35] Rice, G. S., Safety in Coal Mining: Bureau of Mines Bull. 277, 1928, 141 pp.

atmosphere containing a given concentration of carbon monoxide will produce, other conditions being equal, a higher percentage of blood saturation than will the same concentration of carbon monoxide in an atmosphere of normal oxygen content.

SYMPTOMS OF CARBON MONOXIDE POISONING

The symptoms caused by various percentages of carbon monoxide in the blood [38] are given in table 3.

TABLE 3.—*Symptoms of carbon monoxide poisoning*

Blood saturation, percent:	Symptoms
0 to 10	None.
10 to 20	Tightness across the head, possibly headache.
20 to 30	Headache, throbbing in temples.
30 to 40	Severe headache, weakness, dizziness, dimness of vision, nausea and vomiting, and collapse.
40 to 50	Same as previous item with more possibility of collapse and unconsciousness, increased pulse and respiration.
50 to 60	Unconsciousness, increased respiration and pulse, coma with intermittent convulsions.
60 to 70	Coma, with intermittent convulsions, depressed heart action and respiration, possibly death.
70 to 80	Weak pulse and slowed respiration, respiratory failure, and death.

The symptoms decrease in number with the rate of saturation. If suddenly exposed to high concentrations, a man may collapse before he experiences any warning symptoms. The rate at which a man is overcome and the sequence in which the symptoms appear depend on several factors—the concentration of gas, the extent to which he is exerting himself, the state of his health and individual susceptibility, and the temperature, humidity, and air movement to which he is exposed. Exercise and high temperature and humidity, with little or no air movement, tend to increase respiration and heart rate and consequently result in more rapid absorption of carbon monoxide. Under conditions that may be encountered in mining, interest centers mainly on the symptoms of "acute" carbon monoxide poisoning that may develop rather suddenly upon exposure to high concentrations of the gas. However, prolonged exposure to low concentrations of carbon monoxide that do not produce immediate, serious effects (sometimes referred to as "chronic" exposure or poisoning) may result in a continual feeling of tiredness, headache, nausea, palpitation of the heart, and sometimes mental dullness.

In severe cases of carbon monoxide poisoning that result in prolonged unconsciousness, with accompanying depletion of the normal supply of oxygen to the body tissues, permanent damage may be suffered, particularly by the brain, so that the victim, although surviving, may do so with impaired mind, suffering loss of memory and paralysis or sensory defects.[39] Such effects are not caused specifically by the carbon monoxide but rather by the prolonged lack of oxygen

[38] Sayers, R. R., and Yant, W. P., The Pyrotannic Acid Method for the Quantitative Determination of Carbon Monoxide in Blood and in Air. Its Use in the Diagnosis and Investigation of Cases of Carbon Monoxide Poisoning: Bureau of Mines Tech. Paper 373, 1925, 18 pp.

[39] Henderson, Y., and Haggard, H. W., Noxious Gases and Principles of Respiration Influencing Their Action: Reinhold Publishing Corp., New York, 1943, 294 pp.

Start next page

in the tissues and may result from asphyxia (unconsciousness caused by lack of oxygen) from any cause.

The physiological effects of various concentrations of carbon monoxide and the significance of time of exposure[40] are given in table 4.

TABLE 4.—*Physiological effects of carbon monoxide*

Concentration of carbon monoxide, percent by volume:	*Physiological effects*
0.01	Allowable for exposure of several hours.
.04 to 0.05	Can be inhaled for 1 hour without appreciable effect.
.06 to .07	Just noticeable effects after 1 hour exposure.
.10 to .12	Unpleasant, but probably not dangerous after 1 hour exposure.
.15 to .20	Dangerous for exposure of 1 hour.
.4 or more	Death in less than 1 hour.

The gen[illegible] recognized maximum allowable concentration[41] for [illegible]posure to air containing carbon monoxide and with normal oxygen content is 0.01 percent (100 parts of carbon monoxide per million parts of air, by volume). Somewhat higher concentrations may be considered allowable for shorter periods of exposure. For example, in the ventilation of vehicular tunnels, the maximum is generally set at 0.02 percent, as based upon the exposure of traffic officers in alternate 2-hour periods over an 8-hour shift.

HYDROGEN SULFIDE (H_2S)

Hydrogen sulfide—called stinkdamp from its odor, which resembles that of rotten eggs—is a colorless gas and is usually a product of the decomposition of sulfur compounds.[42] It may be produced also by burning explosives containing sulfur and may be liberated in using black blasting powder or dynamite in blasting sulfide ores. Hydrogen sulfide is also found in large and extremely toxic amounts in the natural gas and oil from certain fields, and it is frequently found in gypsum mines. Occasionally, though rarely, it has been found issuing with methane from gas blowers or feeders in coal mines,[43] and in numerous instances it is carried into mine workings by water, in which it is easily dissolved. Enough has been found in coal mines during normal conditions to cause severe eye irritation. The specific gravity of hydrogen sulfide is 1.1906,[44] and its weight per cubic foot at sea-level pressure and 70° F. is 0.089 pound. Air that contains 4.3 to 45 percent of hydrogen sulfide will ignite when subjected to ordinary flames and will explode.[45] Hydrogen sulfide is very poisonous; wherever it exists the possibility of poisoning is

[40] See footnote 39.
[41] American Medical Association Archives of Industrial Hygiene and Occupational Medicine. American Conference of Governmental Industrial Hygienists, Threshold Limit Values for 1953: Vol. 8. 1953. pp. 296–297.
[42] Sayers, R. R., Mitchell, C. W., and Yant, W. P., Hydrogen Sulfide as an Industrial Poison: Bureau of Mines Rept. of Investigations 2491. 1923, 6 pp.
[43] Sayers, R. R., and others, Mine Rescue Standards: Bureau of Mines Tech. Paper 334. 1923. 44 pp.
[44] Burrell, G. A., and Seibert, F. M. (revised by G. W. Jones). Sampling and Examination of Mine Gases and Natural Gas: Bureau of Mines Bull. 197. 1926. 108 pp.
[45] Coward, H. F., and Jones, G. W., Limits of Flammability of Gases and Vapors: Bureau of Mines Bull. 503. 1952. 144 pp.

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present. The physiological effects attending exposure to various concentrations of hydrogen sulfide in air[46] are given in table 5.

TABLE 5.—*Physiological effects of hydrogen sulfide*

Concentration of hydrogen sulfide, percent by volume:	*Effects*
0.005 to 0.010	Subacute poisoning—slight symptoms, such as mild conjunctivitis (eye irritation) and respiratory tract irritation after 1 hour exposure.
.02 to .03	Subacute poisoning—marked conjunctivitis and respiratory tract irritation after 1 hour exposure.
.05 to .07	Subacute poisoning—dangerous in ½ to 1 hour.
.07 to .10	Possible acute poisoning—rapid unconsciousness, cessation of respiration, and death.
.10 to .20 or more	Acute pois[illegible] rapid unconsciousness, [illegible] of respiration, and death in [illegible] minutes.

The generally recognized maximum allowable concentration of hydrogen sulfide in the air of working places is 0.002 percent by volume (20 parts of hydrogen sulfide per million parts of air) during an 8-hour exposure.[47]

Hydrogen sulfide acts mainly as an irritant in subacute poisoning caused by concentrations up to about 0.07 percent; and irritation of the eyes, ranging from mild to severe depending on the extent and intensity of exposure, is the most common symptom. In higher concentrations acute poisoning occurs, which is far more dangerous than the subacute effects, as systemic poisoning results, which may have a general action on the nervous system and cause almost immediate respiratory paralysis and death. Experiments have shown that dogs exposed to concentrations of hydrogen sulfide ranging from 0.1 to 0.2 percent collapsed and ceased breathing in about 1 minute. If the dogs were withdrawn from the contaminated atmosphere at once and given artificial respiration they were revived and in a matter of minutes showed no ill effects of the experience. This demonstrates the need for immediate rescue, removal to fresh air, and resuscitation of persons overcome by hydrogen sulfide, although it must be emphasized that many persons have lost their lives in attempting to rescue victims of hydrogen sulfide poisoning by entering the contaminated atmosphere without respiratory protective equipment. If there is any evidence or suspicion that hydrogen sulfide is present, respiratory protective equipment should be worn by persons entering the affected area. Although hydrogen sulfide has a distinctive odor, the sense of smell cannot be relied upon as a means of detection because after 1 or 2 inhalations the olfactory nerves become paralyzed and the odor of hydrogen sulfide can no longer be detected.

In addition to eye irritation, low concentrations of hydrogen sulfide produce symptoms of subacute poisoning, such as headache, dizziness, excitement, nausea or other disturbances of the stomach and intestinal tract, dryness and sensation of pain in the nose, throat, and chest, and coughing.[48] The acute effects of high concentrations of

[46] Yant, W. P., Hydrogen Sulfide in Industry; Occurrence, Effects, and Treatment: Am. Jour. Pub. Health, vol. 20, 1930, pp. 598–608.

[47] American Medical Association Archives of Industrial Hygiene and Occupational Medicine, American Conference of Governmental Industrial Hygienists, Threshold Limit Values for 1953: Vol. 8, 1953, pp. 296–297.

[48] Patty, F. A., Industrial Hygiene and Toxicology: Vol. II Interscience Publishers, Inc., New York, 1949, 750 pp.

hydrogen sulfide, as described above, are immediate and decidedly dangerous.

ETHANE (C_2H_6), PROPANE (C_3H_8), AND BUTANE (C_4H_{10})

Ethane, propane, butane, and other heavier (higher molecular weight) members of the methane or paraffin-hydrocarbon series are components of natural gas but are not found normally in coal mines, except possibly in traces. The specific gravity of ethane is 1.0493, of propane 1.5625, and of butane 2.0100,[49] and the weights per cubic foot at sea-level pressure and 70° F. are 0.079 pound for ethane, 0.117 pound for propane, and 0.151 pound for butane. These gases are sometimes present in small quantities in association with methane in gases from mine fires and explosions. They tend to increase the explosibility, because their lower limits of flammability are less than that of methane, but usually they are not present in amounts large enough to be dangerous or even to be detected readily. However, when over 1 percent of these "higher hydrocarbons" is found in a mine, leakage from a gas or oil well is suggested. Air that contains 3.2 to 12.5 percent of ethane is explosive. For propane-air mixtures the corresponding limits are 2.4 to 9.5 and, for butane-air mixtures, 1.9 to 8.4 percent.[50]

OXIDES OF NITROGEN (NO, NO_2, ETC.)

Oxides of nitrogen are formed in mines by burning, by afterburning, and, under certain conditions, by detonation of high explosives. They are also components of the exhaust of diesel and gasoline engines and are formed by the reaction of atmospheric oxygen and nitrogen in the air in close proximity to electric arcs and sparks. Oxides of nitrogen are produced also by burning or decomposition of nitrates and nitrated materials. Nitrogen forms several oxides—N_2O, NO, NO_2, N_2O_4, N_2O_3, and N_2O_5. Of these, only nitrous oxide (N_2O) is harmless and is sometimes used as an anesthetic. The others are toxic. The most commonly occurring toxic oxides of nitrogen are nitric oxide (NO) and nitrogen dioxide, which occurs in two forms (NO_2 and N_2O_4), depending on the existing temperature. Nitric oxide does not exist in significant amount in the air, as in the presence of moisture and oxygen it is oxidized to the dioxide. Therefore, when air samples are analyzed for oxides of nitrogen the results usually are reported in terms of nitrogen dioxide (NO_2), as such designation gives proper evaluation of the toxic properties of the atmosphere. Nitrogen dioxide is brownish red but is not visible, particularly in dimly lighted places, in low concentrations, which nevertheless may be quite toxic. Oxides of nitrogen, in their several forms, are believed to contribute to the powder-fume odor that follows blasting with high explosives.[51] The specific gravity of nitrogen dioxide is 1.5894,[52] and its weight per cubic foot at sea-level pressure and 70° F. is 0.119 pound.

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[49] Burrell, G. A., and Seibert, F. M. (revised by G. W. Jones), Sampling and Examination of Mine Gases and Natural Gas: Bureau of Mines Bull. 197, 1926, 108 pp.

[50] Coward, H. F., and Jones, G. W., Limits of Flammability of Gases and Vapors: Bureau of Mines Bull. 503, 1952, 144 pp.

[51] Gardner, E. D., Howell, S. P., and Jones, G. W., Gases From Blasting in Metal-Mine Drifts: Bureau of Mines Bull. 287, 1927, 96 pp.

[52] Burrell, G. A., and Seibert, F. M. (revised by G. W. Jones), Sampling and Examination of Mine Gases and Natural Gas: Bureau of Mines Bull. 197, 1926, 108 pp.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

DISTRICT H

FINAL REPORT OF MAJOR MINE-EXPLOSION DISASTER
CANE CREEK MINE, POTASH DIVISION
TEXAS GULF SULPHUR COMPANY
GRAND COUNTY, UTAH

(Mine development under contract with
HARRISON INTERNATIONAL, INCORPORATED)

August 27, 1963

by

James Westfield
Assistant Director--Health and Safety
Washington, D.C.

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Subdistrict Supervisor, Salt Lake City, Utah

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Technical Assistant, Denver, Colorado

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INTRODUCTION

This report is based on an investigation made by the writers, who through the Director of the Bureau of Mines were assigned by the Assistant Secretary--Mineral Resources, Department of the Interior to undertake a full scale investigation of the explosion. As part of the investigation, survivors, many employees, and officials were interrogated informally to secure information on the explosion, to ascertain events prior to the explosion, and to learn of practices which might have set the stage for the disaster. This hearing was conducted as a result of a request to the Honorable George Dewey Clyde, Governor of Utah, from Assistant Secretary John M. Kelly, Department of the Interior (see Appendices A, B, and C).

A gas explosion occurred in the Cane Creek mine about 4:40 p.m., Tuesday, August 27, 1963. Twenty-five men were underground at the time; 18 died from the flame, forces, or asphyxiation. Three men erected a barricade near the face of 2 south and died behind it. The other 7 men erected a barricade in 3U drift; 2 of these men left the barricade and traveled to the shaft station where they were met by a rescue crew and brought to the surface at 11:55 a.m., August 28, about 19 hours after the explosion occurred. The other 5 men remained behind the barricade until a recovery crew contacted them and they reached the surface without assistance at 6:30 p.m., August 29, about 50 hours after the explosion. A surface employee received minor injuries and was hospitalized.

The names of the victims, survivors, and the injured surface employee, their ages, marital status, occupations, and number of dependents are listed in Appendices D and E of this report.

Bureau of Mines investigators believe the explosion originated in the shop area where an explosive mixture of combustible gases was ignited by electrical arcs or sparks, open flame, or heated metal surfaces. Forces of the explosion extended to the shaft station, up the shaft to the surface, and throughout the greater part of 2 south and 3U drifts.

GENERAL INFORMATION

The Cane Creek mine, Potash Division of the Texas Gulf Sulphur Company is in Grand County about 20 miles southwest of Moab, Utah, by road, and is reached by paved State Highway 279. The mine is served by the Denver and Rio Grande Western Railroad, and is being developed on State and Federal land.

Officials of the Texas Gulf Sulphur Company are:

Claude O. Stephens	President and Chief Executive Officer, New York, New York
Dr. Charles F. Fogarty	Senior Vice President, New York, New York
Frank E. Tippie	General Manager, Moab, Utah
J. F. Henderson	General Superintendent and Acting Plant Superintendent, Moab, Utah
K. J. Kutz	Mine Superintendent, Moab, Utah
R. J. Ferranti	Assistant Plant Superintendent, Moab, Utah

Officials for Harrison International, Incorporated dealing with the Cane Creek project are:

Nathaniel Harrison	Chairman, Miami, Florida
Patrick Harrison	President, Miami, Florida
Norman Harrison	Project Manager, Moab, Utah
George E. Smith	Chief Engineer, Moab, Utah
A. W. Trenfield	Mine Superintendent, Moab, Utah

The mine is in the development stage and production of ore has not been started. A contract for the sinking of the shaft and driving the development drifts in waste to the ore body was given to the Harrison International, Incorporated, of Miami, Florida, and practically all work being done at the time of the explosion was by the contractor. Likewise, most underground employees were the contractor's. The work schedule was 7 days a week, 3 shifts a day. The average underground employment for Harrison International, Incorporated was 80 men, divided approximately into 30 men on day shift and

25 men each on swing and graveyard shifts. Engineering and maintenance of some equipment was provided by Texas Gulf Sulphur Company. There were many occasions for personnel of the Texas Gulf Sulphur Company to enter the mine, such as for ventilation checks, temperature readings, gas testing, and for collecting other pertinent data. Texas Gulf men worked underground in the shop regularly on 2 shifts daily.

The mine is opened by a circular shaft 22 feet in diameter, inside the concrete lining. The shaft is 2,789 feet in depth; the station is 2,712 feet below the surface. Four sinking buckets, equipped with crossheads and rope guides, were used in the shaft sinking operations and are now used to hoist muck and handle men and materials. Two main development drifts, designated 2 south and 3U and paralleling each other, were advanced about 2,080 and 3,170 feet, respectively, from the shaft station. The 2 south drift was driven downgrade 10 percent from the No. 1 crosscut, a short distance from the shaft. The 3U drift driven downgrade 14 percent is offset slightly but is a continuation of 1 south drift driven 10 percent downgrade from the No. 1 crosscut for a distance of about 360 feet, then level for a distance of 800 feet to the start of 3U which was driven downgrade 14 percent. The face of 3U was within one or two rounds of intersecting the potash bed, which averages 11 feet in thickness and dips 15 percent northeasterly as determined by test drilling.

Strata over the potash bed is variable and consists of salt and various clastics. The floor is salt.

A regular Federal inspection of this mine was made November 28-29, 1961, when the shaft was at a depth of 840 feet. In addition, four separate investigations of fatal accidents were made by Bureau of Mines personnel prior to the explosion.

MINING METHODS, CONDITIONS, AND EQUIPMENT

Mining Methods: Mine projections show that a block system of mining will be followed when the potash bed is reached. Development at the time of this occurrence consisted of driving the two aforementioned drifts, 2 south and 3U. In addition, a ventilation drift was used for a temporary shop and drifts for ore bins and conveyor ways were partly developed (see Appendices G, H, and J).

The presently developed drifts, when driven in salt, were 18 feet wide and 6 feet high on the walls and the back was arched so the center was 8 feet high. When driven in other than salt, the drifts were blasted 17 feet wide allowing for a total of 1-foot sloughing on the two walls. Reportedly, the contractor's plans required that in salt formation the face be undercut its full width to a depth of 1C feet. However, the shift or crew leaders used their judgment concerning depths and widths of the undercuts, rather than follow the stipulated requirements. Undercutting was done only in salt formations.

The salt back was generally self supporting, but rock bolts were used sporadically where necessary. Rock bolts and chain link fencing were installed for support in other than salt back, and steel H-beam arch sets were installed in shales where the back was poor. Rock bolting was as follows: Rock bolt holes, 1½ inch in diameter, were drilled with compressed-air stopers. The bolts were 6 feet in length and 3/4 inch in diameter. Expansion shells were used to anchor the bolts and the bearing plates were 6 inches square by ¼-inch thickness. The bolts were tightened with the stoper. Chain link fence used was 25 feet long by 6 feet wide. The sections of chain link fence were held tight against the back by 3 rows of bolts installed widthwise in the drifts, 7 bolts to the row. The bolts were about 2½ feet apart widthwise and 2 feet apart lengthwise. The chain link fence sections overlapped so that the rows of bolts along the edges caught both sections. Pull tests were not made to test the effectiveness of the bolts nor were torque readings made.

The drifts were developed with mobile loading machines.

Explosives: Blasting was done with 40- and 60-percent dynamite, regular delay detonators, and nonpermissible blasting machines. The detonators were 0 to No. 14 delays with 12-foot long copper leg wires, and the shots were blasted from stations in the drifts. All blast holes were bottom primed, but stemming was not used.

Reportedly, the explosives and detonators were transported from the surface magazines in their original containers to the shaft collar, lowered in the sinking buckets to the shaft station, from where they were transported in Diesel-powered shuttle cars to the storage locations in the various drifts. At times detonators and explosives were transported together.

Explosives and detonators were stored underground in separate recesses along the walls of the drifts, and reportedly underground storage was limited to a 2-day supply. During the investigation, containers of oil and rock bolting materials were stored with the detonators. A wooden detonator box was provided but the lid was open with detonators stacked on the lid. In 3U drift, 2 cases of deteriorated explosives and 3 bags of AN/FO explosives were in the explosives storage area.

According to the contractor's representatives, blasting was about as follows:

When undercutting was done, blast holes were drilled in a pattern about 2½ feet apart horizontally and vertically in the center of the place and at lesser distances between the center and the walls. Blast holes in places that were not undercut were drilled on about 2-foot and 2½-foot vertical centers at the walls and vertical center line, respectively. Horizontally, the blast holes at the bottom and top were about 4 feet apart. Holes were drilled on about 1-foot centers around the four burn cut holes that were drilled in the center of the face. Blast holes were drilled 10-, 8-, and 6-feet deep depending on whether the strata were considered good, fair, or poor, respectively. Blast holes were fired on shift with men underground.

The cycle of mining called for undercutting (when in salt), drilling, blasting, and loading. However, there were times when the blast holes were charged with explosives while undercutting and drilling were in progress. After the explosion, officials of Harrison International stated that all shots not in salt would be fired from the surface when all men were out of the mine.

Ventilation and Mine Gases: Ventilation of the mine at the time of the explosion was temporary, because only one shaft was available and a dividing partition wall was not yet installed in the single shaft. Intake air was directed into the mine by means of metal tubing. Two sets of 3 Joy Axivane, 40-horsepower fans connected in tandem, were located on the surface near the shaft collar and operated blowing. One set of the fans provided intake air for the 2 south drift, and the other set of fans provided the intake air for 3U drift. The intake air was conducted from the fans through 26-inch diameter spiral steel vent tubing extending from each set of fans down the shaft and along 1 south and 2 south drifts, distances of 200 and 325 feet from the shaft station in 2 south drift and 1 south drift, respectively. At these locations, 36-inch diameter corrugated galvanized metal tubing was connected to the 26-inch tubing and extended into 2 south and 3U drifts.

In an effort to increase the amount of air being delivered to inby ends of the tubing, booster fans of the same size as those on the surface were installed in the 36-inch metal tubing at 900- to 1,050-foot intervals. Such installations are conducive to recirculation of air in the event of damage to and/or leaks in the tubing. Such damage and/or leaks in the tubing would occasionally occur in installation and during movement of shuttle cars in the same drift. Two booster fans were installed in the tubing in 3U drift and one such fan was installed in 2 south drift.

Four 15-horsepower Axivane fans without tubing were installed at electric power load center locations to provide a cooling effect on the load centers by forcing air over or by pulling air past them. Obviously, such installations resulted in recirculation of the air.

In addition, a 15-horsepower Joy Axivane fan without tubing was suspended near the back at the beginning of the return air flow through the 3 south shop area to increase air velocity in the shop. To provide a volume of cool air for this fan, compressed air was fed through a 3/4-inch diameter hose into the fan intake and an additional supply of compressed air was released in the shop area through a second 3/4-inch diameter hose. A check curtain was installed in the shop inby the fan, reportedly to prevent smoke from blasting from entering the shop. This check curtain would have made recirculation of air by the fan in the shop inevitable, although shop employees stated the curtain opened somewhat while the fan was operating.

Air readings recorded on a ventilation map by Texas Gulf Sulphur Company were: On August 16, 1963, 14,500 cfm returning along 2 south as determined by smoke cloud velocity tests made about 475 feet inby No. 1 crosscut. The metal tubing extended into 2 south for 1,350 feet inby this point. The end of the metal tubing was about 60 feet from the face and flexible rubberized tubing extended toward the face from that point. On August 19, 1963, 12,500 cfm of air was returning from 3U as determined by smoke cloud velocity measurements made in 3U drift about 850 feet outby the present working face. On August 20, 1963, 15,900 cfm was returning from 3U drift as determined by smoke cloud velocity tests made in No. 1 south about 550 feet inby No. 1 crosscut. The metal vent line was extended to within 125 feet of the face of 3U; flexible rubberized tubing extended from the end of the metal tubing to within 50 feet of the face. Two booster fans were installed in the metal tubing inby the point of the last air measurement.

The temperature readings, recorded in connection with air readings in 3U drift on August 19 and August 20, 1963, were 104° and 100° Fahrenheit, respectively. Temperature readings were not recorded in connection with the air measurement in 2 south on August 19, 1963. Recorded random mine temperatures in 3U drift on August 27, 1963, ranged from 102 to 105 degrees Fahrenheit. A temperature reading of 98 degrees Fahrenheit in the shop was also recorded the same day.

Early during shaft sinking operations, crude oil was encountered, and about 11:00 p.m., on July 31, 1963, four men were burned when combustible gas was ignited in 3U drift. These occurrences were not reported to the Bureau of Mines, but were reported to a state mine inspector. The combustible gas emitted from a rock bolt hole and was ignited when one of the workmen attempted to light a cigarette with the flame from a cigarette lighter; flame flashed throughout the area and flame continued to burn in crevices and the muck pile until the next day. The gas emitting from the hole and muck pile burned until 5:00 a.m., August 1, when the flame was extinguished. It was extremely hot while the gas burned. Following this ignition, examinations for combustible gas were increased, and a "No Smoking" rule was put into effect underground.

Following the July 31 explosion, additional flame safety lamps were issued, but questioning of employees revealed that some had not been properly instructed in the use of these lamps.

Also, tests for combustible gas were made by personnel of the Texas Gulf Sulphur Company, using permissible electric methane testers and permissible flame safety lamps. The results of tests were included in memoranda on the subject "Shift Summary" starting on August 5, 1963. Following are examples of "Methane Reading" notations included in the memoranda:

August 5, 1963 - Methane in 3U: 0.2%
August 6, 1963 - Sequence of methane readings in 3U:

Day shift	0.1%
Swing shift	Blast face at 5:30 p.m.
6:00 p.m.	4.0%
7:30 p.m.	2.0%
10:30 p.m.	0.8%
11:00 p.m.	Nil

During the period August 7 through August 26 gas in amounts ranging from 0.1 to 5.0 percent was found at various locations.

During the recovery work and investigation, tests made for combustible gases by a company official and State and Federal investigators, using permissible flame safety lamps and permissible methane detectors, showed combustible gases ranging from 0.2 percent along 2 south at No. 4 crosscut to an explosive mixture at the face. Combustible gas in the amount 0.2 to 1.5 percent was detected along 3U from its entrance to within about 600 feet of the face. Following the explosion, ventilation was eventually provided by increasing the compressed airflow into 3U and proving compressed airflow into 2 south. This was the only means by which these areas could be ventilated sufficiently to dilute and remove the combustible gases from the mine until such time as the fan ventilating system could be restored and improved (see Table 1, Composition of Mine Air Samples Taken At the Cane Creek Mine After Explosion on August 27 1963, and Table 2, Representative Composition of Hydrocarbon Gases Reported as Total Hydrocarbons in Table 1).

Permissible flame safety lamps were carried by the shift leaders (walkers) of Harrison International, Incorporated after the ignition of July 31, 1963. Tests for combustible gases were made by personnel of Texas Gulf Sulphur Company during and after drilling blast holes. Prior to the July 31, 1963 ignition, a representative of the U. S. Geological Survey had recommended that drill holes 10 to 14 feet in depth be drilled ahead of the face to release gas from the strata or give indications that gas might be encountered, and this recommendation was followed. In addition, a diamond drill test hole 110 feet long had been drilled recently in the face of 3U drift. This test hole was 35 feet ahead of the face of 3U at the time of the explosion. It was stated that on occasions gas released during drilling was of sufficient pressure to blow water out of the hole and on one occasion the gas pressure was strong enough to eject the drill steel--throwing the drilling machine and driller 20 feet up the drift. At times gas was released from fractures in the strata during mining operations. Reportedly, a lighted permissible flame safety lamp was hung in each drift close to the face and was observed occasionally. Apparently, the casual observing of the hanging lamp was considered proper gas testing, and the necessary usual type of gas tests were not made with regularity. Also, a flame safety lamp was suspended in the shop, and the flame of this lamp was observed occasionally and considered a gas test. There were occasions when a flame safety lamp was passed from one crew to another as the shifts changed in the shop and thus was not properly cleaned and serviced.

A broken flame safety lamp found in the shop during the investigation was sent to the Bureau of Mines laboratories in Pittsburgh, Pennsylvania for examination. Part of the findings were: The wick had been turned down to a point where a flame could not be initiated or supported. There was no evidence of charring such as would be expected when the fuel was exhausted in burning. Fuel was available and seemed to be of normal quality as indicated by the appearance of a 1-inch flame when the wick was extended to permit lighting with a match. Flame could not be established with the ignitor. The flame was extinguished when the wick was turned down to the position as found. The conclusions reached on the tests were: From the generally dirty conditions of the lamp and rusty gauzes, the safety lamp maintenance program was poor or the lamp had been abandoned and left in the mine. The position of the wick, the lack of normal combustion deposit on the gauzes, and the amount of gauze rust suggest that this lamp was not in use or burning just prior to the explosion.

Water and Dust: The mine development areas were dry. Water under pressure was piped to the working faces, and reportedly, all drilling when not in salt was done wet.

Transportation: Hoisting of muck and water was accomplished by 4 sinking buckets that ranged in capacity from 71 to 117 cubic feet. Two double-drum hoists were used to hoist the sinking buckets. Each hoist was equipped with Lilly hoist control systems and overwind safety switches. Two sinking buckets, operated in counterbalance by each hoist, were equipped with crossheads which traveled in rope guides. The 1-1/8-inch diameter hoisting ropes were attached properly to the sinking buckets. Compressed-air operated shaft doors and dump doors were provided.

Transportation of muck and materials between the shaft station and working faces was accomplished with Diesel driven shuttle cars. Men were also transported in the shuttle cars. Each car was powered by a Diesel engine rated at 110 brake horsepower at 2,000 rpm and equipped with a 24-volt electrical battery system and starter. The Diesel shuttle cars bore Bureau of Mines Approval Plates 2414. These Approval Plates, as issued, signify that the Diesel equipment had been tested and approved by the Bureau of Mines for operation in nongassy, noncoal mines, as defined in Bureau of Mines Schedule 24; the ventilation requirement stamped on each Approval Plate was 17,100 cfm. The Diesel shuttle cars were not approved for safe use in a gassy mine, as such cars are capable of igniting gas from the electrical components or heating of the exhaust manifold.

Following the explosion, four of these Diesel shuttle cars, Nos. 1, 2, 3, and 5, were inspected as to condition of intake, exhaust, fuel, electrical and crankcase engine systems, and of overall unit condition. Diesel shuttle car No. 4 was inspected for damage to the crankcase only. All Diesel shuttle cars were empty of muck. Exhaust gas conditioners on all cars contained sufficient water for normal operation. Only Nos. 3, 4, and 5 shuttle cars were in the immediate explosion area.

The No. 1 shuttle car, Serial No. 841, was found at the junction of 2U and 3U drifts and appeared to have been parked here as all controls were in "off" positions. All engine systems of this car were normal and the car appeared to be undamaged.

The No. 2 shuttle car, Serial No. 842, was found parked in 3U drift just over the start of the 14 percent grade, approximately 60 feet inby the junction of 2U and 3U drifts. This car was used for transportation by survivors of the explosion before they barricaded themselves and left parked at this location. The car was not damaged and all engine systems were normal.

The No. 3 shuttle car, Serial No. 843, was found on the downslope, 25 feet inby the junction of No. 2 south right and No. 2 south left. The right rear corner of the car was jammed against the east rib, blocking movement down the drift. The directional gear lever was in "low reverse" position and the traveling gear and conveyor levers were in "zero" or neutral position. The emergency brake lever was in "off" position. The light switch, found in the "off" position by the Diesel engineers, was turned off after the explosion by rescue team members. From the position of the front wheels and various objects around the car, it seemed likely that the car drifted against the east rib after the explosion, and from the position of the traveling gear, it seems unlikely that this car was moving under power at the time of the explosion. The engine intake system, exhaust piping, and exhaust conditioner appeared normal and undamaged. The exhaust conditioner contained water although the "make-up" tank was dry. The fill cap of the "make-up" tank was missing and the fill cap cover plate hinge was ajar, a condition that probably existed prior to the explosion. The engine fuel system, crankcase, radiator, and transmission appeared to be in normal condition.

The No. 5 shuttle car, Serial No. 880, was located in No. 3 south, 120 feet west of the shaft, the front or operator's end facing the shaft. This shuttle car had been driven to this location and parked at the beginning of swing shift; overall damage to this shuttle car was extensive; it appeared that most of the damage was caused by the explosion.

The No. 4 Diesel shuttle car, Serial No. 844, was found at the north end of the shop area in No. 3 south. Since this car was in the shop for general overhauling and was not in operating condition, a general inspection of its condition was not made.

Electricity and Compressed Air: Three-phase, 60-cycle power was received at the main substation at 69,000 volts and was reduced to 12,470 volts for distribution to the secondary substations. A delta-wye connected transformer reduced the 12,470-volt power to 4,160 volts for delivery underground.

The primary underground power was received through the shaft to the No. 1 crosscut load center from where it was dispatched to the 2 south, bin area, and 3U load centers. Proper overload and ground fault protection were provided. Secondary power at 480 volts was supplied to the face equipment, fans, and the shop. Multiple conductors and three conductor type G cables were used for secondary power distribution. Power for lights in the shop and shaft area at 110 volts was provided by dry type transformers.

Extensive damage on the cables was not observed except in the shop and shaft area and in the primary feeder to No. 4 crosscut load center, which was dislodged from the back and was on the floor for about 350 feet in 2 south. The No. 1 crosscut load center equipment was completely destroyed.

The frame-grounding conductors of the secondary and primary system were interconnected through the load centers and were carried out to the surface plant grounding medium. Ground fault relays deenergized the equipment in case of ground faults and regular checks were made on the face equipment to ensure the proper operation of the ground fault relays.

Power for the shaft pumps on the 1330 level was received from the surface at 2,300 volts which was also the operating voltage of the pumping equipment on that level; it was reduced on the 1330 level to 440 volts and transmitted to the 1760 and 2200 level pumping equipment. The 1760 and 2200 level pumping equipment was not in use. Power at 110 volts for the shaft signal system was also supplied from the surface to junction boxes on each level to which 4 signal bell knockers were connected.

The electric face equipment in the 3U section was of the permissible type and consisted of one 15RU Joy mining machine, one CD-43 Joy drill, and one 967-LC Goodman loader. In addition, two National Mine Service 60-ED Diesel shuttle cars were provided. Fire-resistant trailing cables, (Type G), were used on the loader, cutter, and drill and were provided with suitable overload protection through circuit breakers installed in face distribution boxes. Examination of this equipment showed one bolt missing from the starter compartment and two bolts missing from the main breaker compartment on the cutter; three bolts missing from the starter compartment of the drill; and an opening in excess of .004 inch in the left headlight between the headlight cover and lens of the loader. The two shuttle cars were examined; however, there was no indication of electrical arcing or burning. Similar face equipment was used in 2 south. Examination disclosed one bolt broken and an opening in excess of .004 inch in the main breaker cover of the cutter; three missing bolts, one broken bolt, one loose bolt and an opening in excess of .004 in the controller cover and openings in excess of .004 inch between the headlight cover and lens on both headlights of the drill; and two bolts broken, two bolts missing and one bolt loose on the starter compartment of the loader.

Permissible type 15-horsepower fans were used to ventilate the load center installations and shop. Nonpermissible type 25- and 40-horsepower booster fans were installed in the vent tubing. Nonapproved type magnetic starters and push buttons were used on the nonpermissible type fans. Permissibility defects were not observed on any of the permissible type fans.

In the underground shop area a permissible type loader and two shuttle cars were being repaired at the time of the explosion. Examination showed that three bolts were broken, one bolt was missing, and there was an opening in excess of .004 inch in the starter compartment of the loader. The No. 4 shuttle car was under major repairs. It was observed that the ground cable for the electric welder was equipped with a piece of reenforcing steel instead of a standard ground clamp.

The forces of the explosion had sheared the bolts in the metal shield that protected the 24-volt batteries of No. 5 shuttle car and it was torn loose. The batteries were electrically connected; however, the top battery was destroyed.

An electric hand-held drill, grinder, several shop tools, including a 50-foot section of oxygen and acetylene hose taken out of service, and parts of the shop panel and battery charger were scattered throughout the shop area.

The shop area had been illuminated with 8 incandescent light bulbs in weatherproof sockets and two outlets had been provided for connecting power tools and extension cords.

During the inspection of the distribution system and equipment, it was noted that the distribution equipment was well installed and that the face equipment, except for the few defects mentioned, was generally well maintained.

Compressed-air for operating stopers, jackleg drills, sump pumps, and air driven fans was provided by compressors located on the surface. These included an Ingersoll-Rand 750 cfm, an Ingersoll-Rand 1,000 cfm, and a Babcock-Wilcox 2,700 cfm. A mobile 600 cfm compressor was used as standby. The compressed air was taken down the shaft through a 6-inch pipe line, and 3-inch pipe lines extended to the face areas in 3U and 2 south.

Oxygen-Acetylene Cylinders and Cutting Torch: Acetylene and oxygen cylinders were found in the shop with gages still attached but damaged. The hoses leading to the cutting torch were torn away at the gages and found at the outby end of the No. 4 shuttle car stretched out under debris. The valves of the cutting torch were found open 2½ quarter turns. The valve wheel on the acetylene cylinder had been blown off, but the valve on the oxygen cylinder was intact. Later when tested on the surface, the acetylene cylinder was empty and the oxygen cylinder contained 1,100 pounds pressure. A small acetylene cylinder with the valve closed and two oxy-acetylene torch ignitors were also found in the area along with other scattered tools. Short sections were cut off the ends of the acetylene and oxygen hoses where they were broken off the gages and these with the damaged acetylene and oxygen gages were sent to the Bureau of Mines laboratories in Pittsburgh for examination. The broken ends of the hoses made reasonable fits with the portion of hoses in the ferrules on the gages. The reports on the tests were summarized thusly: None of the exhibits showed evidence of damage from internal disruptive forces or from overheating by local persistant flame.

Samples of residue scraped from the outside of the oxygen and acetylene cylinders and samples of fine solid material collected in the shop area were sent to the Pittsburgh, Pennsylvania laboratories for tests. The summary of the tests was as follows: Examinations of thirteen samples of materials, brushed or scraped from various locations and equipment in the underground shop area, and two from a flame safety lamp recovered from the mine, were made by chemical, X-ray diffraction, emission spectrographic, infrared absorption, and microscopic methods.

1. The samples principally were a mineral mixture of halite, silicon dioxide (alpha quartz), calcium carbonate, dolomite, and calcium sulphate. Small amounts of magnetic metallic particles and wood splinters were present.

2. All samples contained oil; in amounts ranging from approximately 1 to 21 weight percent.

3. The oil, acetone-extracted and filtered from the solid material, was dark brown-black in color, very viscous, and resembled heavy, oxidized lubricating oil.

4. No evidence was obtained that adsorbed acetylene was contained in two samples of deposits from the acetylene cylinders or in two other samples tested.

5. No evidence was obtained that soot or low density carbon particles were present in the acetone-insoluble residues from any of the samples.

Another oxygen cylinder and another acetylene cylinder were found on the shaft station on the west side of the shaft. The gages were blown off and the valves on each cylinder were found in the shut-off position. The hoses leading to the torch were strung out toward the shaft.

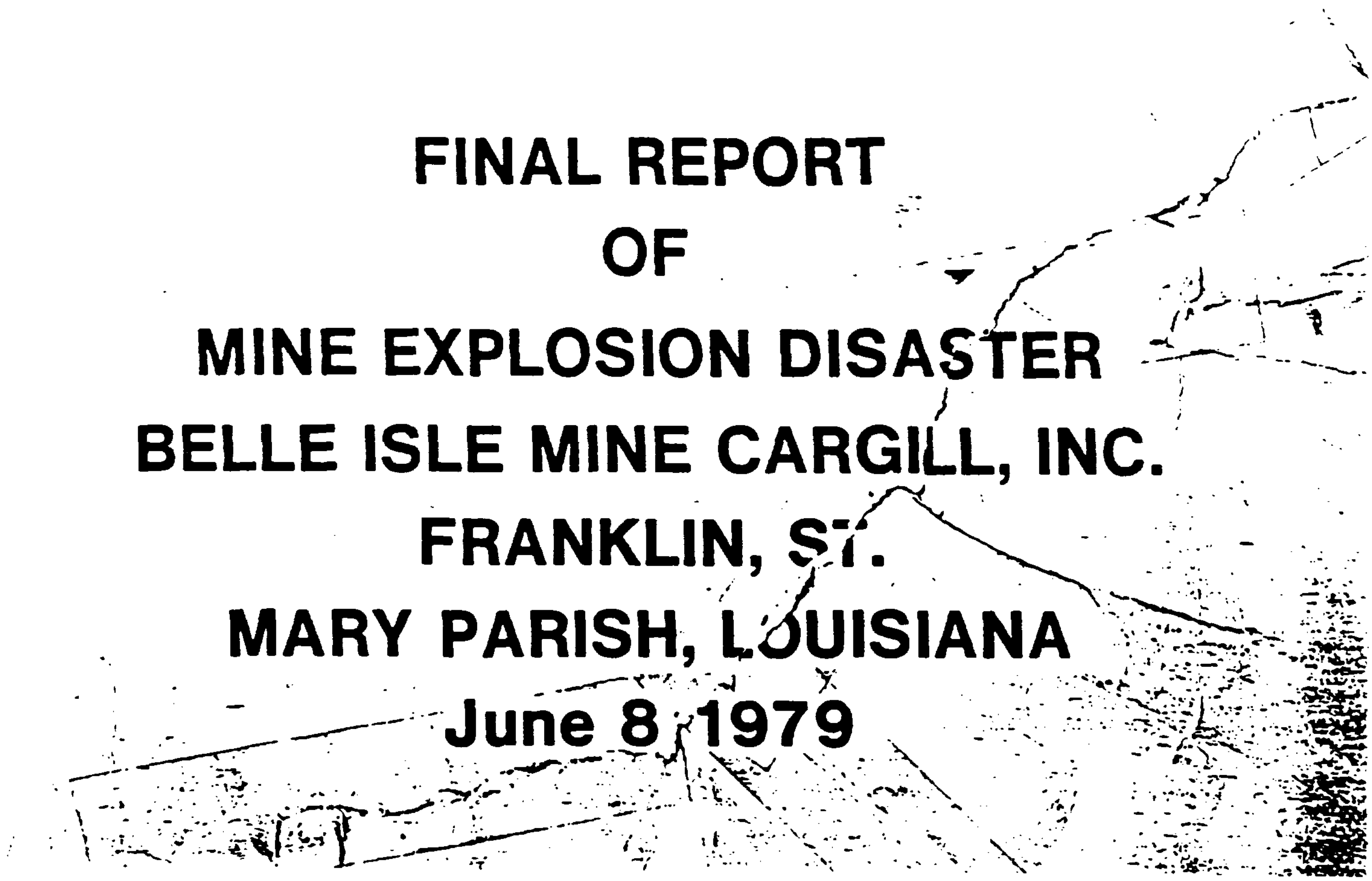
These tests indicate that the combustible gas involved in this explosion was not acetylene.

Illumination and Smoking: The shaft station and shop were illuminated by 110-volt incandescent light bulbs in weather proof sockets. Each underground workman carried a permissible electric cap lamp. Mobile equipment was equipped with headlights.

Prior to July 31, 1963, smoking was practiced freely in the mine; the flame from a cigarette lighter set off the ignition which occurred on this date. Following the ignition, the Industrial Commission of Utah required that smoking in the mine be prohibited and that "No Smoking" signs be posted. Although the "No Smoking" signs were posted, employees were not searched to see that smoking materials were not carried into the mine, and it was quite evident that smoking underground was continued by some persons. Numerous cigarette butts, empty cigarette packages, a book of matches, and other empty match books were found during the investigation in areas driven after the July 31 ignition.

Mine Rescue: The Texas Gulf Sulphur Company maintains a mine rescue station at the mine. Before the explosion, the equipment included 6 McCaa self-contained 2-hour breathing apparatus and spare parts, an electrically driven oxygen pump, 6 Chemox self-generating oxygen breathing apparatus, one permissible mine rescue communication system, a 1,000 foot life line, 6 permissible flame safety lamps, 48 self-rescuers, and 10 first-aid kits. Following the explosion, 10 Universal gas masks and 6 additional permissible flame safety lamps were purchased and used in the rescue and recovery operations. Employees had not been trained as a rescue team.

U.S. Department of Labor
Mine Safety and Health Administration



FINAL REPORT
OF
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BELLE ISLE MINE CARGILL, INC.
FRANKLIN, ST. MARY PARISH, LOUISIANA
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INTRODUCTION

This is an investigation report of a mine explosion disaster that occurred June 8, 1979, at the Belle Isle Mine, Cargill, Inc., near Franklin, St. Mary Parish, Louisiana, MSHA mine I.D. Number 16-00246. The investigation is made pursuant to the provisions of the Federal Mine Safety and Health Act of 1977, Public Law 91-173, as amended by Public Law 95-164 (30 USC 801 et. seq.).

The investigation was authorized by Thomas J. Shepich, Administrator, Metal and Nonmetal Mine Safety and Health, Mine Safety and Health Administration. The purposes of this investigation were: to determine the location and cause of the explosion, including conditions and practices at the Belle Isle Mine that resulted in the explosion: to make recommendations to prevent a similar occurrence; and, to examine the MSHA's related policies and practices.

Briefly, for the reasons set forth in this report, the investigators believe that the underground explosion was initiated in 8 Main Entry East near Room 10 where an explosive mixture of flammable gas was ignited by burning electrical conductor insulation, or arcing electrical wires, or both.

SUMMARY

On Friday, June 8, 1979, an outburst of flammable gases and salt occurred following a face blast in 8 Main Entry East at about 2300 hours, and a gas explosion occurred in the mine approximatel 10 minutes later. At the time of the explosion, 22 persons were in the mine. Ten persons were on the upper level and twelve persons were on the lower level. Seventeen persons were rescued and five persons died as a result of the explosion.

A few minutes before 2300 hours, near the end of the shift, all employees left their working places with the exception of two men who were designated to initiate blasts in three working places charged with explosives. Twelve of the employees attended a scheduled meeting and eight employees were enroute to the No. 1 Shaft to be hoisted to the surface. The blasts were initiated from 7 Main Entry East at Room 13 by the two designated employees, and approximately 10 minutes later the explosion occurred. According to the autopsy reports, four of the fatalities occurred as a result of acute pulmonary hemorrhage secondary to alveolar rupture due to the air blast in the mine explosion. The fifth victim apparently died from a combination of acute pulmonary hemorrhage and carbon monoxide poisoning (See Appendixes C and D). The autopsy report on the fifth victim showed a carboxhemoglobin saturation of 75 percent. Three victims were found within 300 feet of the No. 1 Shaft Station. The fourth and fifth victims were found about 1,400 feet and 1,800 feet, respectively, from the No. 1 Shaft Station. All victims were recovered by mine rescue teams within 41 hours after the explosion. The rescue effort involved 73 dedicated mine rescue team members who assembled from local mines and from around the Nation and involved a total of 14 team entries into the mine in that period of time.

From a position of hindsight, there were a number of significant events which in combination should have established the forewarning of the potential disaster. However, when the events were considered one at a time, on a mine-by-mine basis, the overall significance was overlooked or lost. The multiple indicators of significant gas problems explained hereinafter in this report in the Belle Isle Mine were not adequately correlated by either MSHA or Cargill management.

MSHA'S INITIAL RESPONSE

Charles von Dreusche, Mine Manager, notified Wayne D. Kanack, District Manager, South Central District, Mine Safety and Health Administration (MSHA), Dallas, Texas, at 0030 hours on June 9, 197

EVENTS BEFORE AND AFTER THE EXPLOSION

During the day shift of June 7, 1979, the face in Room 14 south of 7X Entry East was drilled in preparation for blasting. During the investigation MSHA investigators were informed by Cargill employees that methane had been released from these blastholes. The face was charged and blasted at the end of the evening shift. A methanometer was not available underground for use by the evening shift.

Two miners were assigned to pick up blasting lines in Room 14 at the beginning of the day shift on June 8. Upon arriving at Room 14, they heard an audible gas emission and observed characteristic cone-shaped blown-out pockets in the right side and upper left-hand corner of the face. The audible emission was coming from the center of the left blown-out pocket and was described as sounding like air coming out of an inner tube. The sound could be heard above the noise created by a nearby ventilation fan. A short time later, John McFarlain, the individual assigned to monitor gas emissions, arrived and obtained methane readings sufficiently high to warrant withdrawal of employees. The heading was placed off limits, smoking and open flame restrictions were established, and ventilation adjustments were made in an attempt to dilute the methane in the face.

The face of 8 Main Entry East to the east of Room 13 was drilled. The drilling was toward the projected intersection of 8 Main Entry East and Room 14, where the gas was emitting. Approximately 48 feet of salt separated the two advancing faces.

Shortly before the end of the day shift an electrical fire occurred in an auxiliary fan motor and cable located south of the shop area in 2 Main Entry South. A mine evacuation was underway when it was determined that the fire was minor and brought under control. Employees in the vicinity of the fire had evacuated to the No. 2 Shaft station. Some employees assigned to remote sections of the mine failed to receive notifications and remained in their work areas.

Elray Granger, General Mine Foreman, and A. J. Boutte, Shift Foreman, assigned to the evening shift, met with day shift management at approximately 1530 hours on June 8, 1979. This meeting concerned normal production activities and it was reported by the participants that there was no mention of the methane gas emissions, as noted above, in the east area. Despite the presence of flammable gases in this area, mine personnel did not monitor for concentrations of these gases. Methane detection equipment was not available in the mine during the evening shift. Normally, shift personnel did not sample for methane or other flammable gases during the evening shifts, but relied solely on sampling done during the day.

Employees of the evening shift were assigned their regular duties of hauling salt from lower level production areas to the crusher, drilling, undercutting and charging blastholes in the faces and floors in the upper level East area. Sometime after lunch, diesel emission accumulations from the haulage equipment caused the production crew to leave the lower level and begin hauling salt from headings on the upper level. The crew hauled salt from Room 14 south off 7X Entry East where the gas emission had occurred during the day shift. Another crew drilled floors in Room 14 south of 6 Main Entry East and Room 11 north of 8 Main Entry East, and undercut the face in 8 Main Entry East at Room 13. After the drilling and undercutting was completed, the three rounds were charged by the undercutter and drill operators with assistance from haulage personnel and Shift Foreman Boutte.

At approximately 2250 hours, eleven employees assembled at the bottom of the lower level manlift, off 1 Main Tunnel South, for a scheduled meeting. Two additional employees, Adam Sampay and Amedee Olivier (victims), returned to detonate the three charged rounds from the blasting board at 7 Main Entry East, Room 13. Eight other employees, including victims Zimmerman, Collins and Mayon, were on the upper level preparing to leave their work areas at the end of the shift.

As A. J. Boutte stepped out of the underground operations office on his way to conduct the meeting, he heard one of the scheduled blasts and assumed it was the floor round in Room 14 off 6 Main Entry East. A. J. Boutte proceeded to the manlift area and conducted the meeting for approximately seven minutes. Just as he finished the meeting about 2308 hours, a larger explosion was heard followed almost immediately by extreme concussion and strong winds, which rapidly rose to destructive levels. The explosion forces and winds destroyed or damaged equipment and fixtures throughout the mine and caused injuries to some of the 11 miners at the meeting.

At the time of the explosion, A. J. Boutte was kneeling on the front seat of his production truck with his back to the steering wheel talking to the men. Ten employees were seated on benches in the bed of the production truck. Alton Oppenheimer was standing along-side the passenger side of the production truck, which was a 3/4-ton open cab military-type Jeep. Some of the men were knocked down by the forces of the explosion.

It was extremely dusty and visibility was zero due to the hurricane like winds. A. J. Boutte became separated from the 11 employees.

A. J. Boutte took the escape route south on 1 Main Tunnel South and through the first set of corrugated culverts to the Airway Tunnel, which led to the No. 2 Shaft. At the Airway Tunnel, A. J. Boutte was blown approximately 30 feet down the tunnel toward the No. 2 Shaft by an increase in wind velocity. Due to the extreme heat and high wind in the Airway Tunnel, A. J. Boutte decided to crawl back to the corrugated culverts and cross over 2 Main Tunnel South. At this time visibility was zero in 2 Main Tunnel South, but the wind was not blowing as hard as in the Airway Tunnel and the extreme heat was not present. A. J. Boutte was disoriented and confused while going up the equipment ramp. He fell down, stumbled, weaved from side to side and bumped into various objects in the travelway. A. J. Boutte was confused and thought he was lost until he heard Peggy Blaney screaming. As he walked toward the screaming sounds and made contact with Peter Boutte and Perry Thompson, who were enroute to the No. 2 Shaft. A. J. Boutte advised them about the extreme wind and heat in the Airway Tunnel to the No. 2 Shaft and stated that the intake air appeared to be coming down the No. 1 Shaft at this time, rather than the No. 2 Shaft. The three men started toward the No. 1 Shaft. A. J. Boutte found Peggy Blaney, who kept screaming that she was burning and on fire. Blaney was dragged part way and eventually crawled the rest of the way to the No. 1 Shaft.

Floyd Linton had followed A. J. Boutte to the corrugated culvert but then returned to the other ten employees at the manlift. Linton, who was trained in mine rescue. suggested that all the miners join hands and try to make their way through the escape route to the No. 2 Shaft (See Appendix O). Hurricane-like wind made the travelway extremely dusty and visibility was zero. The miners had trouble breathing and the dust caused them to choke and cough. The temperature increased considerably. The 11 miners moved slowly south through 1 Main Tunnel South to the corrugated culverts and proceeded north in the Airway Tunnel toward the No. 2 Shaft. The miners were subjected to intense heat but there was no evidence of fire in the Airway Tunnel. The air movement at the No. 2 Shaft appeared to have reversed from intake to exhaust because the main fan which was located underground was destroyed by the explosion. The miners again had trouble breathing. All of the miners were carrying self-rescuers but no one used them.

Floyd Linton climbed on top of a salt stopping by the fan located in the Airway Tunnel and advised the others that the air was better at that location. The other miners climbed up and joined him. A cloud of smoke came toward them and they decided to move toward the No. 2 Shaft. The 11 miners arrived at the No. 2 Shaft at approximately midnight. Several of the men sat on boxes of explosives which were stacked on pallets approximately 50 feet from the No. 2 Shaft. There were an estimated 350 fifty-pound boxes of explosives at this location. One of the miners began hitting the No. 2 Shaft station gate with a short piece of pipe in an attempt to let the people on the surface know that they were alive. The mine phones and the cords used to signal between the mine level and the surface were blown out. Audio and visual communications eventually were made with the surface by shouting and use of cap lamps.

Immediately after the outburst, shot-firers Sampay and Olivier (victims) abandoned their vehicle near the blasting board at 7 Main Entry East Room 13, and moved on foot toward the shaft. Sampay was found approximately 3,300 feet from the vehicle in 2 Main Entry West at Section 1. Olivier had traveled about 2,600 feet and was found in 1 Main Entry South, adjacent to Section 4 (See Appendix P).

Five of the remaining eight employees on the upper level were enroute to the No. 1 Shaft to be hoisted to the surface at the end of the shift. Herman Zimmerman (victim) was riding in a jeep-type vehicle in 1 Main Entry South when the explosion forces knocked the vehicle out of control. The vehicle came to rest with the rear half hanging over the edge of the P-39 conveyor decline and Zimmerman fell about 30 feet to the floor of the decline on the east side of the conveyor. Jason Mayon, the driver, remained behind the wheel during the explosion but as he got out of the vehicle he also fell onto the conveyor and received back injuries.

Perry Thompson and Peter Boutte were riding on a small tractor-like "boss buggy" some distance behind Zimmerman and Mayon, and although one of them was blown off the vehicle, neither man received a significant injury. These two men made voice contact with Jason Mayon and the three men walked the short distance to the No. 1 Shaft Station. Eldridge Roman, the tunnel conveyor operator, who was working alone in the 1 Main Tunnel South area, also arrived at the No. 1 Shaft slightly injured.

The telephone by No. 1 Shaft Station was broken, so Mayon and Roman went to the tunnel to use the telephone, but it was also out of order. Parts from this phone were used to repair the phone at the No. 1 Shaft Station. A. J. Boutte then phoned Elray Granger who was on the surface and related the location of the six employees at the No. 1 Shaft Station.

Prior to the explosion, three employees were sitting in a vehicle adjacent to the No. 1 Shaft Station while waiting for the end of the shift. This vehicle was blown from the shaft area into 2 Main Entry South. Donald Mayon and Richard Collins died from the explosion forces and Peggy Blaney was injured seriously.

General Mine Foreman Elray Granger had been underground throughout the shift but had returned to the surface around 2300 hours via the No. 1 Shaft. Granger proceeded to the mine office which was adjacent to the No. 1 Shaft collar. About 10 minutes later, Granger heard the underground explosion and ran outside the mine office. He stated that the sound of the explosion first started faintly and then grew louder and louder until it reached a peak and held for several minutes. Granger stated that the sound was like five freight trains and was coming out of both the No. 1 and No. 2 Shafts along with dust, smoke and debris. Granger ran back into the mine office and phoned Charles von Dreusche, Mine Manager, at home to report the explosion. Granger then went to the No. 1 Shaft collar with Terry Hebert, Topside Foreman, where they found the mancage a few feet above the collar and a great deal of debris and loose power cables around the collar area.

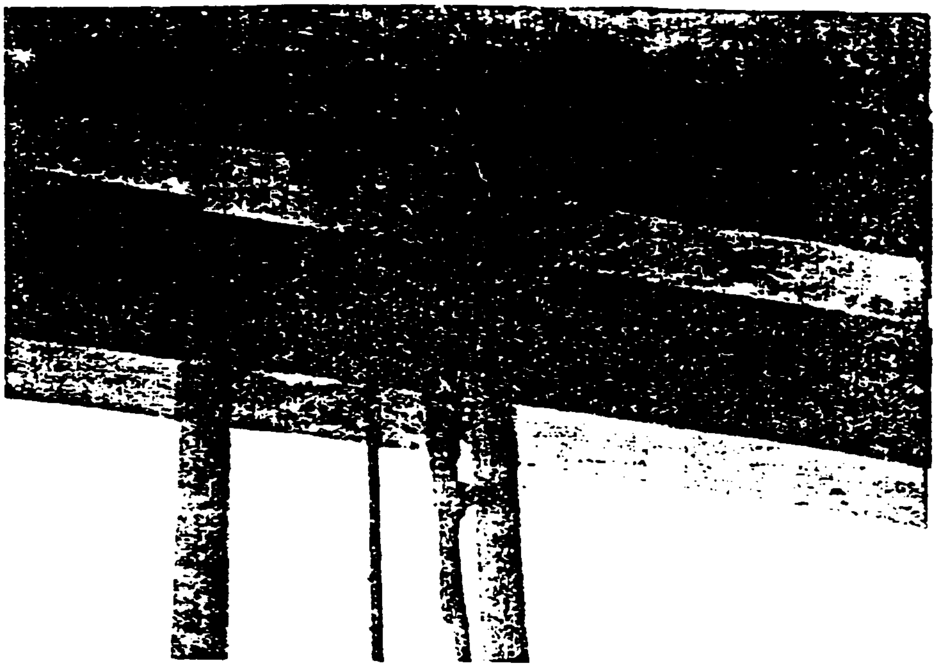
Granger and Hebert decided to clean up the area and to send the cage down to the mine level with a communications radio aboard. While they were doing this, the mine phone at the headframe rang. Granger answered and talked to A. J. Boutte who was at the upper level shaft station with five other people. Boutte reported that Zimmerman, Donald Mayon and Collins were dead and that he thought the rest of the employees also were dead. A. J. Boutte called again asking the surface to hurry because he could see "the bad air coming". About five minutes later, or approximately 2340 hours, the No. 1 Shaft collar was cleared. The cage was lowered, and the upper level survivors -- A. J. Boutte, Eldridge Roman, Peter Boutte, Perry Thompson, Jason Mayon and Peggy Blaney -- were hoisted to the surface. The empty cage was then returned to the mine level with a radio on board in case other survivors reached the Shaft Station.

At the time of the explosion, the No. 2 Shaft conveyance also was at the collar. The explosion forces lifted the cage to the top of the headframe where the safety dogs engaged because of the slack rope. The cage was lodged in the upper part of the headframe. Clyde McKay, No. 2 Shaft Hoistman, heard pounding signals and other noises from the bottom of the No. 2 Shaft at approximately 0045 hours, June 9, 1979. Efforts were then concentrated on clearing the No. 2 Shaft conveyance to effect the rescue of the miners at the lower level Shaft Station.

The cage was lowered, but it became "hung up" at 500 feet and also at 700 feet below the shaft collar on steel plumb lines left from the shaft-sinking operations which were entangled with all four guide ropes (See Appendix NN). The cage was raised and dropped several times until the obstruction was cleared, and then the cage was lowered to the 11 men -- Al Thompson

Alton Oppenheimer, Floyd Linton, Charles Verdun, Joseph W. Boutte, Girault Frilot, Joseph Buttler, Brian McFarlain, Prentis Shaw, Esau Mitchell and Lenneth Hill -- who were at the lower level Shaft Station.

These miners reached the surface at approximately 0245 hours on June 9, 1979. All 17 survivors were transported by helicopter to the Franklin Foundation Hospital in Franklin, Louisiana. At the time, five miners were still underground, one had been determined to be a fatality and the location of two other miners was known and it was believed that they were fatalities. The location and condition of the remaining two miners were not known.

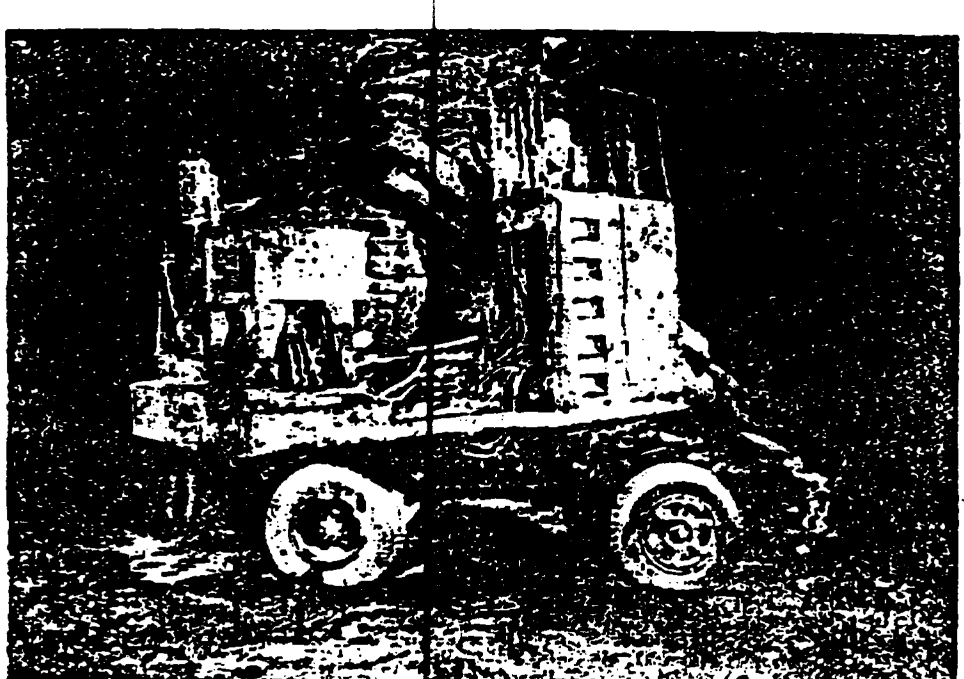


View of rope damaged when cage was blown to the top of No. 2 shaft headframe.

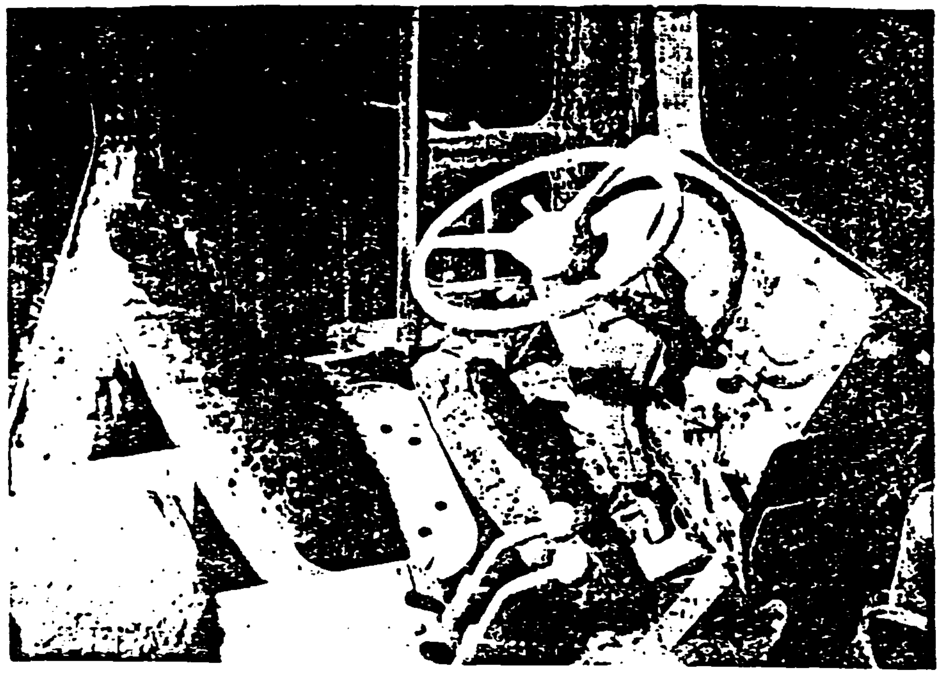
Plumb line and signal wire pulled up from No. 2 Shaft sump. Rope around the cage in the headframe and around the cage guide rope delayed recovery of survivors.

APPENDIX NN

Viewing east or inby side of the Gradall scaler along south rib at 8 Main Entry East at Room 11. Paint does not show heat deterioration.



Viewing the west or outby side of the Gradall. Paint shows heat deterioration and a heavy salt encrustation from a high, hot wind moving east is evident.

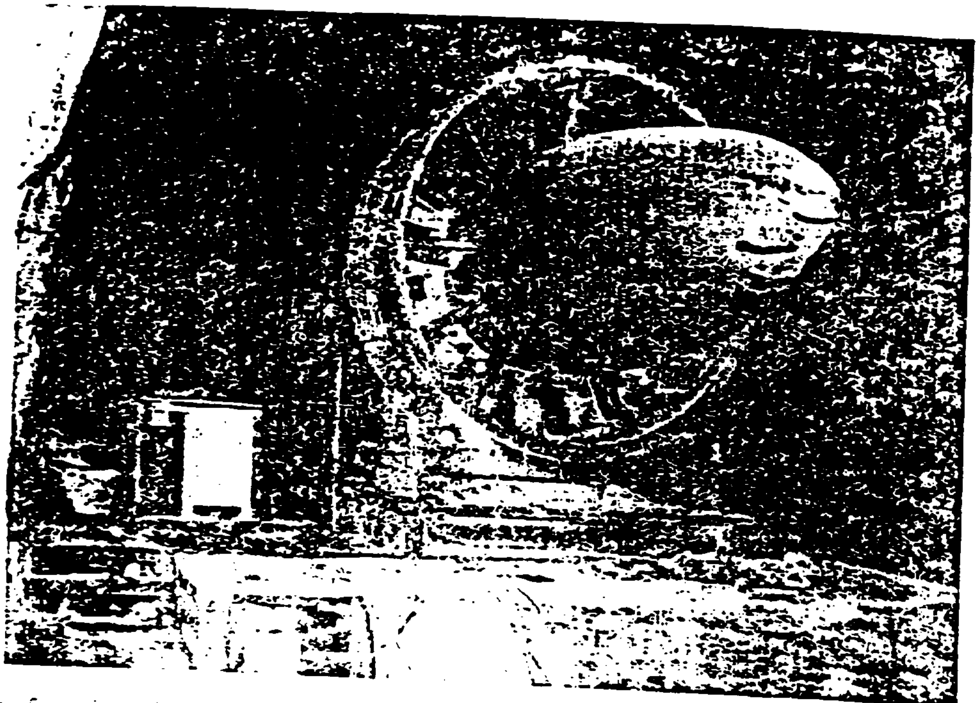


Heat damage in cab of the Terex loader at 7X Entry East and Room 10 lower level Vinyl seat covering burned off, leaving edge - scorched foam.

Rear recapped tires showing chars and salt on Terex loader at 7X Entry East and Room 10 lower level.

Viewing west from 2 Main Entry South just west of No. 1 shaft station. Overturned cart at the right was one in which two victims and one survivor were riding.

Viewing north to south from the P-39 belt line decline in 1 Main Entry South survivor and victim were riding in the Jeep shown overhanging the decline cu .

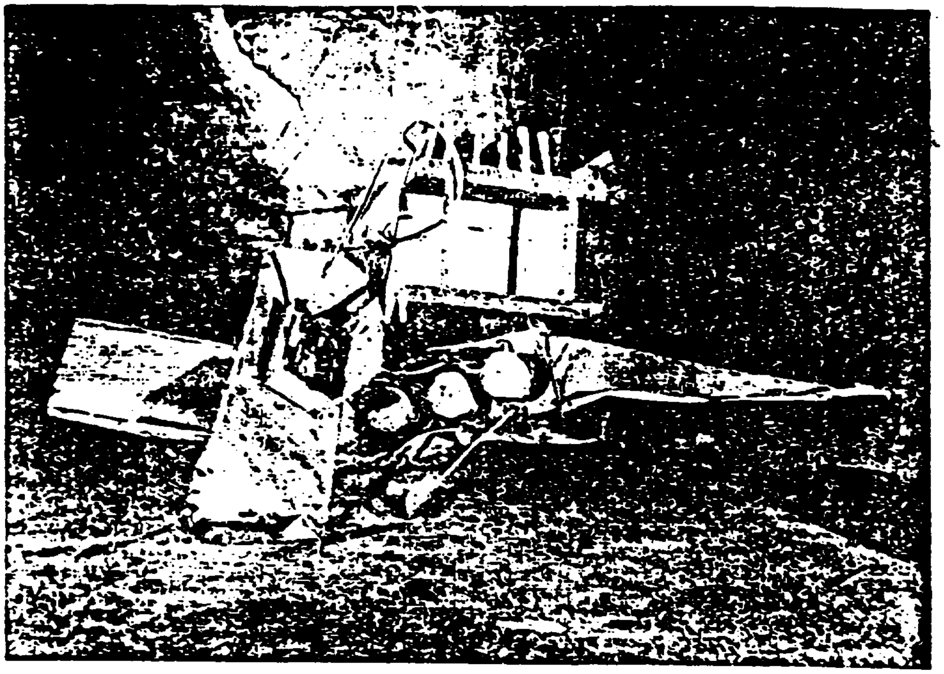


Main fan in airway tunnel south of No. 2 shaft. Portion of the metal fan bulkhead found in No. 2 shaft sump.

Remnants of free-standing fan originally in No. 2 Main Entry South, south of 7 Main Entry East, blown north to between 4 and 5 Main Entry East in 2 Main Entry South.

1975 blowout in 7 Main Entry West Room 4.

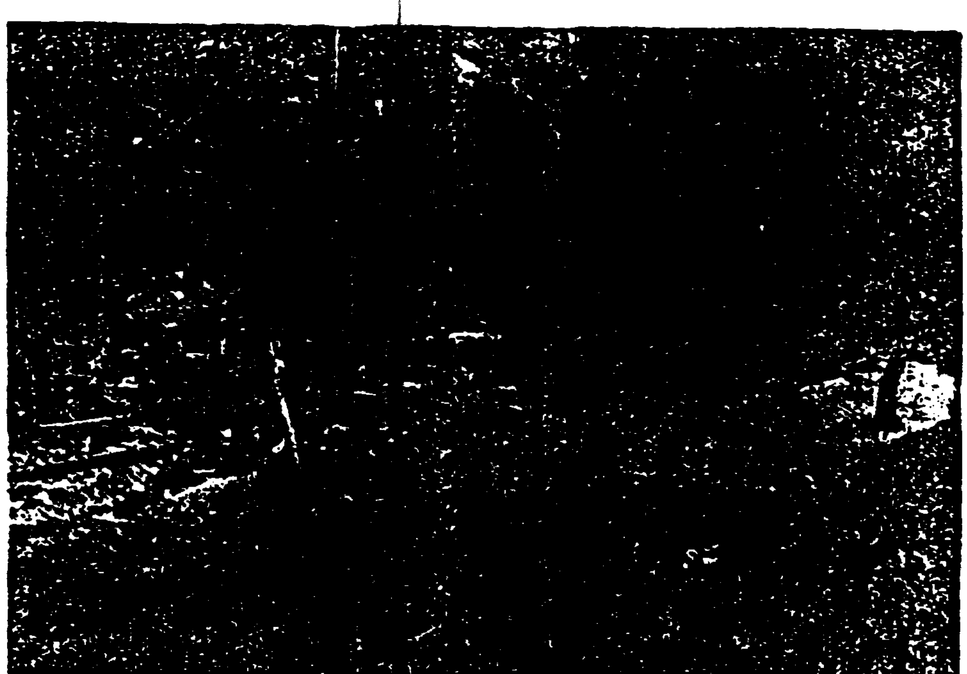
Viewing south from 7X Entry East at outburst salt piled in Room 13.



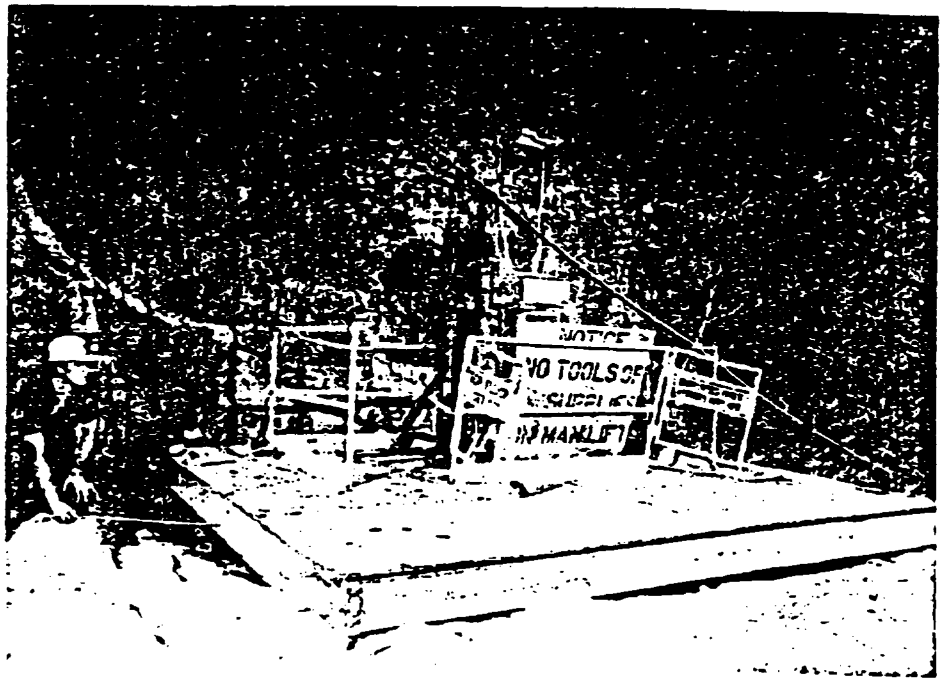
Transformer blown west from 1X crosscut east of 2 Main Entry South into middle of 2 Main Entry South.

Viewing north at damaged maintenance office and parts room in 2 Main Entry South, north of 1X crosscut.

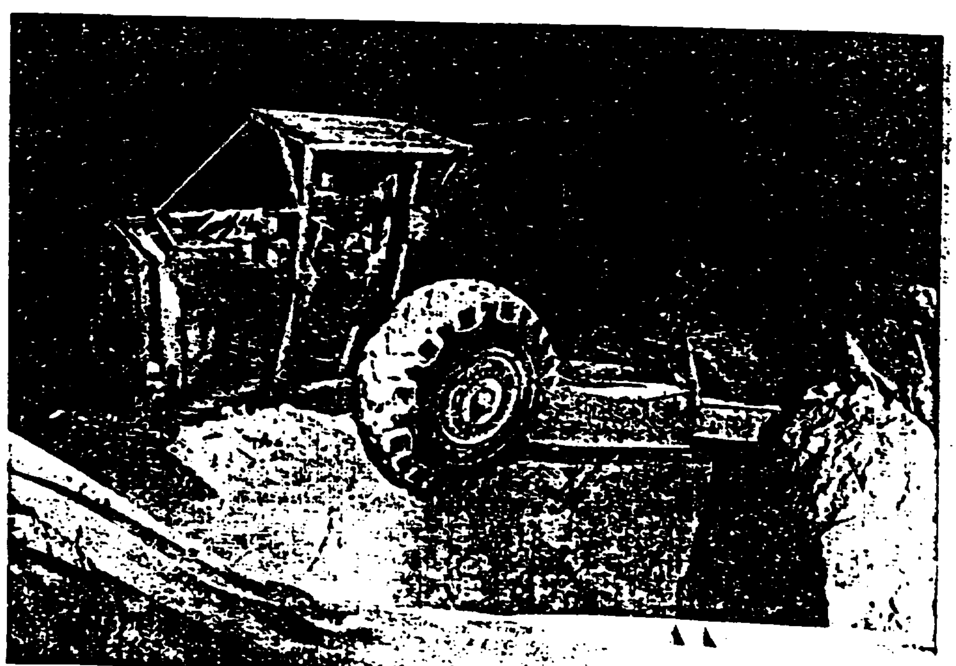
Truck at 2 Main Tunnel West of 1 Main Tunnel South in which the 11 men were sitting and one standing for the safety meeting.



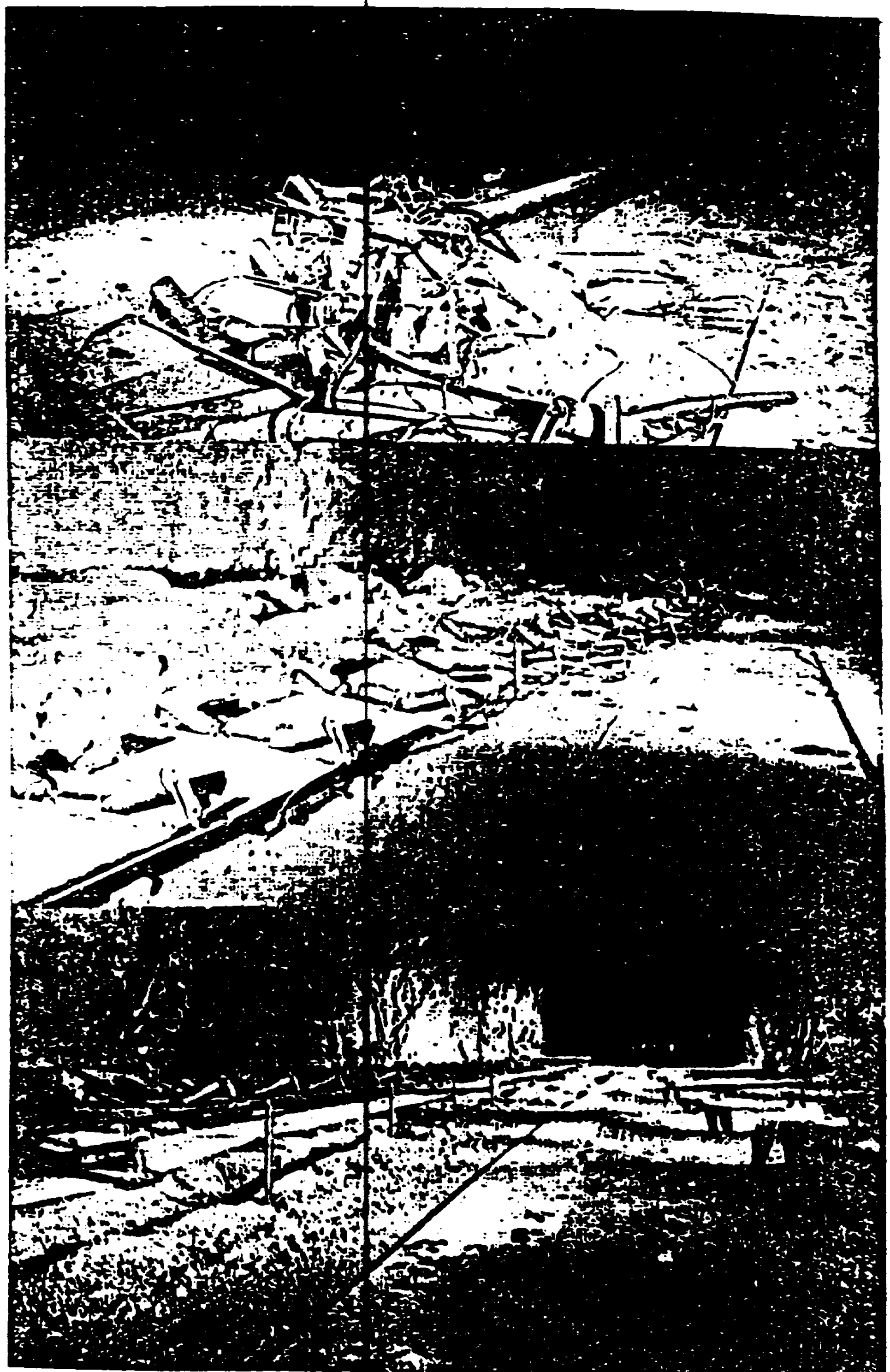
Pictures at the same location as above. Manlift escapeway in background with wood debris from cabinets.



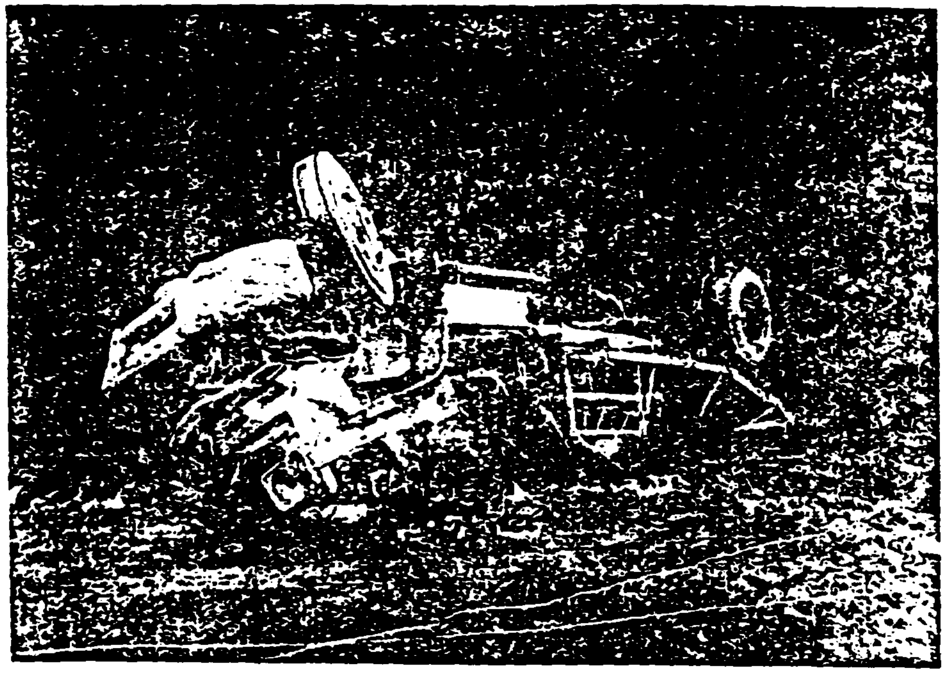
Top of manlift at 2 Main Entry East just west of 1 Main Entry South. Entire frame moved to the west 2 feet.



Terex truck in 1 Main Entry South moved north by the explosion into the reclaim bin located just north of 2 Main Entry East.



Pictures show the decay of the explosion forces as they moved north in 1 Main Tunnel South. Conveyor system in 1 Main Tunnel South. Upper picture shows complete destruction of the conveyor just north of the primary crusher between 5X crosscut and 5 Main Entry East. The middle picture shows partially dam conveyor north of 5 Main East and the lower picture shows the conveyor just south of 3 Main Entry East.



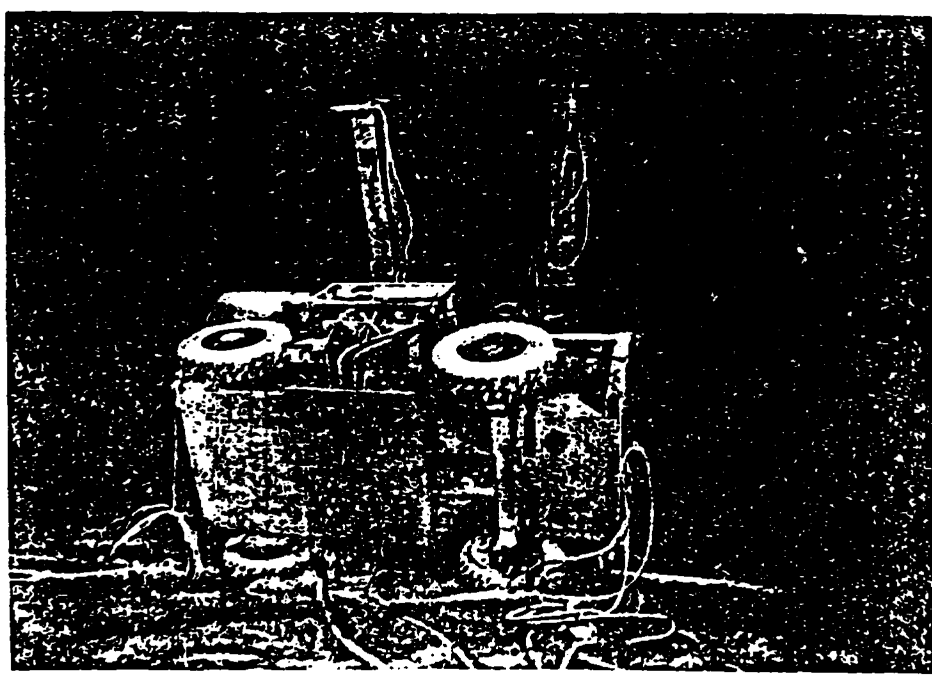
Turned over red shop truck. Picture taken viewing the truck from the south. Truck was located in 7 Main East Entry just west of Room 13.

Turned over core drill in the southeast corner of Room 2 cutout just south of 9 Main Entry East.

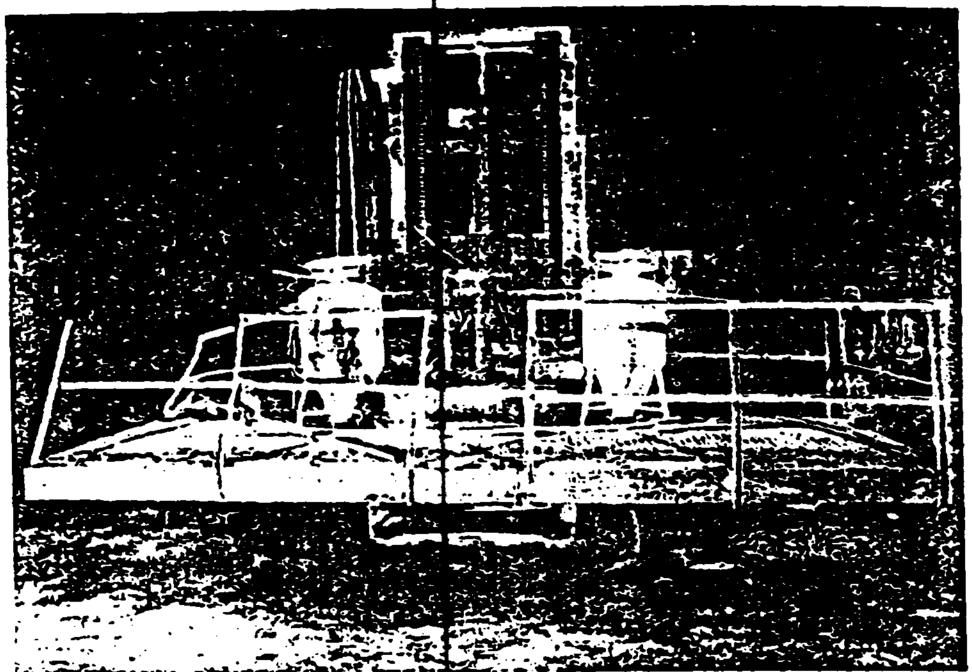
Negative terminal on overturned maintenance shop truck in 7 Main Entry East and west of Room 13. The terminal exhibited that lead had melted.

Pinched positive conductor on overturned truck. Bare copper wire exposed.

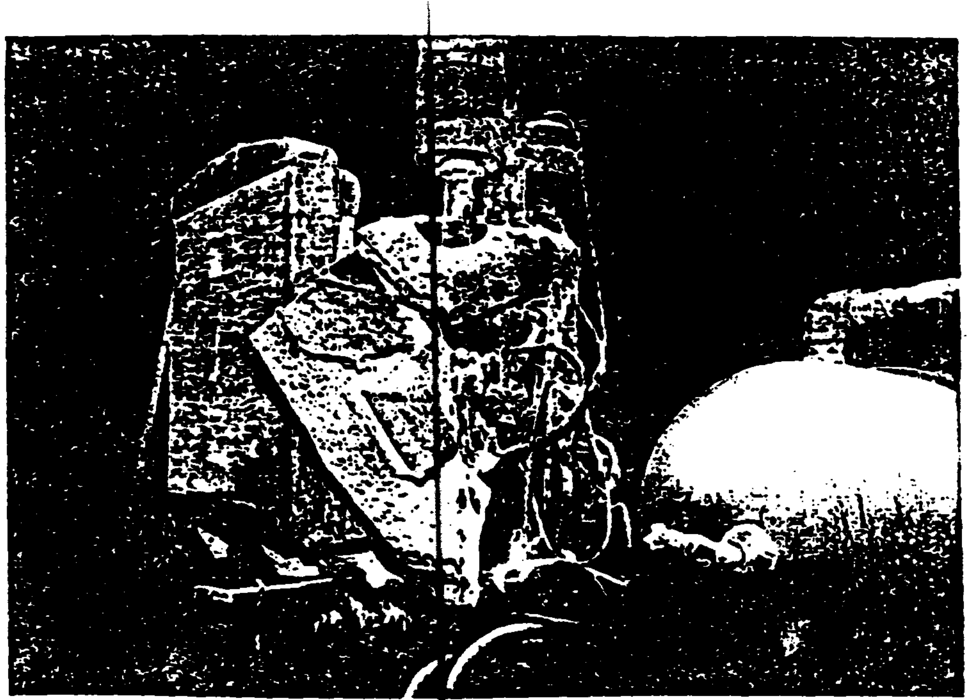
Viewing to the southwest at the face drill located at the southeast corner of 7X Entry East and Room 13. Drill was blown 50 feet to the southeast.



Viewing southeast at the bottom side of the face drill above.

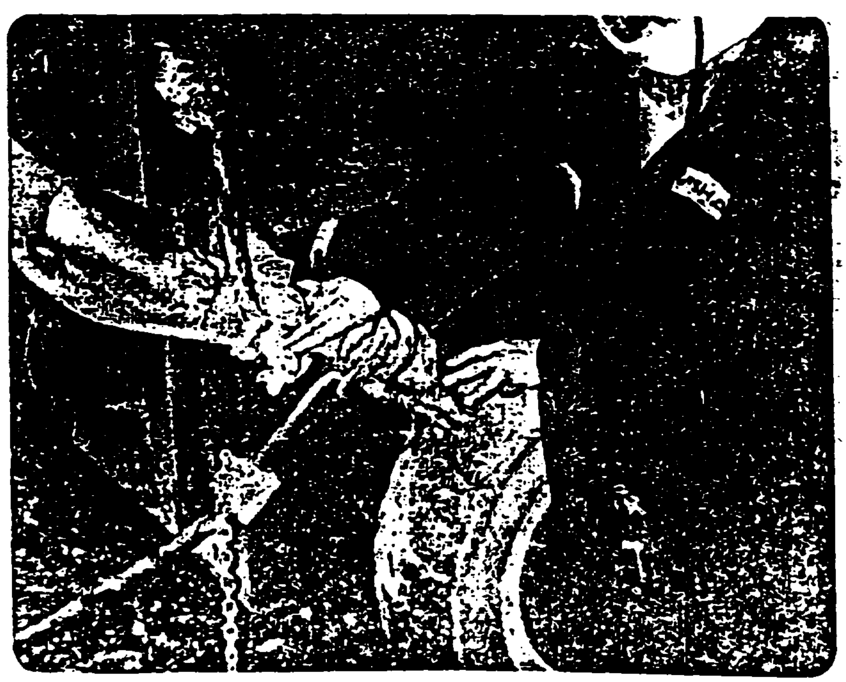


Explosives loading Jumbo facing south. Located just north of 8 Main Entry East along the east rib at Room 12.

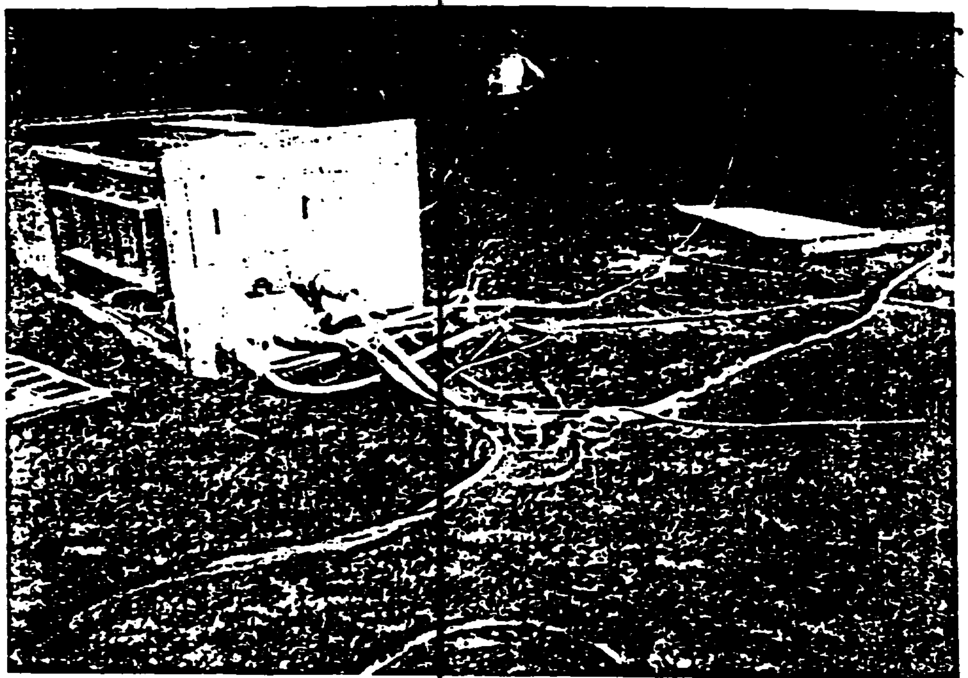


Portable blasting board impaled on south side of engine of loading Jumbo. Board was located between Rooms 11 and 12 in 8 Main Entry East before the blast and distributed power to the 8 Main East face shot and bench shot at Room 11X.

Viewing floor drill at northeast corner of 7 Main Entry East and Room 14. Boom bent away from normal vertical position. Hydraulic unit on left side badly damaged and pushed to the east. Electric cable on right side pulled apart.

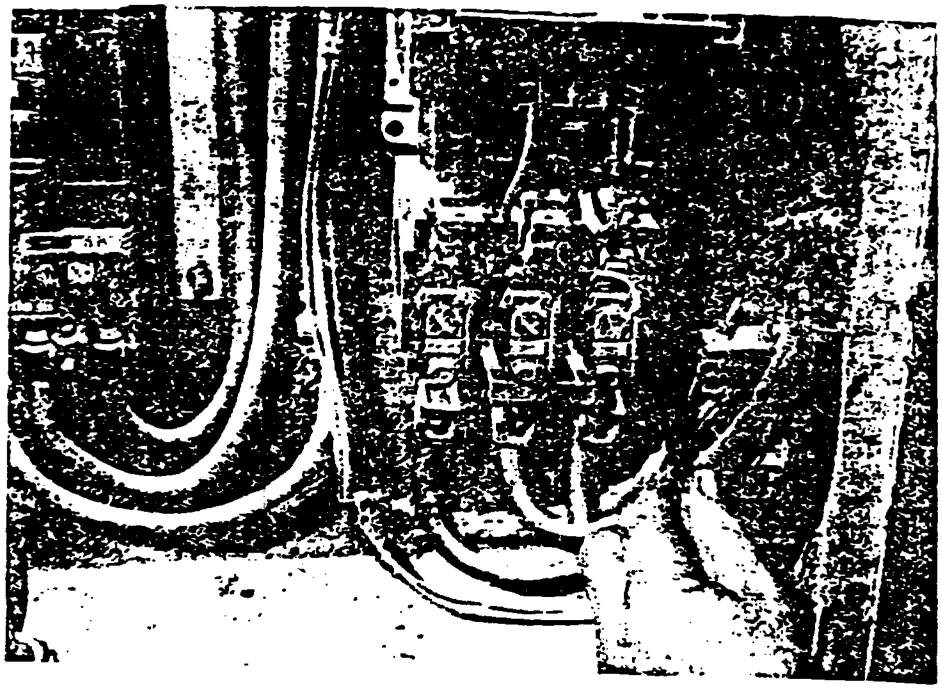


Close-up view of parted cable.

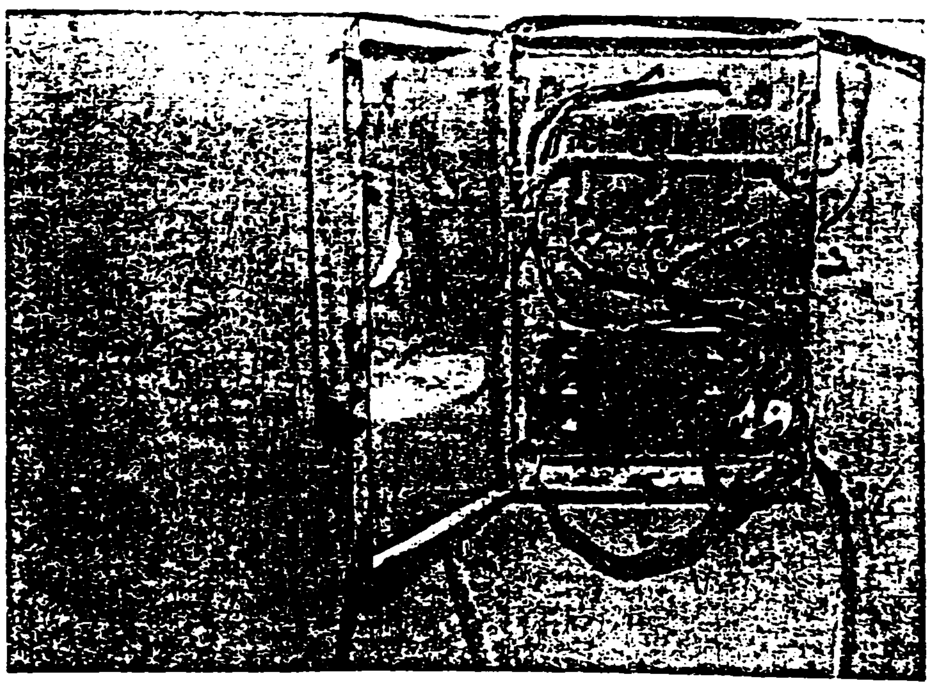


Viewing northwest at No. 2 portable load center located just south of 7 Main Entry East in Room 13.

East end of the No. 2 portable load center with cables coming from nips.

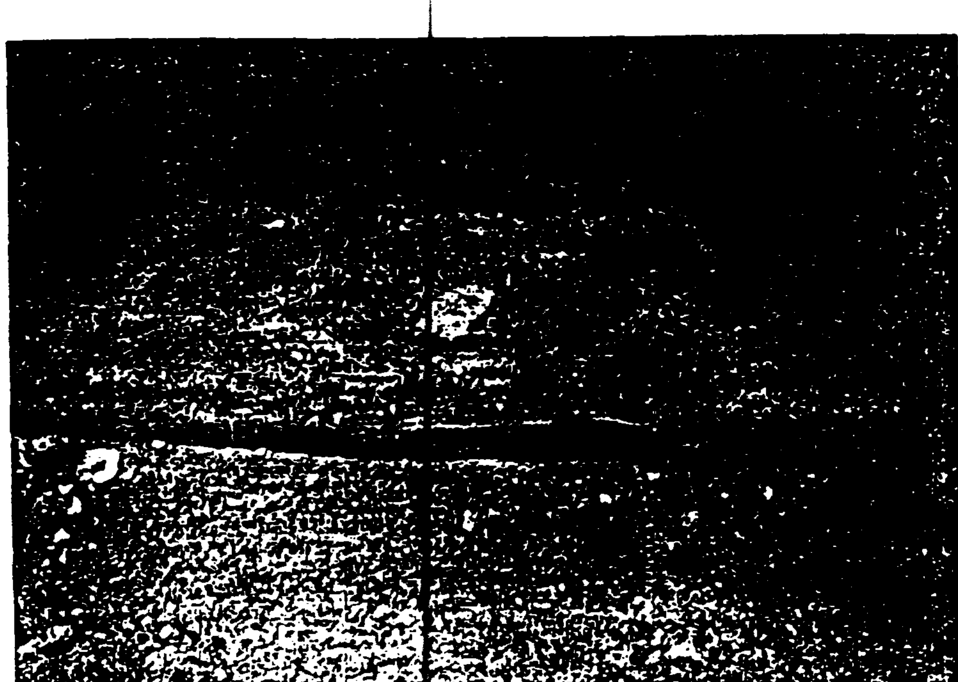


Joy fan circuit-breaker at 8 Main Entry East and Room 9. The overload heaters jumpered out and breaker in "on" position.

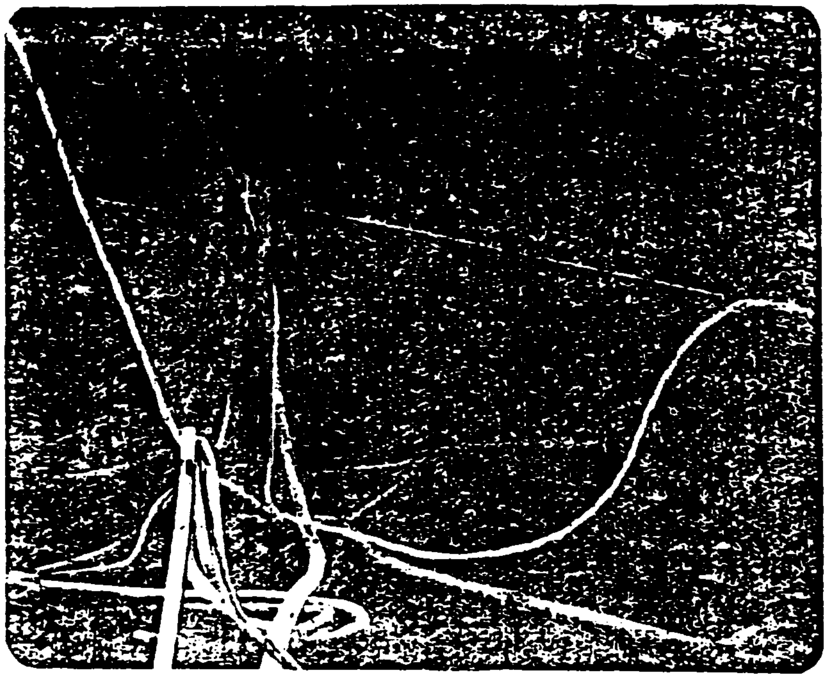


Metal enclosed safety switch and circuit-breaker on west end of portable load center No. 2 at Room 13, 7 Main Entry East. The breaker was part of the shooting board circuit and the ground wire showed heating while other wires do not. Wooden handle intact with no burning.

Damaged 4160 V cable blown north from roof in 7 Main Entry East into intersection of Room 12.

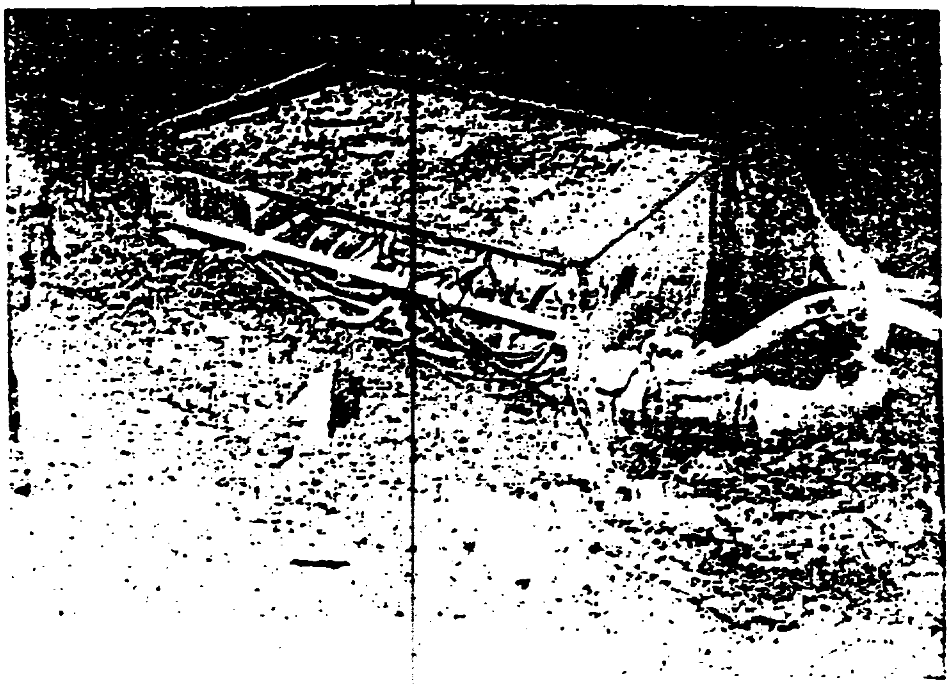


Spliced 4160 V cable in 7 Main Entry East just west of Room 10. Unshielded cable at the left shows more heat deterioration than shielded cable to the right.



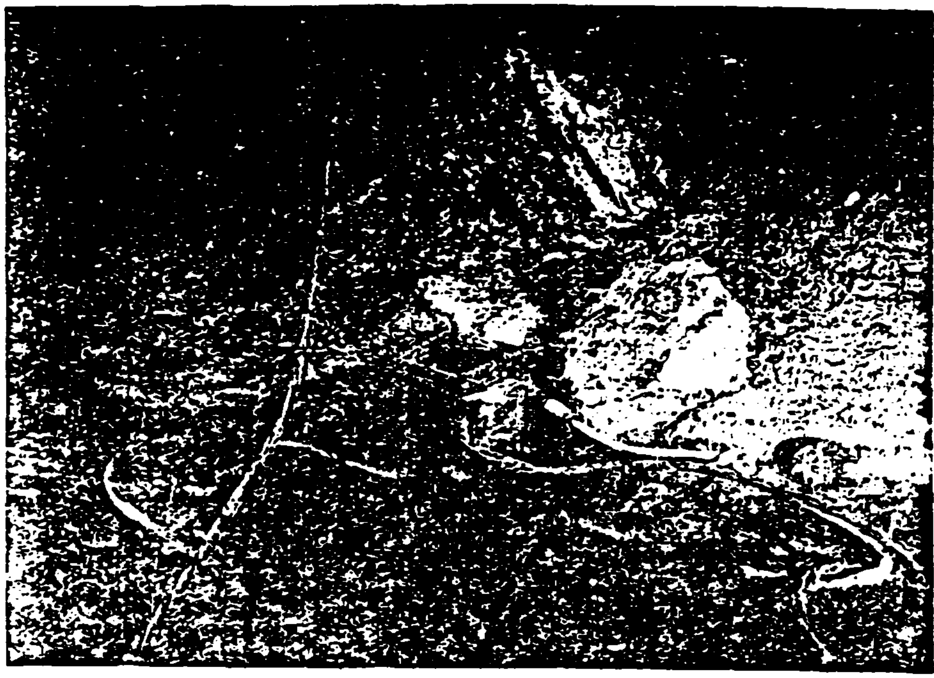
Entangled electric cables blown from the roof at 7 Main Entry East Room 13.

Burned wires at base of turned over face drill at 7X Entry and Room 13.



Damaged distribution box at 7X Entry and Room 12.

Damaged distribution box at northeast corner of 7 Main Entry East and Room



Junction box at North rib line of 8 Main Entry East near Room 11. Ty S.E. cable from roof had badly burned insulation.

Joy coupler destroyed by fall of ground on lower level at 7X East and Room 8.

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Mine Safety and Health Administration
Arlington, Va. 22203

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Exploration

2

BEFORE THE

Oil Conservation Commission

SANTA FE, NEW MEXICO

April 20, 1955

IN THE MATTER OF:

CASE NO. 862 - Regular Hearing

TRANSCRIPT OF PROCEEDINGS

ADA DEARNLEY AND ASSOCIATES

COURT REPORTERS

ROOMS 105, 106, 107 EL CORTEZ BUILDING

TELEPHONE 7-9546

ALBUQUERQUE, NEW MEXICO

BEFORE THE
OIL CONSERVATION COMMISSION
Santa Fe, New Mexico
April 20, 1955

IN THE MATTER OF:

Application of the Commission upon its own motion for an order (a) creating the North Benson-Queen Oil Pool in Eddy County, New Mexico, described as follows:

Township 18 South, Range 30 East
E/2 Section 33; W/2 Section 34

and (b) prescribing rules and regulations pertaining to the proposed pool in accordance with provisions of Order R-111, which pertains to the drilling and completion of oil or gas wells within the designated "potash - oil" area.

Case No. 862

BEFORE:

Mr. E. S. (Johnny) Walker
Mr. William R. Macey

TRANSCRIPT OF HEARING

MR. MACEY: The next case on the docket is Case 862.

S. J. S T A N L E Y,

called as a witness, having been first duly sworn, testified as follows:

DIRECT EXAMINATION

By MR. KITTS:

Q Will you state your name and position, please?

A S. J. Stanley, Engineer for the Oil Conservation Commission.

Q Mr. Stanley, since the last meeting of this case when it was first heard, you have been appointed to a Committee to study further this matter?

A Yes, sir, we have had two meetings in Carlsbad to study this particular problem.

Q Mr. Stanley, in connection with your study, you prepared an exhibit which you wish to comment upon at this time, and introduce?

A Yes, sir, I have prepared one exhibit and also have obtained two exhibits from the United States Geological Survey, which I intend to introduce into the record.

Q This plat on the wall is your Exhibit 1?

A Yes.

Q That was prepared by you?

A Yes, sir, under my direction.

Q Will you proceed with Exhibit 1 and explain what that shows?

A Case 862 deals particularly with Order R-111. The objective of Order R-111, generally referred to as the Potash Order, is as follows: "The objective of these rules and regulations is to prevent waste, protect correlative rights, assure maximum conservation of oil and gas resources of New Mexico and permit the simultaneous economic recovery of potash minerals in the area hereinafter defined."

The potash - oil areas are divided into two parts. Area A includes the various parts in which potash mining operations are in progress, and Area B includes the various parts of which potash mining operations are in progress or in which coring tests indicate potential potash reserves.

Therefore, Exhibit No. 1, marked in red coloration includes the entire area defined in Order R-111 of potential potash recovery determined by actual exploration or core test date. The scale of the map showing the potash area is one inch equal to two miles, and therefore it can readily be seen that the area so defined is very large in extent, and for the sake of understanding the area itself I would like to point out on Exhibit No. 1 various landmarks. Here is Artesia, New Mexico, here is Carlsbad, New Mexico and here is Hobbs, New Mexico.

Q That shows both area A and B?

A Yes, sir, it incorporates both areas.

In Order R-111 in the problem before the Commission, the rules specifies the casing program of wells drilled to a shallow depth of less than 5,000 feet, and deeper wells drilled to depths of greater than 5,000 feet.

The surface pipe in shallow holes will be landed in the red bed section, and cemented to the surface. The salt string will be set between 100 and 200 feet below the base of the salt and cemented to the surface. The oil string shall be cemented with sufficient cement to protect the oil pay zone. Now, in lieu of offsetting a salt string, an operator can pull such string whenever it is landed for water shut-off and then the oil string shall be cemented to surface.

I, at this particular time, would like to read into the record the problem before ~~up~~ us pertaining to two wells of Simms and Reese Oil Company, which have been completed within the designated potash area as defined by Order R-111. The Simms and Reese Oil Company's McClay No. 1, located 1980 from the south and 660 from the east of Section 33, Township 18 South, Range 30 East, perforations are 2,844, that is the top of the perforation. The seven inch casing is set at 763 feet, four and a half inch casing at 2,093 feet cemented with 100 sacks. The top of the anhydrite, by our information is 250 feet. The top of the salt is 550 feet, the base of the salt is 1,494 feet and the top of the Queen is 2,810 feet.

The Simms and Reese Oil Company's McClay No. 2, 1980 from the north and 660 from the east of Section 33, Township 18 South, Range 30 East, perforations, 3,036 to 61 feet. That is 3,036 to 3,061 feet. Eight and five inch casing set at 590 feet with 80 sacks. Five and a half inch casing set at 3,064 feet with 30 sacks. The top of the salt in this well is at 560 feet, the base of the salt is at 1,495 feet, and the top of the Yates at 2,626, and the top of the Queen to the producing fromation is 2,844 feet.

Q I would like to interrupt for a moment here. You are aware the original applicant in this case, Simms and Reese Oil Company, stated in their application and testified at the last hearing, that they did not believe that in the area concerned, the area of their wells, there was potash salt in commercial quantities. Do you have any information as to that? Did your study go that far?

A I don't know whether there is potash of commercial quantities in that area or not.

Q I see.

A In fact, in reading the Simms and Reese Oil Company, the McClay No. 2 file, I might add this is a Federal well. That on the Federal form of sundry notices and reports on wells, the operator, Simms and Reese Oil Company makes the following statement.

"We will drill to approximately 3,000 feet and set eight and five inch surface casing and cement back to surface. Five and a half inch casing will be set and cemented through the red sand and sand fraced. We will comply with New Mexico Oil Conservation

Commission's Order R-111 on any modification thereto."

Q That was filed well before their application for exception to R-111, wasn't it?

A Yes, sir. The point that Simms and Reese Oil Company have argued is that potash is not present in this area. It is evidently uneconomical to produce oil from this area in stripper production with the cost of cementing, without exception of Order R-111. The date of the Order R-111 is July 10, 1951, and since that time 18 wells have been drilled in the potash area. Of the 18 wells that have been drilled, 16 wells have complied with the order and the two wells of Simms and Reese Oil Company seek an exception to this rule in this area where the wells are drilled.

To better acquaint ourselves with the problem of the potash company and the oil companies, two meetings were held in Carlsbad prior to this hearing. Certain topics were discussed and probably should be mentioned and introduced into the record. Area A as defi e by this order, is a continuously changing picture. I have what is marked Exhibits No. 2 and 3, showing the irregular pattern of potash occurrences.

Q Were those prepared by you, Mr. Stanley?

A No, sir, these were prepared by the United States Geological Survey, and they show 40 scale on the exhibit. However, that is considered a trade secret and, therefore, it is not actually defined in any one particular area referred to as actual description referred to as township, range.

Q Are you satisfied with the accuracy of these?

A No, sir, I know nothing about the exhibits. All I want to show is the irregular occurrence of potash in this particular area

What I would like to show with these two exhibits is the irregular occurrence of the potash area as determined by core drill. The closer spacing of core well holes could even connect the areas shown in Exhibits 2 and 3, and probably actual mining operations could change the entire picture.

Today the potash industry is able to mine ore ~~are~~ bodies of the thickness of 18 inches, as we understand, it is possible to mine sylvite, an ore of potash, or sylvanite with a 14 percent content, or langbeinite ~~manganite~~ with eight percent. In some instances the percentage of ore can be lower. In other words, with ever changing and improving techniques in mining, as is true in the oil business, and especially refining continually changes the commercial extent of the boundaries of the proven potash reserves.

It has been stated by the potash companies that porosity exists in the salt section that is mined. It has been definitely proven in the oil business that the salt section is charged in the Monument and Hobbs Pool and charged with gas. The charging of oil and gas in these pools was probably man made by casing leaks.

The point I am trying to make is that I feel that porosity and permeability exists in the salt section throughout Lea County, that the extent of charging the zone, and that is the salt zone, from one well would depend on the amount of gas present, and, of course, the pressure of that particular gas. Fortunately the wells of Simms and Reese Oil Company, if typical of the area, have low gas-oil ratios and also have very low bottom hole pressures. The potash areas defined is unexplored for all practical purposes, for oil accumulation and, therefore, who can say that high pressure wells ~~with considerable gas volumes will not be obtained at shallow depths.~~

One interesting point that was mentioned at these meetings was a method of mining ore. This type of mining refers to the removal of pillars, after the conventional mining is completed, these pillar supports are in an order of 100 foot in diameter. One pillar after another is removed until the earth above it subsides. This subsidence is evident at the surface of the ground. It is also believed that horizontal slippage occurs during the period of subsidence, this would have the tendency to shear off the casing of oil well; regardless of the number of strings of casing run in modern completion practices. The well would never be plugged properly since it could never be reentered. This subsidence would affect both the deep and shallow wells. I can see where possible charging of the mine workings would result.

It has been stated that the recoverable potash, based on potash mines at the present going price, is $154,000.00 per acre. 90 percent of the domestic potash, or I might say that the domestic potash in excess of 90 percent is mined in this area defined by Order R-111.

In conclusion, I wish to state that I have no recommendations in the case, that the Commission will have to recommend.

Q Mr. Stanley, let me ask you this. You stated that you had no knowledge as to whether in the area in question there was potash salt in commercial quantities or not, is that correct?

A That is right.

Q Assuming that there is potash salt in commercial quantities in that area, would you care to make any comment on the casing program set out in R-111, and the casing program of the Simms-Rees Company, as it would protect any such salt? Do you have any comment on that?

A Could I elaborate on my answer?

Q Certainly.

A I have studied all the wells in the Hobbs Pool from a corrosion standpoint, have inspected every well in that particular pool, and have also inspected all the wells or virtually all the wells in the north half, or half the wells in the Monument Pool. The casing program as defined in Order R-111 is not exactly the casing program that I would recommend in the potash area, provided that there was no horizontal slippage. However, I do not recommend that the casing program be altered as defined in R-111. My theories on casing program in this particular area and from the experience that I have had in observing the corrosion problems in Hobbs and the Monument Pool is as follows: If I intended to write an order to protect any potash area or any mine workings, I would write an order whereby the surface pipe would have to be set at 100 feet or 200 feet below the salt string in this manner.

MR. MACEY: Below the salt string?

A Yes. Not set any surface pipe below the salt section, not set any surface pipe at all, but set it — Assume that this is the salt section, set it a hundred feet below and cement that particular pipe to surface, then the oil string should be cemented in such a fashion that the cement behind the pipe shall come to a point below the oil section, or below the salt section, excuse me. Therefore, at any time we observe this in the Hobbs and Monument Pool, the potash companies, the oil companies or any individual could go to that particular well in question and observe between the annulus at the surface pipe and oil string whether a leakage occurred at any particular time during the life of the well.

At the present time, by cementing through the salt section, and we have found this in Hobbs and in Monument, there is no method at the surface of determining whether you have a leak or not. The only method that could determine whether you had a leak or not in any particular well, whereby the oil string is cemented through the salt section, it to run your tubing with a packer in such a fashion that you could observe or record the pressures between the tubing and the oil string.

However, I am not making any recommendations that the casing program be altered in Order R-111.

Q Do you feel that the casing program set forth in R-111, you feel that if that were followed it does afford protection to the potash salt section?

A I think it affords protection by merely running an oil string through the salt section.

Q You feel that the cementing helps appreciably?

A I think it possibly could help, but there would be no known method of ever testing the well, due to the fact that most of the corrosion is due to hydrogen sulphide, as we have observed in the Hobbs Pool, that the corrosion is internal, that it is not external adjacent to the salt section. That pipe pulled in the Hobbs Pool and in the Monument Pool, adjacent to the salt section showed that it would be in condition A, that is considered in new condition externally, but that the holes were formed from the inside by hydrogen sulphide. I do not feel that a rim of cement around this pipe a fraction of an inch in diameter in some cases would protect that particular salt or potash section, and it would aggravate the problem if you had considerable bottom hole pressure, or gas pressure. I feel that cement would not be able to hold, say, a thousand pounds pressure as we have in the Hobbs Pool, or the Monument Pool.

MR. KITTS: That is all.

MR. MACEY: Any questions of the witness? Mr. Rhodes?

CROSS EXAMINATION

By MR. RHODES:

Q These discussions with the potash operators, was any mention made of the possibility of bringing water in on the potash by drilling in the area?

A You mean from the surface or from the bottom?

Q Below the line water table.

A They do seek protection by setting the surface pipe to prevent any water to go ahead and flow downward into their mine workings. That is the intent of setting surface pipe.

Q Also, you mentioned the potash operators coming through and pulling pillars and letting the back come in and subside?

A Yes,sir.

Q Do you suppose that the potash operators would be willing to conduct a selective program on pulling these pillars in areas where there are producing wells?

A Well, I don't know anything about the potash people. I feel certainly sure that if I owned the potash mines I wouldn't go ahead and pull the pillars out, especially in the area where a deep well is present. What we usually have, by the drilling of several wells in the area, especially by Sid Richardson, and knowing the pressure of the Pennsylvanian section, that if a well were drilled to the Pennsylvanian section in any one particular area whereby mine workings were in operation, I feel reasonably sure that no one would dare pull these pillars out.

Q That is exactly my point. I wondered if that was any consideration.

A I think the discrepancy in the order, the most dangerous thing about the entire deal is to go ahead and drill a deep well to the Pennsylvanian and then have subsidence and lateral-horizontal movement. It does not mention the concern about the deep wells themselves. I believe by shearing the casing off in the deep wells is what probably will cause all the trouble.

Q I was just wondering if that was too much of a consideration, if accommodation couldn't be made by which that danger could be alleviated?

A I think that would be the concern of the potash company and the concern of the oil operator in that particular case.

MR. RHODES: That is all.

MR. MACEY: Anyone else?

By MR. LANE: — U. S. M. & C. Co

Q You have a value for the potash in this area. Do you have a value for the oil?

A Yes, we had a value of potash as stated by the potash companies of a recovery of past experience of $154,000.00 per acre. I seriously doubt that the shallow wells in this area with the exception of the Caddy Pool, would recover more than 1,500 barrels per acre, or roughly approximately $4,000.00 per acre.

Q It is our knowledge that the pillars remaining after the first extraction is about 30 or 35 percent, it would be roughly $50,000.00?

A Yes, sir.

MR. MACEY: Mr. Rhodes?

By MR. RHODES:

Q Do you believe that possibly pulling the pillars in one area would result in horizontal movement in some quite distant area?

A It could possibly affect it. It would have the effect of the earthquake. I understand you can drive over this particular area whereby these mining techniques were followed and see the subsidence on the surface of the ground.

Q I wonder if that is not directly over the particular area where the pillars were pulled?

A Yes, sir. I don't know the extent of the lateral movement.

MR. WEAVER: I can answer that. G. C. Weaver, representing Duval Sulphur and Potash. We have horizontal threats there as well as vertical. Just where it would show up, we can't tell. Assume we are mining at 1,000 feet, I would thoroughly expect to get horizontal displacement a thousand feet from any area we rocked. You can figure on about a 45 degree break there. When we talk about mining an area, when we go in and mine an area, in the first mining in the room and pillar system we extract about, well, from 50 to 75 percent of the potash present, we get subsidence. It is not enough to hinder our mining operations, however, if there are any oil and gas wells within a hundred feet of any one of those pillars, in in any one of those pillars 100 feet in diameter, I certainly wouldn't want to be very close to it. It wouldn't take much subsidence to shear a casing. Suppose the casing was sheared and gas and oil is escaped in the workings, how in the world would you ever replug that well? You have a loss of oil and gas which will never be recovered, and you will never recover the potash.

MR. MACEY: Does anyone have any further questions? Mr. Yates?

By MR. YATES:

Q Harvey Yates. I would like to ask the witness, Mr. Stanley, if, under the circumstances there is any long wall mining, is there any kind of pipe program that you could conceive of that could stand that shearing, so-called?

A No, I can't conceive of the oil industry inventing anything that would stand the shock of any lateral movement.

Q How is the oil industry and potash industry compatible in this area, for instance?

A I don't know.

Q I have a little field out there in the so-called area of the potash company. If you will recall, one potash company said they wanted no wells whatsoever drilled in this area. I would like to know how I am going to protect my leases?

A If I understand, and I believe Mr. Jack Frost with the United States Geological Survey is in the audience. If I undetstand it correctly from Mr. Frost in conversations that there are particular areas here owned by the government, whereby they do not issue any oil leases for shallow rights. That effective date was probably two or three years ago, I don't know the exact date. They do not issue any oil rights for shallow depths. It is only those that can drill who had the oil rights prior to that particular date. I wish Mr. Frost would elaborate on that subject.

MR. FROST: Jack Frost, United States Geological Survey. I believe you misunderstood some of our little discussion.

A I am sorry.

MR. FROST: There is a provision in those new leases in the potash area that my office can not approve the drilling of a shallow well without clearing it through Washington in advance.

A I see. May I ask you a question? You can drill anywhere in the defined potash area, an oil well if you do own the oil and gas leases on Federal acreage?

MR. FROST: I think you have something mixed up there. There is no provision that I know of where we can't approve the drilling of a well with a valid oil and gas lease, but there would be areas in there where we would have to consult with the potash companies and reach an agreement between the operator and the potash company before I could approve the drilling. Does that clear it up?

A Yes.

MR. MACEY: Does that pertain solely to shallow wells or both?

MR. FROST: No shallow, those from 5,000 feet up. If, on the new leases I would have to clear through Washington.

MR. MACEY: Mr. Yates?

MR. YATES: I would like to ask, under the circumstances, how is a man going to get approval from the potash companies to drill a well. He says that he can't issue a permit to drill a well without approval of the potash company if they don't want any wells drilled in their so-called A or ore body, how is a man going to get the approval.

A I am sure they have to approve the drilling of the oil well if you conform to Order R-111.

MR. YATES: That suits me.

MR. FROST: This may help clear that up. That oil and gas exploratory test well should not be drilled through any open potash mines or within 1,320 feet thereof, unless agreed to in writing by the potash lessee involved. That is on your R-111, Page 7, Section 3, Exploration of Areas, and this was Area A, a portion of Sub-paragraph A there.

MR. MACEY: Anyone have any further questions of Mr. Stanley? Mr. Stanley, I think we have possibly gotten off the beam here a little bit. I don't think we have done any harm. It appears to me from what you have said, that you are more concerned with the deep drilling than you are with the shallow. Am I right?

A That is correct, if you take into consideration the subsidence and the pressure of the Pennsylvanian Formation.

MR. MACEY: That is all I have.

RE-DIRECT EXAMINATION

By MR. KITTS:

Q Mr. Stanley, leaving the question of subsidence for the moment, you commented on the casing program of R-111. Would you care to make any comment on the casing program of the Reese-Simms Oil Company?

A No, sir, I do not wish to make any comment.

MR. KITTS: That is all.

~~A Well, I might say that they have not complied with Order~~

R-111, but they are here to seek an exception.

Q How would you compare the protection afforded by their casing and that afforded by R-111?

A That would be an argument to know whether that core of cement actually protects the salt section on that part of the pipe.

Q That would be the point?

A Yes.

MR. MACEY: Mr. Lane?

RE-CROSS EXAMINATION

By MR. LANE:

Q Things have been said here, how can a potash company agree to a well, when an operator has already been put into intent that he would comply with the regulations and he hasn't? How can we ever agree to it before the well is drilled? We are not getting very much assurance there. He stated that he was going to comply with the regulations.

A You want me to answer that question? I don't know.

MR. MACEY: Anyone else? If not the witness may be excused.

(Witness excused.)

MR. MACEY: Does anyone have anything further in this case? If not we will take the case under advisement.

STATE OF NEW MEXICO)
: ss.
COUNTY OF BERNALILLO)

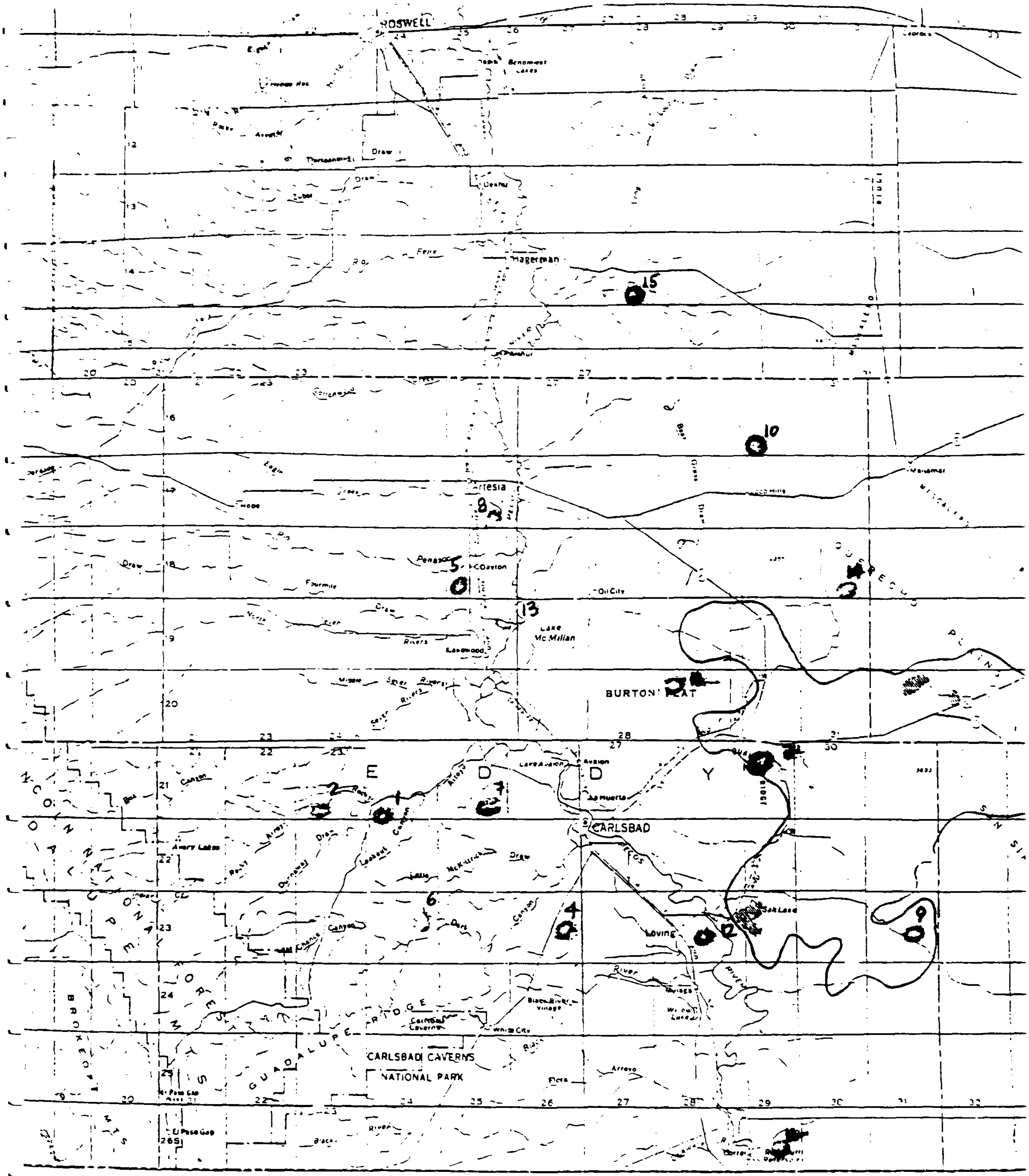
I, ADA DEARNLEY, Court Reporter, do hereby certify that the foregoing and attached transcript of proceedings before the New Mexico Oil Conservation Commission at Santa Fe, New Mexico, is a true and correct record to the best of my knowledge, skill and ability.

IN WITNESS WHEREOF I have affixed my hand and notarial seal this 28th day of April, 1955.

Ada Dearnley
Notary Public, Court Reporter

My Commission Expires:

June 19, 1955



3 Reviewed file, info. attached.

Location of Oil & Gas Mishaps (16)

Washington Ranch Storage Facility

BLOW OUTS

	DATE REPORTED	INCIDENT CODE	OPERATOR	LEASE NAME	LOCATION
1	1 -3-64	*3	Robert G. Hanagan	Teepee State #1	Sec.32-21S-24E
2	2-23-66	*3	Texaco Inc.	St.of New Mexico "DF" Com #1, unit J	Sec.32-21S-23E
3	9-27-66	*3	Stoltz & Co.	Hudson Federal #1-C	Sec. 4-21S-29E
4	4-22-72	*1-3	Michael P & Corinne Grace	Panagra #1-B	Sec.11-23S-26E
5	12-21-72	*3	Yates Petr. Corp.	Nickson BM #2-A	Sec.30-18S-26E
6	3 -1-73	*3	Adobe Oil Co.	Smith Fed.#2-P	Sec.11-23S-24E
7	9-14-73	*2	Hanagan Petr.Corp.	Catclaw Draw Ut.#9-E	Sec.35-21S-25E
8	7-30-74	*2	Hanson Oil Corp.	Clyde Guy Com #1-I	Sec.34-17S-26E
	12 -4-74	*3	Skelly Oil Company	Todd"25"Fed. #1-F	Sec.25-23S-31E
10	2-21-75	*2	Yates Petr.Corp.	Marco Polo"EA"State #1	Sec.32-16S-30E
11	8-25-77	*2	Yates Petr.Corp.	Williamson BC #4-K	Sec. 7-20S-29E
12	1-26-78	*3	Delta Drlg.Co.	S.Culebra Bluff Ut.#1-G	Sec.23-23S-28E
13	9-22-78	*3	Robert N. Enfield	N.Lake McMillan Ut.#1-J	Sec.12-19S-26E
14	4 -2-79	*2	Amoco Production Co.	Greenwood Pre Gray-burg Unit #12-F	Sec.35-18S-31E
15	9-12-80	*2	Yates Petr.Corp.	Nine Mile OB St. #1-F	Sec.32-14S-28E
16	9-15-81	*4	J.C.Williamson	EP-USA #1-I	Sec.26-26S-29E

INCIDENT CODES:

*1 Workover rig

*2 Blow out - drilling rig (no fire)

*3 Blowout - drilling rig (fire)

*4 Blowout - cable tool rig

*5

MEADCO PROP. LTD.	4-21S-29E
Hudson Federal #1	NE NW
	Unit C

Instructions

...rable to perform certain well operations, and reports of such operations when completed, as indicated, on Fed... and regulations, and, if approved or accepted by any State, on all lands in such State, pursuant to applicable State... ...tions concerning the use of this form and the number of copies to be submitted, particularly with regard to... ...are shown below or will be issued by, or may be obtained from, the local Federal and/or State office.

...ll locations on Federal or Indian land should be described in accordance with Federal requirements. Consult local...

...al reports of abandonment should include such special information as is required by local Federal and/or State offices... reasons for the abandonment; data on any former or present productive zones, or other zones with present significant... and method of placement of cement plugs; mud or other material placed below, between and... ...top and bottom; and method of... ...tool liner or tubing pulled and the depth to top of any left in the hole; method of closing top of well; and date well site... the abandonment.

U.S. GOVERNMENT PRINTING OFFICE

SUNDRY NOTICES AND REPORTS ON WELLS

(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir. Use "APPLICATION FOR PERMIT—" for such proposals.)

6. IF INDIAN, ALLOTTEE OR TRIBE NAME

1. OIL WELL [X] GAS WELL [ ] OTHER

7. UNIT AGREEMENT NAME

2. NAME OF OPERATOR: Stoltz & Company ✓

8. FARM OR LEASE NAME: Hudson Federal

3. ADDRESS OF OPERATOR: c/o Oil Reports & Gas Services, Box 763, Hobbs, N. M.

9. WELL NO.: 1

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements.* See also space 17 below.) At surface: 838.4' FNL & 1650' FWL of Section 4

10. FIELD AND POOL, OR WILDCAT: Wildcat

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA: Sec. 4, T21S, R29E

14. PERMIT NO.

15. ELEVATIONS (Show whether DF, RT, GR, etc.)

12. COUNTY OR PARISH: Eddy

13. STATE: N.M.

16. Check Appropriate Box To Indicate Nature of Notice, Report, or Other Data

NOTICE OF INTENTION TO:				SUBSEQUENT REPORT OF:			
TEST WATER SHUT-OFF	[ ]	PULL OR ALTER CASING	[ ]	WATER SHUT-OFF	[ ]	REPAIRING WELL	[ ]
FRACTURE TREAT	[ ]	MULTIPLE COMPLETE	[ ]	FRACTURE TREATMENT	[ ]	ALTERING CASING	[ ]
SHOOT OR ACIDIZE	[ ]	ABANDON*	[ ]	SHOOTING OR ACIDIZING	[ ]	ABANDONMENT*	[ ]
REPAIR WELL	[ ]	CHANGE PLANS	[ ]	(Other) Control Blow Out	[X]		
(Other)							

(NOTE: Report results of multiple completion on Well Completion or Recompletion Report and Log form.)

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

Fire extinguished October 1, 1966. Cleaned debris and cleaned location. McVey Drilling Company resumed drilling operations October 11, 1966.

RECEIVED

RECEIVED
OCT 24 1966
U. S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

18. I hereby certify that the foregoing is true and correct

SIGNED [signature] TITLE Agent DATE 10/20/66

(This space for Federal or State office use)

APPROVED BY ______ TITLE ______ DATE ______

CONDITIONS OF APPROVAL, IF ANY:

APPROVED
OCT 26 1966
R. L. BEEKMAN
DISTRICT ENGINEER

*See Instructions on Reverse Side

MEADCO PROP. LTD.
Hudson Federal #1
4-21S-29E
NE NW
Unit C

SUNDRY NOTICES AND REPORTS ON WELLS

(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir. Use "APPLICATION FOR PERMIT—" for such proposals.)

1. OIL WELL [X] GAS WELL [ ] OTHER

2. NAME OF OPERATOR: Stoltz & Company

3. ADDRESS OF OPERATOR: c/o Oil Reports & Gas Services, Box 763, Hobbs, New Mexico

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements.* See also space 17 below.) At surface: 838.4' FNL & 1650' FWL of Section 4

6. IF INDIAN, ALLOTTEE OR TRIBE NAME:

7. UNIT AGREEMENT NAME:

8. FARM OR LEASE NAME: Hudson Federal

9. WELL NO.: 1

10. FIELD AND POOL, OR WILDCAT: Wildcat

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA: Sec. 4, T21S, R29E

14. PERMIT NO.:

15. ELEVATIONS (Show whether DF, RT, GR, etc.):

12. COUNTY OR PARISH: Eddy

13. STATE: N. M.

16. Check Appropriate Box To Indicate Nature of Notice, Report, or Other Data

NOTICE OF INTENTION TO:		SUBSEQUENT REPORT OF:	
TEST WATER SHUT-OFF [ ]	PULL OR ALTER CASING [ ]	WATER SHUT-OFF [ ]	REPAIRING WELL [ ]
FRACTURE TREAT [ ]	MULTIPLE COMPLETE [ ]	FRACTURE TREATMENT [ ]	ALTERING CASING [ ]
SHOOT OR ACIDIZE [ ]	ABANDON* [ ]	SHOOTING OR ACIDIZING [ ]	ABANDONMENT* [ ]
REPAIR WELL [ ]	CHANGE PLANS [ ]	(Other)	
(Other) Report blow out	[X]	(NOTE: Report results of multiple completion on Well Completion or Recompletion Report and Log form.)	

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

9:00 A.M. 9/23/66 TD 11,100. Well blew out and caught on fire. Tom Brown Drilling Company's rig completely destroyed, two men seriously burned. Red Adair on location in charge of operations to snuff blaze and bring well under control.

APPROVED FOR ... ONLY
SEP 29 1966
DATE
ACTING DISTRICT ENGINEER

RECEIVED
SEP ...

RECEIVED
SEP 29 1966
U. S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

18. I hereby certify that the foregoing is true and correct

SIGNED W. L. Smith TITLE Agent DATE 9/27/66

(This space for Federal or State office use)

APPROVED BY ______ TITLE ______ DATE ______
CONDITIONS OF APPROVAL, IF ANY:

*See Instructions on Reverse Side

MADCO PROP. LTD.
Hudson Federal #1
4-21S-29E
NE NW
Unit C

September 27, 1966

Oil Conservation Commission
P. O. Box 2088
Santa Fe, New Mexico

Gentlemen:

Application is hereby made on behalf of Stoltz & Company for a discovery well allowable on their Hudson Federal #1, located 838.4' FNL & 1650' FWL of Section 4, Township 21 South, Range 29 East.

Details are as follows:

1. Well blew out and caught fire 9:00 A.M. 9/25/66, total depth 11,100'.

2. Well now flowing and burning an estimated 600 barrels oil per day.

3. Top pay approximately 11,063' in the Strawn.

It is believed that the well can be brought under control in the next few days and successfully completed as a producing well.

Yours very truly,

OIL REPORTS AND GAS SERVICES

W. L. Smith

DH/be

cc: Stoltz & Company
P. O. Box 1714
Midland, Texas

Oil Conservation Commission
Drawer DD
Artesia, New Mexico

RECEIVED
SEP 3 1966
O. C. C.
ARTESIA, OFFICE

MEADCO PROP. LTD.
Hudson Federal #1
4-21S-29E
NE NW
Unit C

Oil Reports and Gas Services
P. O. BOX 763 HOBBS, NEW MEXICO

SUNDRY NOTICES AND REPORTS ON WELLS

(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir. Use "APPLICATION FOR PERMIT—" for such proposals.)

6. IF INDIAN, ALLOTTEE OR TRIBE NAME

7. UNIT AGREEMENT NAME

1. OIL WELL [X] GAS WELL [ ] OTHER

2. NAME OF OPERATOR: Stoltz & Company

8. FARM OR LEASE NAME: Hudson Federal

3. ADDRESS OF OPERATOR: c/o Oil Reports & Gas Services, Box 763, Hobbs, New Mexico

9. WELL NO.: 1

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements.* See also space 17 below.) At surface: 835.4' FNL & 1650' FWL of Section 4

10. FIELD AND POOL, OR WILDCAT: Wildcat

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA: Sec. 4, T21S, R29E

14. PERMIT NO.

15. ELEVATIONS (Show whether DF, RT, GR, etc.): 3428.7 GR

12. COUNTY OR PARISH: Eddy | 13. STATE: N.M.

16. Check Appropriate Box To Indicate Nature of Notice, Report, or Other Data

NOTICE OF INTENTION TO:				SUBSEQUENT REPORT OF:			
TEST WATER SHUT-OFF	[ ]	PULL OR ALTER CASING	[ ]	WATER SHUT-OFF	[X]	REPAIRING WELL	[ ]
FRACTURE TREAT	[ ]	MULTIPLE COMPLETE	[ ]	FRACTURE TREATMENT	[ ]	ALTERING CASING	[ ]
SHOOT OR ACIDIZE	[ ]	ABANDON*	[ ]	SHOOTING OR ACIDIZING	[ ]	ABANDONMENT*	[ ]
REPAIR WELL	[ ]	CHANGE PLANS	[ ]	(Other)			
(Other)							

(NOTE: Report results of multiple completion on Well Completion or Recompletion Report and Log form.)

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

Ran 8 5/8" 24# new J-55 casing to 4052' with Halliburton DV cementing tool @ 1982'. Cemented with 425 sacks class "C" 4% gel and 150 sacks class "C" first stage and 400 sacks class "C" neat second stage. Cement failed to circulate. Job complete 10:00 A.M. 9/1/66. Ran temperature survey, found top cement 491'. Cemented around top of casing with 100 sacks regular neat thru 3/4" line pipe. Job complete 10:00 P.M. 9/1/66. WOC 24 hours and pressure tested casing with 1000# for 30 minutes, test O.K. Cementing operations witnessed by USGS representative.

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1966

RECEIVED
SEP 19 1966
U. S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

MEADCO PROP. LTD.
Hudson Federal #1
4-21S-29E
NE NW
Unit C

18. I hereby certify that the foregoing is true and correct

SIGNED [signature] TITLE Agent DATE 9/16/66

(This space for Federal or State office use)

APPROVED BY ____ TITLE ____ DATE ____

CONDITIONS OF APPROVAL, IF ANY:

APPROVED
SEP 1 1966
R. L. BEEKMAN
ACTING DISTRICT ENGINEER

*See Instructions on Reverse Side

PENN - 10720
STR - 11058
ATOKA - 11420

SUNDRY NOTICES AND REPORTS ON WELLS

(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir. Use "APPLICATION FOR PERMIT—" for such proposals.)

1. OIL WELL [X] GAS WELL [ ] OTHER

2. NAME OF OPERATOR: Stoltz & Company

3. ADDRESS OF OPERATOR: c/o Oil Reports & Gas Services, Box 763, Hobbs, New Mexico

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements.* See also space 17 below.) At surface: 838.4' FNL & 1650' FWL of Section 4

5. IF INDIAN, ALLOTTEE OR TRIBE NAME:

7. UNIT AGREEMENT NAME:

8. FARM OR LEASE NAME: Hudson Federal

9. WELL NO.: 1

10. FIELD AND POOL, OR WILDCAT: Wildcat

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA: Sec. 4, T21S, R29E

14. PERMIT NO.:

15. ELEVATIONS (Show whether DF, RT, GR, etc.): 3428.7 GR

12. COUNTY OR PARISH: Eddy

13. STATE: N.M.

16. Check Appropriate Box To Indicate Nature of Notice, Report, or Other Data

NOTICE OF INTENTION TO:				SUBSEQUENT REPORT OF:			
TEST WATER SHUT-OFF	[ ]	PULL OR ALTER CASING	[ ]	WATER SHUT-OFF	[X]	REPAIRING WELL	[ ]
FRACTURE TREAT	[ ]	MULTIPLE COMPLETE	[ ]	FRACTURE TREATMENT	[ ]	ALTERING CASING	[ ]
SHOOT OR ACIDIZE	[ ]	ABANDON*	[ ]	SHOOTING OR ACIDIZING	[ ]	ABANDONMENT*	[ ]
REPAIR WELL	[ ]	CHANGE PLANS	[ ]	(Other)			
(Other)				(NOTE: Report results of multiple completion on Well Completion or Recompletion Report and Log form.)			

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

Spudded 3:00 P.M. 8/19/66. Cemented 16" 55# new H-40 casing @ 566' with 400 sacks class "C" 4% gel and 150 sacks class "C" 2% calcium chloride. Circulated out 200 sacks. Plug down 8:15 A.M. 8/22/66. WOC 24 hours and pressure tested with 600# for 30 minutes, test O.K. ~~Drilled to 1624' using brine mud as speci-fied by Rule 111-A.~~ Cemented 11 3/4" 42# new J-55 casing at 1624' (Base Salt 1513) with 925 sacks class "C" 4% gel and 150 sacks class "C" 2% calcium chloride. Circulated out 500 sacks. Plug down 8:00 P.M. 8/25/66. WOC 24 hours and pressure tested with 600# for 30 minutes, test O.K. Cementing operations witness by Jim Knauf with USGS.

RECEIVED

SEP 9 1966

RECEIVED
SEP 6 1966
U. S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

18. I hereby certify that the foregoing is true and correct

SIGNED [signature] TITLE Agent DATE 9/1/66

(This space for Federal or State office use)

MEADCO PROP. LTD. 4-21S-29E
Hudson Federal #1 NE NW
Unit C

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

APPLICATION FOR PERMIT TO DRILL, DEEPEN, OR PLUG BACK

1a. TYPE OF WORK
DRILL [X] DEEPEN [ ] PLUG BACK [ ]

b. TYPE OF WELL
OIL WELL [X] GAS WELL [ ] OTHER SINGLE ZONE [X] MULTIPLE ZONE [ ]

2. NAME OF OPERATOR
Stoltz & Company

3. ADDRESS OF OPERATOR
c/o Oil Reports & Gas Services, Box 763, Hobbs, New Mexico

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements.*)
At surface 838.4' FNL & 1650 FWL of Section 4
At proposed prod. zone

14. DISTANCE IN MILES AND DIRECTION FROM NEAREST TOWN OR POST OFFICE*
15 miles NE Carlsbad, New Mexico

15. DISTANCE FROM PROPOSED* LOCATION TO NEAREST PROPERTY OR LEASE LINE, FT. (Also to nearest drlg. unit line, if any) 838.4

16. NO. OF ACRES IN LEASE 301

17. NO. OF ACRES ASSIGNED TO THIS WELL 40

18. DISTANCE FROM PROPOSED LOCATION* TO NEAREST WELL, DRILLING, COMPLETED, OR APPLIED FOR, ON THIS LEASE, FT.

19. PROPOSED DEPTH 11,600

20. ROTARY OR CABLE TOOLS Rotary

21. ELEVATIONS (Show whether DF, RT, GR, etc.) 3428.7 GR

22. APPROX. DATE WORK WILL START* Upon Approval

5. LEASE DESIGNATION AND SERIAL NO. LC-070286

6. IF INDIAN, ALLOTTEE OR TRIBE NAME

7. UNIT AGREEMENT NAME

8. FARM OR LEASE NAME Hudson Federal

9. WELL NO. 1

10. FIELD AND POOL, OR WILDCAT Wildcat

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA Sec. 4, 21S, 29E

12. COUNTY OR PARISH Eddy

13. STATE N.M.

23. PROPOSED CASING AND CEMENTING PROGRAM

SIZE OF HOLE	SIZE OF CASING	WEIGHT PER FOOT	SETTING DEPTH	QUANTITY OF CEMENT
17 1/2	16	55#	500*	Circulated
13 3/4	11 3/4	38#	1500**	Circulated
10	8 5/8	32#	4000	Circulated
7 7/8	5 1/2	15.5#	11,600	200

*Estimated depth; actual depth to depend upon top of salt section.
**Estimated depth; actual depth to be 100' below base of salt.

The above location to be drilled as a Strawn test in accordance with all the provisions of Rule 111-A.

RECEIVED
JUN 6 1966
O. C. C.
ARTESIA, OFFICE

RECEIVED
MAY 24 1966
U. S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

RECEIVED
JUN - 3 1966
U. S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

IN ABOVE SPACE DESCRIBE PROPOSED PROGRAM: If proposal is to deepen or plug back, give data on present productive zone and proposed new productive zone. If proposal is to drill or deepen directionally, give pertinent data on subsurface locations and measured and true vertical depths. Give blowout preventer program, if any.

24.
SIGNED [signature] TITLE Agent DATE 5/23/66

(This space for Federal or State office use)

PERMIT NO. ________ APPROVAL DATE ________

APPROVED BY ________ TITLE ________ DATE ________
CONDITIONS OF APPROVAL, IF ANY:

MEADCO PROP. LTD.
Hudson Federal #1
4-21S-29E
NE NW
Unit C

*See Instructions On Reverse Side

[redacted] [redacted]

N. [illegible] C. COPY

Form 9-331 (May 1963)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SUBMIT IN TRIPLICATE* (Other instructions on reverse side)

Form approved. Budget Bureau No. 42-R1424

5. LEASE DESIGNATION AND SERIAL NO.: NM 0544[illegible]

6. IF INDIAN, ALLOTTEE OR TRIBE NAME

SUNDRY NOTICES AND REPORTS ON WELLS

(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir. Use "APPLICATION FOR PERMIT—" for such proposals.)

RECEIVED

FEB 24 1975

O.C.C.
ARTESIA, OFFICE

1. OIL WELL ☐ GAS WELL ☒ OTHER

7. UNIT AGREEMENT NAME

2. NAME OF OPERATOR: [illegible] American Oil Corporation ✓

8. FARM OR LEASE NAME: Todd "25" Federal

3. ADDRESS OF OPERATOR: 1012 Midland Savings Bldg. Midland, TX 79701

9. WELL NO.: 1

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements. See also space 17 below.) At surface: 1980' FNL & 1980' FWL

10. FIELD AND POOL, OR WILDCAT: Wildcat

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA: Sec.25, T-2[illegible], [illegible]

14. PERMIT NO.

15. ELEVATIONS (Show whether DF, RT, GR, etc.): 3437.7 GR

12. COUNTY OR PARISH: Eddy 13. STATE: [illegible]

16. Check Appropriate Box To Indicate Nature of Notice, Report, or Other Data

NOTICE OF INTENTION TO:				SUBSEQUENT REPORT OF:			
TEST WATER SHUT-OFF	☐	PULL OR ALTER CASING	☐	WATER SHUT-OFF	☐	REPAIRING WELL	☐
FRACTURE TREAT	☐	MULTIPLE COMPLETE	☐	FRACTURE TREATMENT	☐	ALTERING CASING	☐
SHOOT OR ACIDIZE	☐	ABANDON*	☐	SHOOTING OR ACIDIZING	☐	ABANDONMENT*	☒
REPAIR WELL	☐	CHANGE PLANS	☐	(Other)			
(Other)							

(NOTE: Report results of multiple completion on Well Completion or Recompletion Report and Log form.)

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

4-16-74 to 5-6-74

Drilled 24" hole to 249' with cable tools. Lost bit in hole, 4-29-74. Abandoned efforts to deepen. Plugged as follows: Moved cable tool back and filled hole with cuttings from 1-Y. Verbal approval received to omit surface marker, as marker would be in way of drilling operations. In the event this hole should cave in after rig has been moved out a 10' plug will be installed in top of hole. No logs were run on this well.

RECEIVED

FEB 20 1975

U. S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

18. I hereby certify that the foregoing is true and correct

SIGNED [signature] TITLE Engineer DATE 2-17-75

(This space for Federal or State office use)

APPROVED BY ____ TITLE ____ DATE ____

CONDITIONS OF APPROVAL, IF ANY:

APPROVED
FEB [illegible] 1975
[signature]
DISTRICT ENGINEER

*See Instructions on Reverse Side

[illegible handwriting]

TEXAS AMER. OIL CORP 25-23S-31E
Todd "25" Fed. #1 SE NW
Unit--F

N. M. O. C. C. COPY

Form 9-331
(May 1963)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SUBMIT IN TRIPLICATE*
(Other instructions on reverse side)

Form approved.
Budget Bureau No. 42-R1424

5. LEASE DESIGNATION AND SERIAL NO.
NM 0[illegible]

6. IF INDIAN, ALLOTTEE OR TRIBE NAME

SUNDRY NOTICES AND REPORTS ON WELLS

(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir. Use "APPLICATION FOR PERMIT—" for such proposals.)

1. OIL WELL ☐ GAS WELL ☒ OTHER

RECEIVED

7. UNIT AGREEMENT NAME

2. NAME OF OPERATOR
[illegible] American Oil Corporation

FEB 24 1975

8. FARM OR LEASE NAME
Todd "25" Federal

3. ADDRESS OF OPERATOR
1012 Midland Savings Bldg. Midland, TX 79701

O. C. C.
ARTESIA, OFFICE

9. WELL NO.
1

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements.* See also space 17 below.)
At surface
1980' FNL & 1980' FWL

10. FIELD AND POOL, OR WILDCAT
Wildcat [illegible]

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA
Sec.25, T-[illegible]

14. PERMIT NO.

15. ELEVATIONS (Show whether DF, RT, GR, etc.)
3437.7 GR

12. COUNTY OR PARISH
Eddy

13. STATE
[illegible]

Check Appropriate Box To Indicate Nature of Notice, Report, or Other Data

NOTICE OF INTENTION TO:				SUBSEQUENT REPORT OF:			
TEST WATER SHUT-OFF	☐	PULL OR ALTER CASING	☐	WATER SHUT-OFF	☐	REPAIRING WELL	☐
FRACTURE TREAT	☐	MULTIPLE COMPLETE	☐	FRACTURE TREATMENT	☐	ALTERING CASING	☐
SHOOT OR ACIDIZE	☐	ABANDON*	☐	SHOOTING OR ACIDIZING	☐	ABANDONMENT*	☒
REPAIR WELL	☐	CHANGE PLANS	☐	(Other)			
(Other)							

(NOTE: Report results of multiple completion on Well Completion or Recompletion Report and Log form.)

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

4-16-74 to 5-6-74

Drilled 24" hole to 249' with cable tools. Lost bit in hole, 4-29-74. Abandoned efforts to deepen. Plugged as follows: Moved cable tool back and filled hole with cuttings from 1-Y. Verbal approval received to omit surface marker, As marker would be in way of drilling operations. In the event this hole should cave in after rig has been moved out a 10' plug will be installed in top of hole. No logs were run on this well.

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FEB 20 1975
U. S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

18. I hereby certify that the foregoing is true and correct

SIGNED [signature] TITLE Engineer DATE 2-1[illegible]

(This space for Federal or State office use)

APPROVED BY ____ TITLE ____ DATE ____

CONDITIONS OF APPROVAL, IF ANY:

FEB [illegible]
[signature]
DISTRICT ENGINEER

*See Instructions on Reverse Side

N. M. O. C. C. COPY

Form 9-331
(May 1963)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SUBMIT IN TRIPLICATE* (Other instructions on reverse side)

Form approved.
Budget Bureau No. 42-R1424

5. LEASE DESIGNATION AND SERIAL NO.
NM 0544986

6. IF INDIAN, ALLOTTEE OR TRIBE NAME

SUNDRY NOTICES AND REPORTS ON WELLS

(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir. Use "APPLICATION FOR PERMIT—" for such proposals.)

1. OIL WELL ☐ GAS WELL ☒ OTHER

7. UNIT AGREEMENT NAME

2. NAME OF OPERATOR
Texas American Oil Corporation

RECEIVED

8. FARM OR LEASE NAME
Todd "25" Federal

3. ADDRESS OF OPERATOR
1012 Midland Savings Bldg. Midland, TX 79701

FEB 21 1975

9. WELL NO.
1

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements.* See also space 17 below.)
At surface

1980' FNL & 1980' FWL

O. C. C.
ARTESIA, OFFICE

10. FIELD AND POOL, OR WILDCAT
Wildcat

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA
Sec.25, T-23-S, R-[illegible]

14. PERMIT NO.

15. ELEVATIONS (Show whether DF, RT, GR, etc.)
3487.7 GR

12. COUNTY OR PARISH
Eddy

13. STATE
N.Mex.

16. Check Appropriate Box To Indicate Nature of Notice, Report, or Other Data

NOTICE OF INTENTION TO:				SUBSEQUENT REPORT OF:			
TEST WATER SHUT-OFF	☐	PULL OR ALTER CASING	☐	WATER SHUT-OFF	☐	REPAIRING WELL	☐
FRACTURE TREAT	☐	MULTIPLE COMPLETE	☐	FRACTURE TREATMENT	☐	ALTERING CASING	☐
SHOOT OR ACIDIZE	☐	ABANDON*	☐	SHOOTING OR ACIDIZING	☐	ABANDONMENT*	☒
REPAIR WELL	☐	CHANGE PLANS	☐	(Other)			
(Other)							

(NOTE: Report results of multiple completion on Well Completion or Recompletion Report and Log form.)

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

4-16-74 to 5-6-74

Drilled 24" hole to 249' with cable tools. Lost bit in hole, 4-29-74. Abandoned efforts to deepen. Plugged as follows: Moved cable tool back and filled hole with cuttings from 1-Y. Verbal approval received to omit surface marker, As marker would be in way of drilling operations. In the event this hole should cave in after rig has been moved out a 10' plug will be installed in top of hole. No logs were run on this well.

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ARTESIA, NEW MEXICO

18. I hereby certify that the foregoing is true and correct

SIGNED Robert L. Thurman TITLE Engineer DATE 2-17-75

(This space for Federal or State office use)

APPROVED BY ________ TITLE ________ DATE ________
CONDITIONS OF APPROVAL, IF ANY:

*See Instructions on Reverse Side

N. M. O. C. C. COPY

Copy

Form 9-331
(May 1963)

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SUBMIT IN TRIPLICATE*
(Other instructions on reverse side)

Form approved.
Budget Bureau No. 42-R1424

5. LEASE DESIGNATION AND SERIAL NO.
NM 0544986

6. IF INDIAN, ALLOTTEE OR TRIBE NAME

SUNDRY NOTICES AND REPORTS ON WELLS
(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir. Use "APPLICATION FOR PERMIT—" for such proposals.)

1. OIL WELL ☐ GAS WELL ☒ OTHER

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MAY 9 1974
O. C. C.
ARTESIA, OFFICE

7. UNIT AGREEMENT NAME

2. NAME OF OPERATOR
Texas American Oil Corporation

8. FARM OR LEASE NAME
Todd "25" Federal

3. ADDRESS OF OPERATOR
1012 Midland Savings Bldg., Midland, Texas 79701

9. WELL NO.
1

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements.* See also space 17 below.)
At surface
1980' FNL & 1980' FWL

10. FIELD AND POOL, OR WILDCAT

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA
Sec. 25, T-23-S, R-31-E

14. PERMIT NO.

15. ELEVATIONS (Show whether DF, RT, GR, etc.)
3486.7 GR

12. COUNTY OR PARISH
Eddy

13. STATE
N. M.

16. Check Appropriate Box To Indicate Nature of Notice, Report, or Other Data

NOTICE OF INTENTION TO:				SUBSEQUENT REPORT OF:			
TEST WATER SHUT-OFF	☐	PULL OR ALTER CASING	☐	WATER SHUT-OFF	☐	REPAIRING WELL	☐
FRACTURE TREAT	☐	MULTIPLE COMPLETE	☐	FRACTURE TREATMENT	☐	ALTERING CASING	☐
SHOOT OR ACIDIZE	☐	ABANDON*	☒	SHOOTING OR ACIDIZING	☐	ABANDONMENT*	☐
REPAIR WELL	☐	CHANGE PLANS	☐	(Other)			
(Other)							

(NOTE: Report results of multiple completion on Well Completion or Recompletion Report and Log form.)

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

4-16-74 to 5-6-74

Spud date 4-16-74. Drilled 24" hole to 249' with cable tools. Lost bit in hole 4-29-74. Fished to 5-6-74 and not able to recover. Propose to plug and abandon this hole as follows:

4" dia. x 4' above surface standard marker.
0 - 10' Cement plug.
10' - 249' Heavy mud & drill cuttings.

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ARTESIA, NEW MEXICO

18. I hereby certify that the foregoing is true and correct

SIGNED [signature] TITLE Engineer DATE 5-6-74

(This space for Federal or State office use)

APPROVED BY [signature] TITLE DISTRICT ... DATE MAY ...
CONDITIONS OF APPROVAL, IF ANY:

*See Instructions on Reverse Side

N. M. O. C. C. COPY

Form 9-331 (May 1963)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SUBMIT IN TRIPLICATE* (Other instructions on reverse side)

Form approved. Budget Bureau No. 42-R1424.

5. LEASE DESIGNATION AND SERIAL NO.
NM0544986

6. IF INDIAN, ALLOTTEE OR TRIBE NAME

SUNDRY NOTICES AND REPORTS ON WELLS

(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir. Use "APPLICATION FOR PERMIT—" for such proposals.)

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APR 30 1974

O. C. C.
ARTESIA, OFFICE

1. OIL WELL ☐ GAS WELL ☒ OTHER

7. UNIT AGREEMENT NAME

2. NAME OF OPERATOR
Texas American Oil Corporation

8. FARM OR LEASE NAME
Todd "25" Federal

3. ADDRESS OF OPERATOR
1012 Midland Savings Building, Midland, Texas 79701

9. WELL NO.
1

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements.* See also space 17 below.)
At surface
1980' FNL & 1980' FWL

10. FIELD AND POOL, OR WILDCAT

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA
Sec. 25, T-23-S, R-31-

14. PERMIT NO.

15. ELEVATIONS (Show whether DF, RT, GR, etc.)
3486.7GR

12. COUNTY OR PARISH
Eddy

13. STATE
New Mexic

16. Check Appropriate Box To Indicate Nature of Notice, Report, or Other Data

NOTICE OF INTENTION TO:				SUBSEQUENT REPORT OF:			
TEST WATER SHUT-OFF	☐	PULL OR ALTER CASING	☐	WATER SHUT-OFF	☐	REPAIRING WELL	☐
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SHOOT OR ACIDIZE	☐	ABANDON*	☐	SHOOTING OR ACIDIZING	☐	ABANDONMENT*	☐
REPAIR WELL	☐	CHANGE PLANS	☐	(Other) Spud Date			☒
(Other)							

(NOTE: Report results of multiple completion on Well Completion or Recompletion Report and Log form.)

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

Spud date April 16, 1974. Daily drilling reports to follow.

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APR 29 1974
U. S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

18. I hereby certify that the foregoing is true and correct

SIGNED [signature] TITLE Engineer DATE April 26, 1974

(This space for Federal or State office use)

APPROVED BY ______ TITLE ______ DATE ______
CONDITIONS OF APPROVAL, IF ANY:

APR 29 1974
R. L. BEEKMAN
ENGINEER

*See Instructions on Reverse Side

N. M. O. C. C. COPY

Form 9-331
(May 1963)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SUBMIT IN TRIPLICATE*
(Other instructions on reverse side)

Form approved.
Budget Bureau No.

5. LEASE DESIGNATION AND SERIAL NO.
NM 0544986

6. IF INDIAN, ALLOTTEE OR TRIBE NAME

SUNDRY NOTICES AND REPORTS ON WELLS

(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir.
Use "APPLICATION FOR PERMIT—" for such proposals.)

RECEIVED

APR 1 6 1974

O. C. C.
ARTESIA, OFFICE

1. OIL WELL ☐ GAS WELL ☒ OTHER

7. UNIT AGREEMENT NAME

2. NAME OF OPERATOR
Texas American Oil Corporation ✓

8. FARM OR LEASE NAME
Todd "25" Federal

3. ADDRESS OF OPERATOR
1012 Midland Savings Building, Midland, Texas 79701

9. WELL NO.
1

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements.* See also space 17 below.)
At surface
1980' FNL & 1980'FWL

10. FIELD AND POOL, OR WILDCAT

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA
Sec. 25, T-23-S,

14. PERMIT NO.

15. ELEVATIONS (Show whether DF, RT, GR, etc.)
3486.7 GR

12. COUNTY OR PARISH
Eddy

13. STATE
New Mex

16. Check Appropriate Box To Indicate Nature of Notice, Report, or Other Data

NOTICE OF INTENTION TO:				SUBSEQUENT REPORT OF:			
TEST WATER SHUT-OFF	☐	PULL OR ALTER CASING	☐	WATER SHUT-OFF	☐	REPAIRING WELL	☐
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SHOOT OR ACIDIZE	☐	ABANDON*	☐	SHOOTING OR ACIDIZING	☐	ABANDONMENT*	☐
REPAIR WELL	☐	CHANGE PLANS	X	(Other)			
(Other)							

(NOTE: Report results of multiple completion on Well Completion or Recompletion Report and Log form.)

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

Due to the shortage of rotary rigs and casing, we propose to drill the upper part of the hole with cable tools.

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APR 11 1974
U. S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

18. I hereby certify that the foregoing is true and correct

SIGNED ____________ TITLE Engineer DATE Apr. 10, 19

(This space for Federal or State office use)

APPROVED BY ____________ TITLE ____________ DATE ____________
CONDITIONS OF APPROVAL, IF ANY:

*See Instructions on Reverse Side

Form 9-331 C
(May 1963)

N. M. O. C. C. COPY

SUBMIT IN TRIPLICATE*
(Other instructions on reverse side)

Form approved.
Budget Bureau No. 42-R1425.

Copy

30-015-21127

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

APPLICATION FOR PERMIT TO DRILL, DEEPEN, OR PLUG BACK

1a. TYPE OF WORK: DRILL [X] DEEPEN [ ] PLUG BACK [ ]

b. TYPE OF WELL: OIL WELL [ ] GAS WELL [X] OTHER — SINGLE ZONE [ ] MULTIPLE ZONE [X]

2. NAME OF OPERATOR: Texas American Oil Corporation ✓

3. ADDRESS OF OPERATOR: 1012 Midland Savings Bldg., Midland, TX 79701

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements.*)
At surface: 1980' FNL & 1980' FWL
At proposed prod. zone

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MAR 1 5 1974
O. C. C.
ARTESIA, OFFICE

5. LEASE DESIGNATION AND SERIAL NO.: NM 0544986 ~~NM0405444~~

6. IF INDIAN, ALLOTTEE OR TRIBE NAME:

7. UNIT AGREEMENT NAME:

8. FARM OR LEASE NAME: Todd "25" Federal

9. WELL NO.: 1

10. FIELD AND POOL, OR WILDCAT: Wildcat

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA: Sec 25, T-23-S, R-31-E

14. DISTANCE IN MILES AND DIRECTION FROM NEAREST TOWN OR POST OFFICE*: 35 miles northwest, Jal, New Mexico

12. COUNTY OR PARISH: Eddy

13. STATE: N. Mexico

15. DISTANCE FROM PROPOSED* LOCATION TO NEAREST PROPERTY OR LEASE LINE, FT. (Also to nearest drig. unit line, if any): 1980'

16. NO. OF ACRES IN LEASE: 600

17. NO. OF ACRES ASSIGNED TO THIS WELL: 40

18. DISTANCE FROM PROPOSED LOCATION* TO NEAREST WELL, DRILLING, COMPLETED, OR APPLIED FOR, ON THIS LEASE, FT.: -

19. PROPOSED DEPTH: 15,500

20. ROTARY OR CABLE TOOLS: Rotary

21. ELEVATIONS (Show whether DF, RT, GR, etc.): 3486.7 GR

22. APPROX. DATE WORK WILL START*: Before 5-1-74

23. PROPOSED CASING AND CEMENTING PROGRAM

SIZE OF HOLE	SIZE OF CASING	WEIGHT PER FOOT	SETTING DEPTH	QUANTITY OF CEMENT
26"	20"	94#	600	1600 sx Circulated
17-1/2"	13-3/8"	61#, 68#, 72#	4,400'	3400 sx Circulated
12-1/4"	9-5/8"	43.5#, 47#	12,700	2400 sx Est top 4000'
8-5/8"	7-5/8" liner	39#	15,500	300 sx

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ARTESIA, NEW MEXICO

IN ABOVE SPACE DESCRIBE PROPOSED PROGRAM: If proposal is to deepen or plug back, give data on present productive zone and proposed new productive zone. If proposal is to drill or deepen directionally, give pertinent data on subsurface locations and measured and true vertical depths. Give blowout preventer program, if any.

24.

SIGNED [signature] TITLE Engineer DATE January 28, 1974

(This space for Federal or State office use)

PERMIT NO. ______ APPROVAL DATE ______

SUBJECT TO ATTACHED DEEP WELL CONDITIONS
REQUIREMENTS DATED JUNE 2 1973

APPROVED BY ______ TITLE ______ DATE ______

CONDITIONS OF APPROVAL, IF ANY:

L. BECKHAM
ACTING DISTRICT ENGINEER

THIS APPROVAL IS RESCINDED IF OPERATIONS NOT COMMENCED WITHIN 3 MONTHS.

1974

NOTIFY USGS IN SUFFICIENT TIME TO

*See Instructions On Reverse Side

NE[illegible]EXICO OIL CONSERVATION COMMISSI[illegible]

WELL LOCATION AND ACREAGE DEDICATION PLAT

Form C-1[illegible]
Supersedes [illegible]
Effective

All distances must be from the outer boundaries of the Section

Operator	Lease	Well No.
[illegible]AS AMERICAN OIL CORP.	TODD "25" FEDERAL	1

Unit Letter	Section	Township	Range	County
F	25	23 SOUTH	31 EAST	EDDY

Actual Footage Location of Well:
1980 feet from the NORTH line and 1980 feet from the WEST line

Ground Level Elev.	Producing Formation	Pool	Dedicated Acreage
[illegible]486.7	Delaware, Atoka, Morrow	Und. Sand Dunes Morrow Gas ~~Wildcat~~	Delaware (40) Morrow (320) Atoka (640)

Outline the acreage dedicated to the subject well by colored pencil or hachure marks on the plat below.

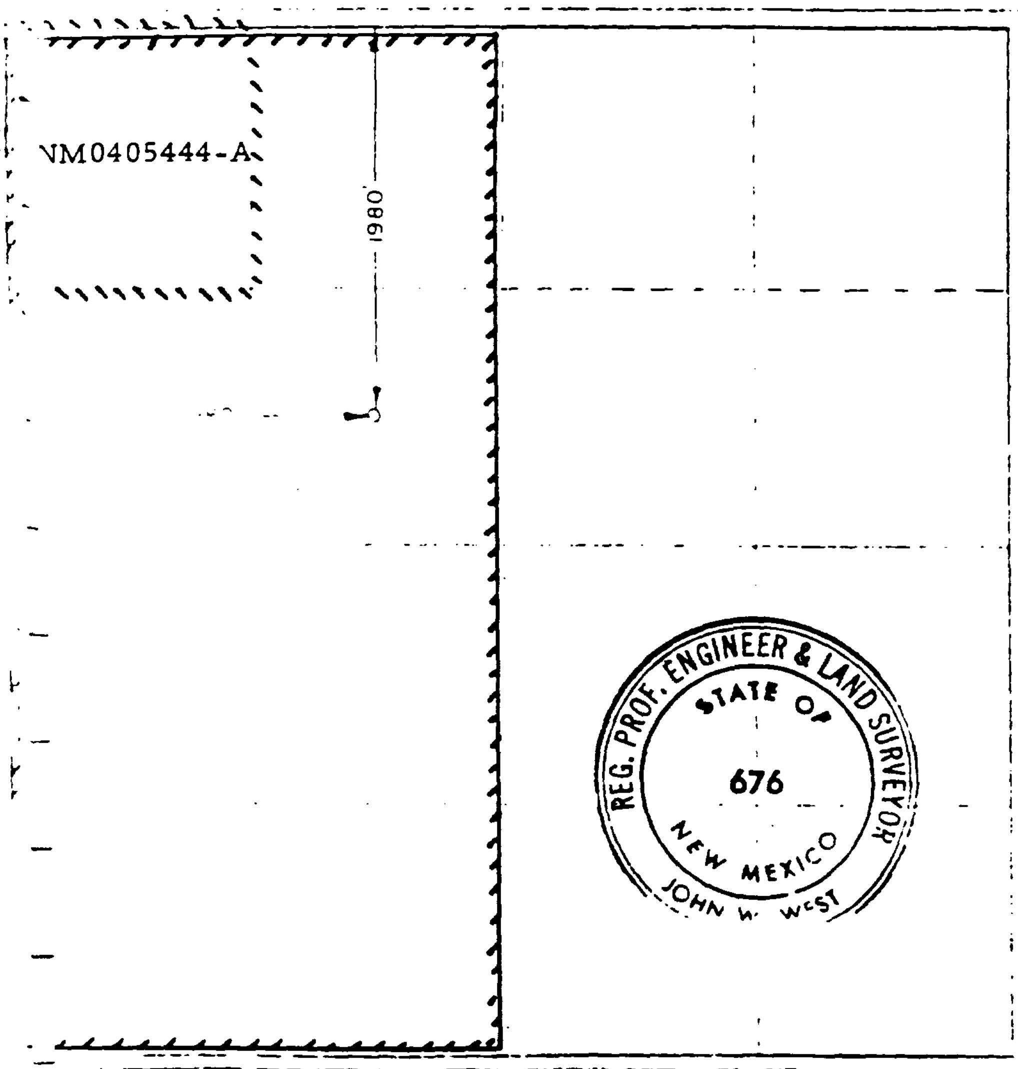
If more than one lease is dedicated to the well, outline each and identify the ownership thereof (both as to working interest and royalty).

If more than one lease of different ownership is dedicated to the well, have the interests of all owners been consolidated by communitization, unitization, force-pooling, etc?

Yes [X] No If answer is "yes," type of consolidation ____________

If answer is "no," list the owners and tract descriptions which have actually been consolidated. (Use reverse side of this form if necessary.) Will be communitized.

No allowable will be assigned to the well until all interests have been consolidated (by communitization, unitization, forced-pooling, or otherwise) or until a non-standard unit, eliminating such interests, has been approved by the Commission.



CERTIFICATION

I hereby certify that the information contained herein is true and complete to the best of my knowledge and belief.

N. T. Emanuel

Engineer

Texas American Oil Co[illegible]

January 28, 1974

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U.S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

I hereby certify that the well location shown on this plat was plotted from field notes of actual surveys made by me or under my supervision, and that the same is true and correct to the best of my knowledge and belief.

January 20, 1974

John W. West

OIL AND GAS PROD...

TEXAS AMERICAN OIL CORPORATION

January 28, 1974

300 WEST WALL, SUITE 1012 MIDLAND, TEXAS 79701

Todd "25" Federal, Well No. 1
1980' FNL & 1980' FWL
Section 26, T-23-S, R-31-E
Eddy County, New Mexico

Gentlemen:

As per instructions for submitting an application to drill on shore or off shore, gas or oil, or geothermal steam wells, on public domain and acquired lands, Texas American Oil Corporation answers these questions as follows:

1) Exhisting Roads: Exhibit "A" shows the exhisting roads in blue lines.

2) Planned Access Roads: Exhibit "A" shows in red lines the proposed road.

3) Loaction of Well: Shown above and also on Exhibit "A".

4) Lateral Roads to Location: None.

5) Location of Tank Battery and Flow Lines: If the above well is productive, Tank Battery and Flow Lines will be located on Caliche Pad at Well.

6) Location and Types of Water Supply: Water to be hauled .

7) Methods for Handling Waste Disposal: A reserve pit located as per Exhibit "B" will be used for handling all wastes.

RECEI...

8) Location of Camps: None.

9) Location of Air Strip: None.

U. S. GEOLOGICAL SU...

10) Location of Rig, Mud Tanks, Reserve Pits, Burn Pits, Pipe Racks, etc.: See Exhibit "C" attached.

11) Plans for Restoration of the Surface: After drilling the well, Texas American will level all pits and location as near to original ground level as possible. This location is in an arid region on which there is very little surface grass.

Page Two

12) Detailed Mud Program:

0 -	600' -	Bentonite and lime.
600 -	4400' -	Brine treated w/Benex to control solids. LCM for loss of fluid. (Max. wt. 10#/gal.)
4400 -	12,700' -	Fresh water/w/Benex to control solids. Flosal for improved samples. LCM for loss of fluid. Start w/8.4#/gal., increase to 9.2#/gal. @ 8000'. Max wt. 10.5#/gal.)
12,700 -	15,500' -	Fresh water w/Benex - Bentonite for vis., Barite for wt., cellex for filter loss, coustic Q-Broxin to control flow properties. (Start w/12.5#/gal. and increase as needed. Max wt. 15.3#/gal.)

13) Blow Out Preventer: See attached Exhibit "C" for detail.

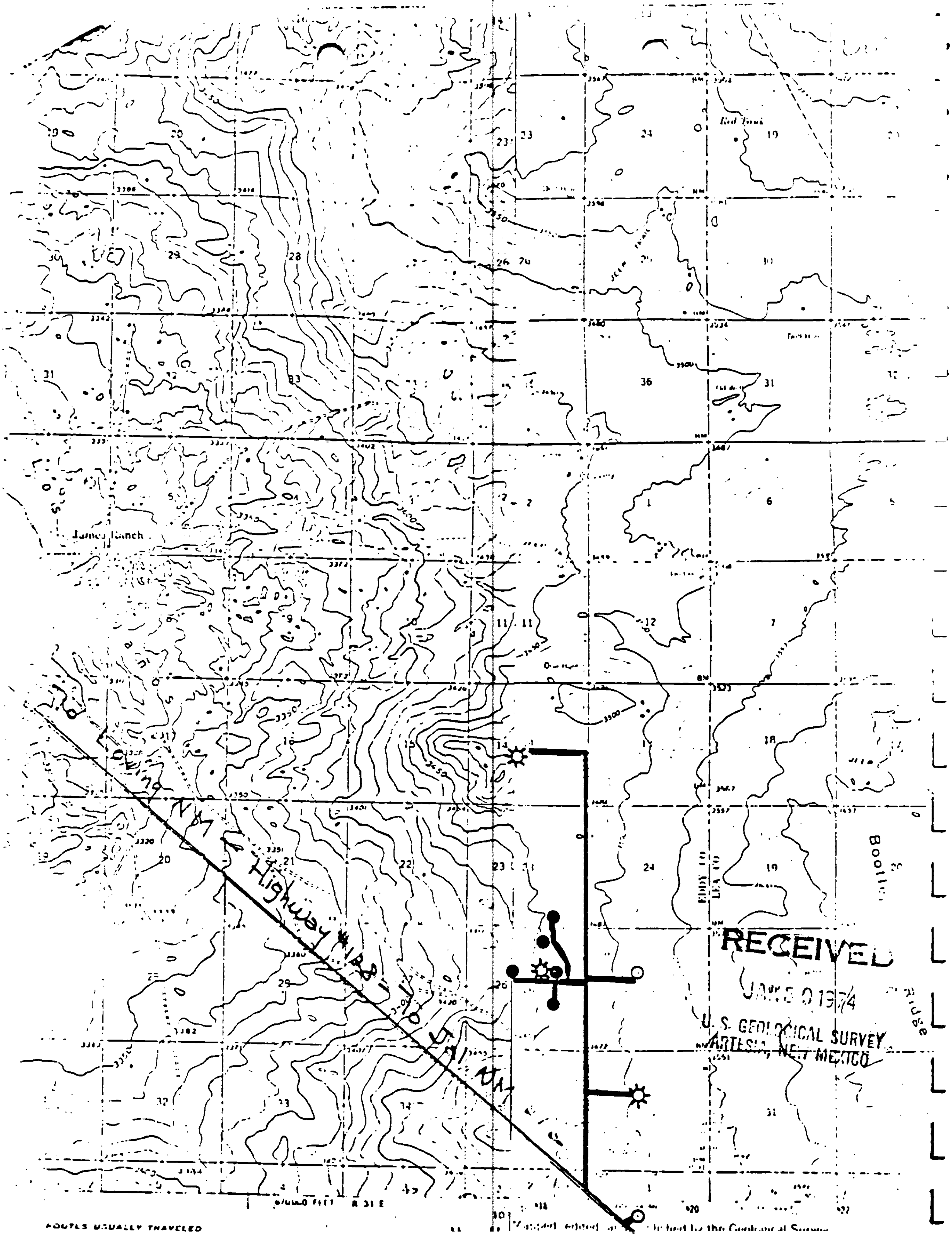
Yours very truly,

N. T. Emanuel

N. T. Emanuel

cc

Attachments


To Loving N.M. & Highway #128, 10 Mi NM
James Ranch
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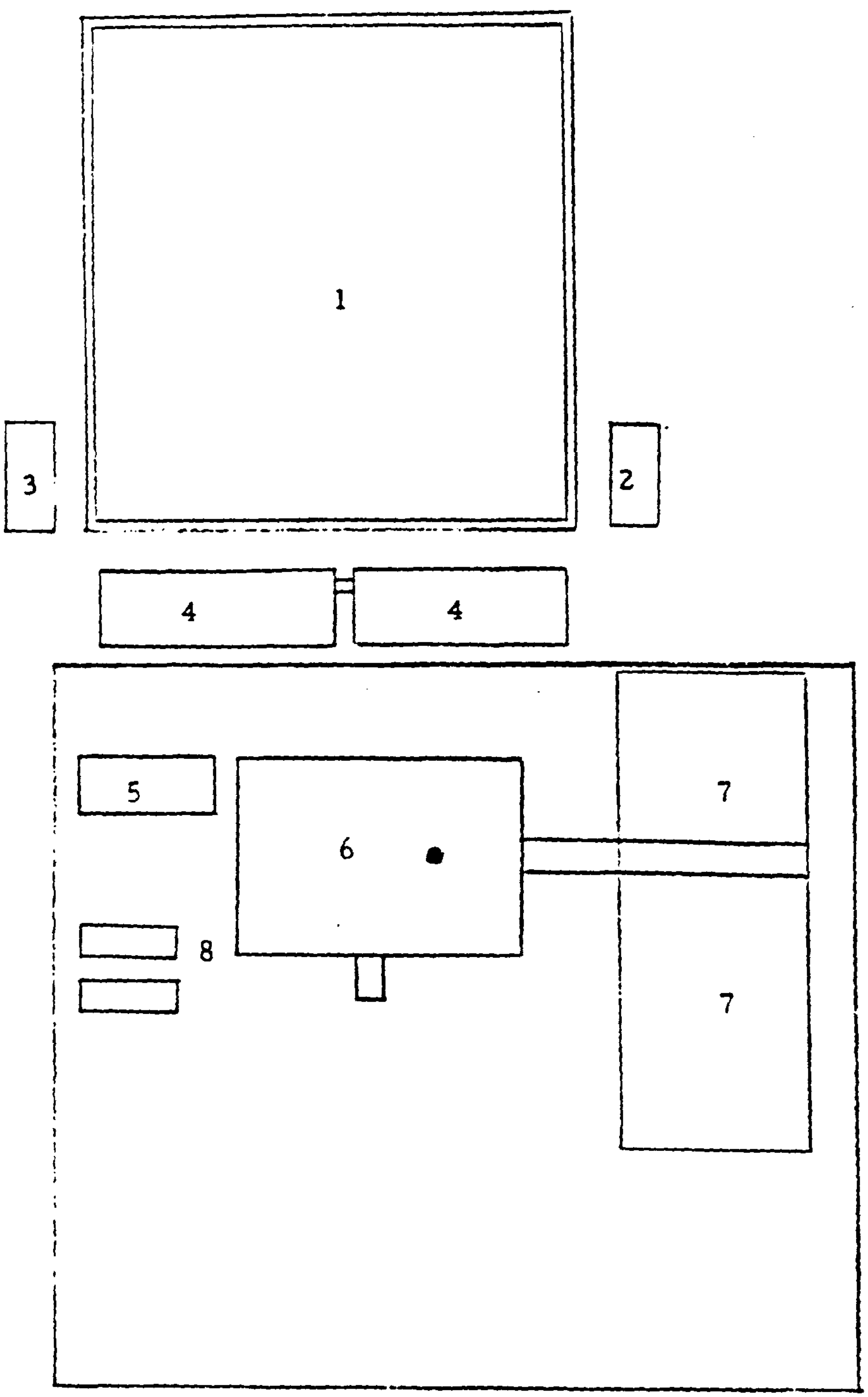
ARTESIA, NEW MEXICO
EDDY CO
LEA CO
Bootle
Ridge
R 31 E
ROUTES USUALLY TRAVELED

DRILLING LOCATION



1 - Reserve Pit
2 - Waste Water Pit
3 - Burn Pit
4 - Mud Tanks
5 - Mud Pump
6 - Drilling Rig
7 - Pipe Racks
8 - Water Storage Tanks

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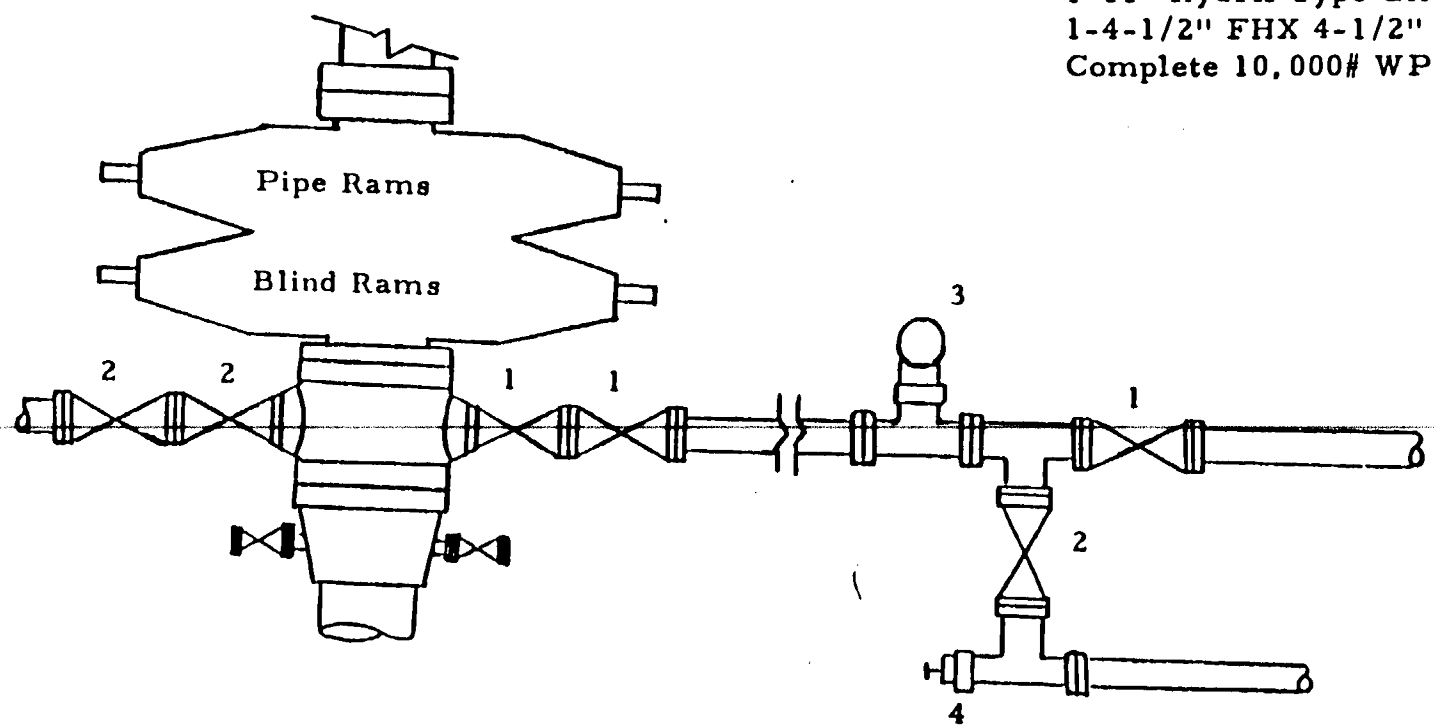
A[illegible], [illegible] MEXICO

DOUBLE SERIES 900 BLOW OUT PREVENTER

NOTE:

Below 4400' the equipment shown will be replaced with the following:
3-11" Shaffer Type XHP 10,000# W.P.
1-11" Hydril Type GK - 10,000, 10,000# W
1-4-1/2" FHX 4-1/2" FH inside BOP
Complete 10,000# WP choke Manifold



1 - 4" Series 900 Valves
2 - 2" Series 900 Valves
3 - 2" Mud Pressure Gauge
4 - 2" Series 900 Choke

EXHIBIT

[redacted] L CONSERVATION DIVISIO [redacted]

P. O. BOX 2088
SANTA FE, NEW MEXICO 87501

FEB 1 7 1983

O. C. D.
ARTESIA OFFICE

REQUEST FOR ALLOWABLE
AND
AUTHORIZATION TO TRANSPORT OIL AND NATURAL GAS

Operator: C. Williamson

Address: P. O. Box 16, Midland, Texas 79702

Reason(s) for filing: Change in Transporter of: Oil [X]

Other (Please explain)

If change of ownership give name and address of previous owner

DESCRIPTION OF WELL AND LEASE

Lease Name	Well No.	Pool Name, Including Formation	Kind of Lease	Lease No.
EP-USA	1	Brushy Draw Delaware	State, Federal or Fee: Federal	13997

Location: Unit Letter I : 1650 Feet From The South Line and 660 Feet From The East

Line of Section 26 Township 26-S Range 29-E County Eddy

DESIGNATION OF TRANSPORTER OF OIL AND NATURAL GAS

Name of Authorized Transporter of Oil [X] or Condensate [ ]	Address (Give address to which approved copy of this form is to be sent)
Navajo Crude Oil Pruchasing Company	P. O. Drawer 175, Artesia, New Mexico 88210

Name of Authorized Transporter of Casinghead Gas [ ] or Dry Gas [ ]	Address (Give address to which approved copy of this form is to be sent)
El Paso Natural Gas	P. O. Box 1492 El Paso, Texas 79978

If well produces oil or liquids, give location of tanks	Unit	Sec.	Twp.	Rge.	Is gas actually connected?	When
	I	26	26	29	Yes	4-1-82

If this production is commingled with that from any other lease or pool, give commingling order number:

COMPLETION DATA

Designate Type of Completion – (X)	Oil Well	Gas Well	New Well	Workover	Deepen	Plug Back	Same Res'v.	Diff. Res'v.
	X	X						

Date Spudded	Date Compl. Ready to Prod.	Total Depth	P.B.T.D.
6/29/81	10/1/81	3047'	3047'

Elevations (DF, RKB, RT, GR, etc.)	Name of Producing Formation	Top Oil/Gas Pay	Tubing Depth
2893.2 GR	Delaware	2988'	2865'

Perforations: Open hole

Depth Casing Shoe

TUBING, CASING, AND CEMENTING RECORD

HOLE SIZE	CASING & TUBING SIZE	DEPTH SET	SACKS CEMENT
18"	10 3/4"	361'	Circulated Cement
10"	8 5/8"	1291'	Mudded In
8"	5 1/2"	2968'	275
5"	2 3/8"	2865'	Hung on well head

TEST DATA AND REQUEST FOR ALLOWABLE

(Test must be after recovery of total volume of load oil and must be equal to or exceed top allowable for this depth or be for full 24 hours)

OIL WELL

Date First New Oil Run To Tanks	Date of Test	Producing Method (Flow, pump, gas lift, etc.)	
10/3/81	10/8/81	Flow	
Length of Test	**Tubing Pressure**	**Casing Pressure**	**Choke Size**
24 hrs	95#	Packer	16/64"
Actual Prod. During Test	**Oil-Bbls.**	**Water-Bbls.**	**Gas-MCF**
1 BBL & 0 BW	1	none	1,458

GAS WELL

Actual Prod. Test-MCF/D	Length of Test	Bbls. Condensate/MMCF	Gravity of Condensate
1,458	24	0.686	42
Testing Method (pitot, back pr.)	**Tubing Pressure (Shut-in)**	**Casing Pressure (Shut-in)**	**Choke Size**
Dead Weight Back Press	350#	Packer	16/64"

CERTIFICATE OF COMPLIANCE

I hereby certify that the rules and regulations of the Oil Conservation Division have been complied with and that the information given above is true and complete to the best of my knowledge and belief.

(Signature)

Production Secretary
(Title)

02-16-83
(Date)

OIL CONSERVATION DIVISION

APPROVED FEB 1 8 1983, 19

Original Signed By

BY

Supervisor District II

TITLE

This form is to be filed in compliance with RULE 1104.

If this is a request for allowable for a newly drilled or deepened well, this form must be accompanied by a tabulation of the deviation tests taken on the well in accordance with RULE 111.

All sections of this form must be filled out completely for allowable on new and recompleted wells.

Fill out only Sections I, II, III, and VI for changes of owner, well name or number, or transporter, or other such change of condition.

Separate Forms C-104 must be filed for each pool in multiply completed wells.

EP-USA Williamson #1

26-26S-29E NE/SE Ut-I

WILLIAMSON, J. C.
EP-USA
Sec 26, T26S, R29E
1650 FSL, 660 FEL of Sec
16 mi SE/Malaga

30-015-23786
1-3-35 NM
7-25-81 10-8-81
WELL CLASS WF DG

10 3/4-361-100 sx
8 5/8-1291-mudded
5 1/2-2968-275 sx
2 3/8-2865

TD 3047 (DLWR)

IP (Delaware) OH 2968-3047 F 1456 MCFGPD. Pot based on 24 hr test thru 16/64 chk. GOR 1456,000; gty (Gas) (NR); (Cond) 42; CP Pkr; TP 354

Landis #1

	F.R. 5-25-81
	PD 4000 RT (Delaware)
1-16-82	AMEND FIELD & ZONE: Formerly reported as Wildcat (Cherry Canyon)
7-27-81	Drlg 1500
8-3-81	TD 1700; fsg
8-11-81	TD 1700; fsg
8-18-81	TD 1700; SD WOW
8-24-81	TD 1700; fsg
8-31-81	Drlg 2075 anny Recd fish
9-15-81	TD 3047; WO Equip DST (Delaware Lime) 2988-91, had GTS, blew tool out of hole - kink in line
9-21-81	TD 3047; WO materials
9-24-81	TD 3047; WOCU
10-5-81	TD 3047; Prep tmp

SIGNED TITLE DATE

(This space for Federal or State office use)

APPROVED BY US GEOL... TITLE DATE
CONDITIONS OF APPROVAL IF ANY.

*See Instructions on Reverse Side

J.C. Williamson 26-1
EP-USA #1 NE/SE 9K-1

SUPPLEMENTAL DRILLING DATA

J.C. WILLIAMSON
WELL #1 EP-USA

1. SURFACE FORMATION: Quaternary Alluvium

2. ESTIMATED TOPS OF GEOLOGIC MARKERS:

Rustler Anhydrite	350'
Lamar	3110'
Ramsey Sand	3165'
Olds Sand	3220'
Top Cherry Canyon	4150'

3. ANTICIPATED POSSIBLE WATER AND HYDROCARBON BEARING ZONES:

Fresh Water	above 350 feet
Delaware (Oil)	3165-3175 feet
Cherry Canyon (Oil)	4000-4200 feet

4. PROPOSED CASING AND CEMENTING PROGRAM:

Casing program is shown on Form 9-331 C.

Hole for surface casing will be drill to below fresh water zones. Surface casing will then be run to bottom and cemented to the surface to protect fresh water zones.

Surface casing is large enough to run 8-5/8: and 7" cave in and/or water shut-off casing strings if necessary to do so. If either or both of these casing strings are run they will be mudded in and will be pulled

10-3/4" surface casing will be cemented to the surface with class "C" cement,

7" protection casing will be cemented with 150 sacks of Class "C" cement at 3300'

4-1/2" in production casing will be cemented at total depth or shallowing if significant shows are encountered in its Middle Delaware formation

5. PRESSURE CONTROL EQUIPMENT:

Pressure control equipment will consist of a control valve and oil saver.

6. CIRCULATING MEDIUM:

This will be a cable tool hole. Water will be the drilling fluid.

J.C.Wi
EP-USA

7. AUXILIARY EQUIPMENT:

Not applicable.

8. TESTING, LOGGING AND CORING PROGRAM:

No coring is planned.

Formation tests will be made as warranted by bailing hole down and measuring fluid entry rate.

It is planned that a Gamma Ray - Sonic log will be run.

9. ABNORMAL PRESSURES, TEMPERATURES OR HYDROGEN SULFIDE GAS:

None anticipated.

10. ANTICIPATED STARTING DATE:

It is planned that operating will commence on June 20, 1981.

J.C.W1
EP-USA

J. C. WILLIAMSON, EP-USA #1-I, 26-26-29

Telephone conversation with Mr. Williamson

9/15/81 @ 2:24 p.m.

TD 3047'

10 3/4 @ 350 circ

8 5/8 @ 850, (Murdock said 1250 of 8 5/8) mud to shut off water

5½ @ 3000'

Can not close in "Boots and Coots" has head to strip in tubing.
BHP approximately 1800#, Surface press approximately 1600#, venting 2½ MMCF Gas

Saturday blowed out (9-12-81)

Changed out well head, will move on pulling unit and start running tubing.

9/16/81 J. C. Williamson called

Have new head on and 1 joint tubing in hole with 3 vent lines.

Will strip tubing this a.m. and kill well and run 5½" and cement back to

intermediate.

9/23/81

5½" casing cemented, well dead, TOC @ 2400'.

J.C.W.
EP-USA

[redacted]EW MEXICO OIL CONSERVATION C[redacted] Form C-122 Revised
MULTIPOINT AND ONE POINT BACK PRESSURE TEST FOR GAS WELLS

RECEIVED
JUN 20 1978
O. C. C.
ARTESIA, OFFICE

Type Test: XX Initial ☐ Annual ☐ Special			Test Date: 5-11-78	
Company: Yates Petroleum Corporation	Connection: El Paso Natural Gas Company			
Pool: North Burton Flat	Formation: Atoka			Unit
Completion Date: 5-9-78	Total Depth: 11,640' KB	Plug Back TD: 10,976	Elevation: 3285' KB	Farm or Lease Name: Williamson "BC" Fed.
Csg. Size: 4-1/2" Wt. 11.6#	d: 3.985 Set At: 11,623'	Perforations: From 10792 To 10800' KB		Well No.: 4
Tbg. Size: 2-3/8" Wt. 4.7#	d: 1.995 Set At: 10790'	Perforations: From 10744 To 10747' KB		Unit K Sec. 7 Twp. 20S Rge. 29E
Type Well — Single — Bradenhead — G.G. or G.O. Multiple: Single		Packer Set At: 10,738' KB		County: Eddy
Producing Thru: Tubing	Reservoir Temp. °F: 162 @ 10800	Mean Annual Temp. °F: 62	Baro. Press. — P_a: 13.2	State: New Mexico
L: 10786	H: 10786	G_g: 0.706	% CO_2: 0.60	% N_2: 0.37
% H_2S: Nil	Prover:	Meter Run: 4"	Taps: Flange	

NO.	Prover Line Size x Orifice Size (Flow Data)	Press. p.s.i.g.	Diff. h_w	Temp. °F	Tubing Press. p.s.i.g.	Tubing Temp. °F	Casing Press. p.s.i.g.	Casing Temp. °F	Duration of Flow
SI					3261	69			24 hours
1.	4.026 x 1.250	549	20	68	3095	73			1 hour
2.		550	41	68	2954	75			1 hour
3		550	69	68	2858	78			1 hour
4		551	95	68	2792	81			1 hour
5.									

RATE OF FLOW CALCULATIONS

NO.	Coefficient (24 Hour)	$\sqrt{h_w P_m}$	Pressure P_m	Flow Temp. Factor F_t	Gravity Factor F_g	Super Compress. Factor, F_{pv}	Rate of Flow Q, Mcfd
1	7.469	106.04	562.2	.9924	1.272	1.050	1050
2	7.469	151.96	563.2	.9924	1.272	1.050	1504
3	7.469	197.13	563.2	.9924	1.272	1.050	1952
4	7.469	231.51	564.2	.9924	1.272	1.050	2292
5							

NO	P_r	Temp. °R	T_r	Z
1	.835	528	1.454	.907
2	.837	528	1.454	.907
3	.837	528	1.454	.907
4	.838	528	1.454	.907
5				

Gas Liquid Hydrocarbon Ratio 48.84 Mcf/bbl.
A.P.I. Gravity of Liquid Hydrocarbons 56.2 Deg.
Specific Gravity Separator Gas .618 xxxxxxxxx
Specific Gravity Flowing Fluid xxxxx .706
Critical Pressure 673 P.S.I.A. 665 P.S.I.A.
Critical Temperature 363 R 452 R

P_c 4406 P_c^2 19413

NO	P_t^2	P_w	P_w^2	$P_c^2 - P_w^2$
1			17703	1710
2			16332	3081
3			15453	3960
4			14861	4552
5				

(1) $\frac{P_c^2}{P_c^2 - P_w^2}$ = 4.2647   (2) $\left[\frac{P_c^2}{P_c^2 - P_w^2}\right]^n$ = 4.2647

AOF = Q $\left[\frac{P_c^2}{P_c^2 - P_w^2}\right]^n$ = 9775

Absolute Open Flow 9775 Mcfd @ 15.025   Angle of Slope θ 45 degrees   Slope, n 1.0000

Remarks: Static pressures by Bennett Wireline; flowing pressures by DWT.
NOTE: Well was not completely cleaned up when put on lineand Gmix reflects 3 bbls water in 1st 24 hours production.

Approved by Commission:	Conducted By:	Calculated By:	Checked By:
	Bill Trembley, Jr.	Eddie M. Mahfood	

13000	24	-	-
Testing Method (pitot, back pr.)	Tubing Pressure (Shut-in)	Casing Pressure (Shut-in)	Choke Size
Back Pressure	3250#	Pkr	3/4"

VI. CERTIFICATE OF COMPLIANCE

I hereby certify that the rules and regulations of the Oil Conservation Commission have been complied with and that the information given above is true and complete to the best of my knowledge and belief.

Christine Tomlinson
(Signature)
Christine Tomlinson-Geol. Secty.
(Title)
5-10-78
(Date)

OIL CONSERVATION COMMISSION

APPROVED MAY 22 1978, 19
BY W. A. Gressett
TITLE SUPERVISOR, DISTRICT II

This form is to be filed in compliance with RULE 1104.

If this is a request for allowable for a newly drilled or deepened well, this form must be accompanied by a tabulation of the deviation tests taken on the well in accordance with RULE 111.

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Fill out only Sections I, II, III, and VI for changes of owner, well name or number, or transporter, or other such change of condition.

Yates Petr. Corp.
Williamson "BC" #1
7-20
NE S
Unit

YATES PETROLEUM CORP.
Williamson "DC"

WELL

Sec 7, T20S, R29E
1980' FSL, 1980' FWL of Sec — 11-1-8 NM
11 mi NE/Carlsbad — SPD 6-28-77 — CMP 10-31-77

13 3/8" at 590' w/480 sx
8 5/8" at 2925' w/450 sx
4 1/2" at 11,623' w/615 sx

WELL CLASS: INIT D FIN SUS ELEV

FORMATION	DATUM	FORMATION	DATUM

TD 11,640' (MRRW) PBD

SUSPENDED OPERATIONS

CONTR Moranco — OPRS ELEV 3270' GL — PD 11,700' RT

WILDCAT
OW

CABLE TOOLS

WAS DIRECTIONAL SURVEY MADE
No

WELL CORED
No

F.R. 2-21-77
(Morrow)

7-5-77	TD 3055'; Rng 8 5/8" Csg
7-19-77	Drlg 7695'
8-3-77	Drlg 11,132'
8-8-77	Drlg 11,600'
8-16-77	TD 11,640'; WOCU
9-1-77	TD 11,640'; WOCU
10-31-77	TD 11,640'; Suspended Operations
	LOGS RUN: DILL, CNDL, CNL, FDC
	BHT 172 deg
11-5-77	COMPLETION ISSUED

11-1-8 NM
IC 30-015-70073-77

PACKER SET
11226

DISPOSITION OF GAS (Sold, used for fuel, vented, etc.)
Vented

TEST WITNESSED BY
H.A. Apple

LIST OF ATTACHMENTS

I hereby certify that the foregoing and attached information is complete and correct as determined from all available records

SIGNED [signature] TITLE Geol. Secty DATE 10-19-77

*(See Instructions and Spaces for Additional Data on Reverse Side)

DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

NM 01165

SUNDRY NOTICES AND REPORTS ON WELLS

(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir. Use "APPLICATION FOR PERMIT—" for such proposals.)

RECEIVED
OCT 19 1977
U.S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

1. OIL WELL ☐ GAS WELL ☒ OTHER

2. NAME OF OPERATOR: Yates Petroleum Corporation

3. ADDRESS OF OPERATOR: 207 South 4th Street - Artesia, NM 88210

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements. See also space 17 below.) At surface: 1980' FSL & 1980' FWL of Section 7-20S-29E

8. FARM OR LEASE NAME: Williamson "BC"

9. WELL NO.: 4

10. FIELD AND POOL, OR WILDCAT: ~~Wildcat~~ East Burton Flat (Morrow)

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA: Sec. 7-20S-29E Unit K NMPM

RECEIVED
OCT 27 1977
O.C.C.
ARTESIA, OFFICE

14. PERMIT NO.:

15. ELEVATIONS (Show whether DF, RT, GR, etc.): 3270' GR

12. COUNTY OR PARISH: Eddy | 13. STATE: NM

16. Check Appropriate Box To Indicate Nature of Notice, Report, or Other Data

NOTICE OF INTENTION TO:

TEST WATER SHUT-OFF ☐ PULL OR ALTER CASING ☐
FRACTURE TREAT ☐ MULTIPLE COMPLETE ☐
SHOOT OR ACIDIZE ☐ ABANDON* ☐
REPAIR WELL ☐ CHANGE PLANS ☐
(Other)

SUBSEQUENT REPORT OF:

WATER SHUT-OFF ☐ REPAIRING WELL ☐
FRACTURE TREATMENT ☒ ALTERING CASING ☐
SHOOTING OR ACIDIZING ☒ ABANDONMENT* ☐
(Other) Set Production casing ☒

(NOTE: Report results of multiple completion on Well Completion or Recompletion Report and Log form.)

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

Ran 45 joints of 4½" 13.5# N-80 (1433'), 320 joints of 4½" 11.6# N-80 (10190') of casing (Total 11623'). Diff-Float Shoe at 11623', Diff-Fill Collar at 11587'. 10 centralizers. Cemented as follows: 250 gallons mud flush, followed w/365 sacks of Halli-Lite + 1/% CFR-2 + 5#/sx KCL, tailed in w/250 sacks of Class H + 1/2% CFR-2 + 5#/sx KCL. PD 2:10 PM 8-11-77. Pressure tested to 2500#. OK. WOC and ran Temperature Survey and found top of cement at 8600'. WLPBTD 11600'.

TD 11640 - WIH w/Tubing Conveyed Gun, Baker Loc-Set Packer on 2-3/8" tubing, set packer at 11442'. Perforated 11455-11468' w/40 .32" shots as follows: 11455-11460' (20 holes), 14463-11468' (20 holes). No shows. Treated perforations w/1000 gallons of 7½" MS acid w/ball sealers. Well cleaned up and flowed an estimated 250 MCFPD w/spray of water.

WIH w/Bridge Plug in packer at 11422'. Pulled tubing out of hole. RIH w/ Tubing Conveyed Gun, Guiberson Uni VI packer, set packer at 11342' and perforated 11387-11391' w/16.32" holes. Swabbed back water.

Set Blanking Plug w/wireline in packer at 11327'. Backed off tubing On-Off Tool at 11326' & POOH. RIH w/Tubing Conveyed Gun on Guiberson Unit VI packer & 2-3/8" tubing, set packer at 11226' and perforated the Upper Morrow at 11264-271' w/28.32" shots. GTS in 1 min. - 1100# 3/4" choke. = 15,750 MCFPD

18. I hereby certify that the foregoing is true and correct

SIGNED Christine Tomlinson TITLE Geol. Secty DATE 10-18-77

(This space for Federal or State office use)

APPROVED BY [signature] TITLE ACTING DISTRICT ENGINEER DATE OCT 25 1977
CONDITIONS OF APPROVAL, IF ANY:

*See Instructions on Reverse Side

RECEIVED

SUNDRY NOTICES AND REPORTS ON WELLS

(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir. Use "APPLICATION FOR PERMIT—" for such proposals.)

JUL 15 1977

U.S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

1. OIL WELL ☐ GAS WELL ☒ OTHER

2. NAME OF OPERATOR: Yates Petroleum Corporation

3. ADDRESS OF OPERATOR: 207 South 4th Street - Artesia, NM 88210

4. LOCATION OF WELL (Report location clearly and in accordance with any State requirements.) See also space 17 below.) At surface: 1980' FSL & 1980' FWL of Section 7-20S-29E

RECEIVED
JUL 19 1977
O. C. C.
ARTESIA, OFFICE

7. UNIT AGREEMENT NAME:

8. FARM OR LEASE NAME: Williamson "BC"

9. WELL NO.: 4

10. FIELD AND POOL, OR WILDCAT: ~~Wildcat~~ (Morrow)

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA: Sec. 7-20S-29E NMPM Unit K

14. PERMIT NO.:

15. ELEVATIONS (Show whether DF, RT, GR, etc.): 3270' GR

12. COUNTY OR PARISH: Eddy

13. STATE: NM

16. Check Appropriate Box To Indicate Nature of Notice, Report, or Other Data

NOTICE OF INTENTION TO:				SUBSEQUENT REPORT OF:			
TEST WATER SHUT-OFF	☐	PULL OR ALTER CASING	☐	WATER SHUT-OFF	☒	REPAIRING WELL	☐
FRACTURE TREAT	☐	MULTIPLE COMPLETE	☐	FRACTURE TREATMENT	☐	ALTERING CASING	☐
SHOOT OR ACIDIZE	☐	ABANDON*	☐	SHOOTING OR ACIDIZING	☐	ABANDONMENT*	☐
REPAIR WELL	☐	CHANGE PLANS	☐	(Other)			
(Other)							

(NOTE: Report results of multiple completion on Well Completion or Recompletion Report and Log form.)

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

Spudded a 17½" hole at 4:00 PM 6-28-77. TD 590' - Ran 15 jts of 13-3/8" csg 61# K-55 ST&C (595.54') set at 590'. Cmtd w/280 sx of Class C 4% CaCl + 1/4# flocele/sx tailed in w/200 sx Class C 4% CaCl. Slurry wt. 14.8, 1.32 cu ft/sx. Compressive Strength at 70 deg 1023 psi in 12 hours. PD 5:05 PM 6-29-77. Cement circulated 35 sx to surface. WOC 12 hours, cut off csg. NU, reduced hole to 12¼" drilled plug and tested to 600#, OK. Resumed drlg. TD 3055' - Ran 12 jts of 8-5/8" 32# J-55 (483') & 59 jts of 8-5/8" 24# J-55 (2442') (Total 2925') of csg. set at 2925'. 1-Guide shoe, insert float at 2885', centralizers at 2885', 1760 & basket at 1750'. Cemented w/1100 sx Howco Lite + 1/4# flocele 2% CaCl tailed in w/200 sx of Class C 2% CaCl. PD 7:04 AM 7-3-77. Cement did not circulate. WOC and ran Temperature Survey at 1:30 PM 7-3-77. Found top of cement at 1850. Ran 1" to 1287', spotted 150 sacks of Class C 4% CaCl. PD 5:30 PM 7-4-77. WOC 4 hrs, dumped 1/2 yd pea. Ran 1" to 1287', spotted 50 sacks of Class C 4% CaCl. PD 4:00 AM 7-5-77. WOC 4 hours dumped 1/4 yd of pea gravel. Ran 1" to 1038', spotted 225 sacks of Class C 4% CaCl. PD 2:10 PM 7-5-77. WOC 6 hrs dumped ½ yd pea gravel. Ran 1" to 1088', spotted 50 sacks of Class C 4% CaCl. PD 11:50 PM 7-5-77. WOC 2 hours. Ran 1" to 1038', spotted 100 sacks of Class C 4% CaCl. PD 1:30 PM 7-6.77. WOC 4 hrs, dumped ½ yd pea gravel. ~~(Cont'd on attached page)~~

18. I hereby certify that the foregoing is true and correct

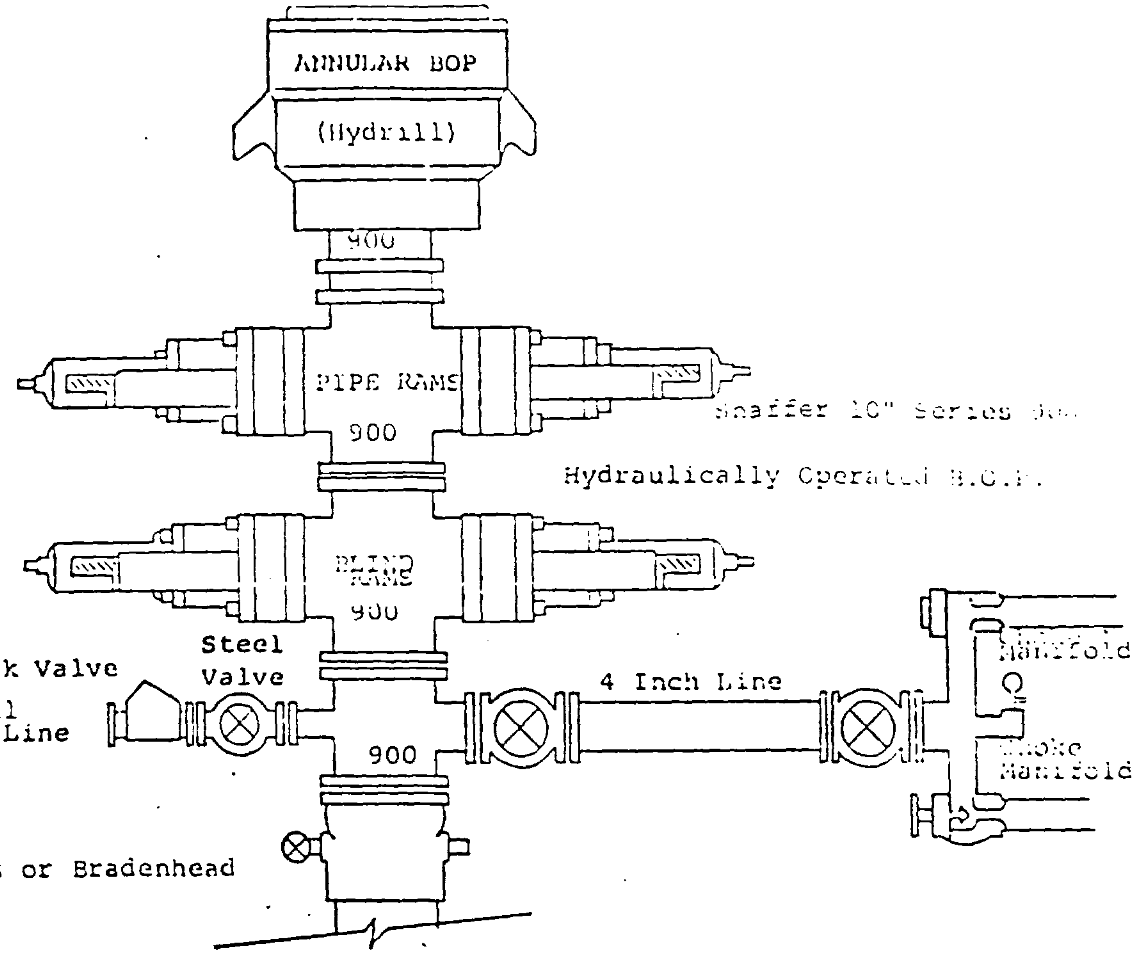
SIGNED [signature] TITLE Geol. Secty DATE 7-15-77

(This space for Federal or State office use)

APPROVED BY [signature] TITLE ACTING DISTRICT ENGINEER DATE JUL 18 1977

CONDITIONS OF APPROVAL, IF ANY:

*See Instructions on Reverse Side



THE FOLLOWING CONSTITUTE MINIMUM BLOWOUT PREVENTER REQUIREMENTS

1. All preventers to be hydraulically operated with secondary manual controls installed prior to drilling out from under casing.
2. Choke outlet to be a minimum of 4" diameter.
3. Kill line to be of all steel construction of 2" minimum diameter.
4. All connections from operating manifolds to preventers to be all steel hole or tube a minimum of one inch in diameter.
5. The available closing pressure shall be at least 15% in excess of that required with sufficient volume to operate the B.O.P.'s.
6. All connections to and from preventer to have a pressure rating equivalent to that of the B.O.P.'s.
7. Inside blowout preventer to be available on rig floor.
8. Operating controls located a safe distance from the rig floor.
9. Hole must be kept filled on trips below intermediate casing. Operator not responsible for blowouts resulting from not keeping hole full.
10. D. P. float must be installed and used below zone of first gas intrusion.

Exhibit "D"

Tops per JWR
– 9107
– 7880
– 10,158
– 10,500

NAME

6-4-7 NM

/Loco Hills

SPD 2-21-79 CMP 6-18-79

WELL CLASS: INIT D FIN SUS ELEV

13 3/8" at 765' w/800 sx
9 5/8" at 4600' w/1750 sx
5 1/2" at 11,800' w/2700 sx

FORMATION	DATUM	FORMATION	DATUM

TD 11,800' (MRRW) PBD 11,758'

nit Federal

nian

URVEY OR

SUSPENDED OPERATIONS

16.

Landis #2 — 3638' GL — TD 13,300' RT

AND WD)

17.

F.R. 6-5-78
(Morrow)

2-23-79	TD 765'; Reaming
3-2-79	Drlg 3255' anhy
3-9-79	Drlg 4680'
3-16-79	Drlg 8400'
3-23-79	Drlg 10,758' lm
4-2-79	TD 11,800'; Prep Run Csg
	DST (Atoka) 11,035-140', open 1 hr 30 mins, GTS in 20 mins @ 450 MCFPD thru 3/8" chk, rec 100' Gas & Cond cut wtr + 1068' WB + 785' GCDF, ISIP failed, FP 591-841#, 3 hr FSIP 2214#, HP 5647-5647#, BHT 159 deg
4-5-79	TD 11,800'; SI
	Well blew out, did not burn
4-6-79	TD 11,800'; Installing BOP

6-4-7 NM

installed
bbing

11,600'.

Amoco Prod. Co. 35-18S-31E
Greenwood Pre Grbg.Ut.Fed.A Com #1 Ut.F SE NW

(This space for Federal or State office use)

APPROVED BY (Orig. Sgd.) ALBERT R. STALL TITLE ACTING DISTRICT ENGINEER DATE MAY 1 0 1979
CONDITIONS OF APPROVAL, IF ANY:

*See Instructions on Reverse Side

AMOCO PRODUCTION CO.

12 Greenwood Unit Federal Page 3

Sec 35, T18S, R31E

4-6-79	Continued Moved rig off loc to install new BOP
4-17-79	TD 11,800'; SD/Rig Rep.
4-20-79	TD 11,800'; SD
4-26-79	TD 11,800'; WOCU
5-6-79	TD 11,800'; PBD 11,758'; Tstg TD 11,800'; PBD 11,758', 11,492-508', 11,566-581' w/4 SPF Perf (Morrow) 11,492-508', 11,566-581' w/4 SPF Flwd 4500 MCFGPD in 7 hrs thru 24/64" chk, TP 1350# (11,492-581') TD 11,800'; PBD 11,758'; SI
6-9-79	TD 11,800'; PBD 11,758'; Suspended Operations
6-18-79	Rig Released 4-25-79
6-23-79	TEMPORARY COMPLETION ISSUED

6-4-7 NM

IC 30-015-70192-78

SUNDRY NOTICES AND REPORTS ON WELLS

(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir. Use Form 9-331-C for such proposals.)

RECEIVED

MAY 14 1979

O. C. C.
ARTESIA, OFFICE

6. IF INDIAN, ALLOTTEE OR TRIBE NAME

7. UNIT AGREEMENT NAME

8. FARM OR LEASE NAME
Greenwood Pre-Grayburg Unit Federal

9. WELL NO.
12

10. FIELD OR WILDCAT NAME
Shugart Silurian-Devonian

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA
35-18-31

12. COUNTY OR PARISH: Eddy 13. STATE: NM

14. API NO.

15. ELEVATIONS (SHOW DF, KDB, AND WD)
3653.9 RDB

1. oil well ☐ gas well ☒ other

2. NAME OF OPERATOR
Amoco Production Company

3. ADDRESS OF OPERATOR
P. O. Box 68, Hobbs, NM 88240

4. LOCATION OF WELL (REPORT LOCATION CLEARLY. See space 17 below.)
AT SURFACE: 1650' FNL & 1980' FWL,
AT TOP PROD. INTERVAL: Sec 35 (Unit F, SE/4 NW/4)
AT TOTAL DEPTH:

16. CHECK APPROPRIATE BOX TO INDICATE NATURE OF NOTICE, REPORT, OR OTHER DATA

	REQUEST FOR APPROVAL TO:	SUBSEQUENT REPORT OF:
TEST WATER SHUT-OFF	☐	☒
FRACTURE TREAT	☐	☐
SHOOT OR ACIDIZE	☐	☒
REPAIR WELL	☐	☐
PULL OR ALTER CASING	☐	☐
MULTIPLE COMPLETE	☐	☐
CHANGE ZONES	☐	☐
ABANDON*	☐	☐
(other)		

RECEIVED

MAY 10 1979

U.S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

(NOTE: Report results of multiple completion or zone change on Form

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

On 4-5-79 2 - 4" relief lines were installed. On 4-6-79 a new BOP was installed and gas was diverted to pit through relief lines. Pressure control snubbing equipment moved in 4-7-79. Drill pipe was snubbed in to a TD of 11,005'. Mudded up hole and stopped gas flow at 4:00 p.m. 4-16-79.

Moved in Landis Rig #2 4-19-79. Set 5-1/2" (4,091' 20# & 7,709' 17# N-80 LT&C) casing at 11,800. Cemented with 1500 SX Trinity Lite cement and 1200 SX Class H cement. Approximate top of cement at 1,160' by temperature survey. Plugged down 1:30 a.m. 4-24-79. Released rig 4-25-79.

Moved in service unit 4-30-79. Spotted 200 gal 10% Acetic Acid 11,386'-11,600'. Perforated intervals 11,492'-508' and 11,566'-581' using 4 JSPF. Set packer at 10,900' and set tailpipe at 10,972'. Drop bar on shear disc and flow test well. Currently shut-in for BHP survey.

Subsurface Safety Valve: Manu. and Type ____ Set @ ____ Ft.

18. I hereby certify that the foregoing is true and correct

SIGNED Ray Cox TITLE Admin. Supervisor DATE 5-7-79

(This space for Federal or State office use)

APPROVED BY (Orig. Sgd.) ALBERT L. STALL TITLE ACTING DISTRICT ENGINEER DATE MAY 10 1979

CONDITIONS OF APPROVAL, IF ANY

*See Instructions on Reverse Side

Amoco Prod. Co.
Greenwood Pre Grbg.Ut.Fed.A Com #1 Ut.F
35-18S-31E
SE NW

RECEIVED
APR 27 1979
O.C.C.
ARTESIA, OFFICE

NAME OF OPERATOR Amoco Production Company	ADDRESS P.O. Drawer "A", Levelland, TX

REPORT OF	FIRE	BREAK	SPILL	LEAK	BLOWOUT	OTHER*
					X	

TYPE OF FACILITY	DRLG WELL	PROD WELL	TANK BTTY	PIPE LINE	GASO PLNT	OIL RFY	OTHER*
	X						

NAME OF FACILITY Greenwood PreGrayburg Unit Federal Well No. 12

LOCATION OF FACILITY (QUARTER/QUARTER SECTION OR FOOTAGE DESCRIPTION)	SEC.	TWP.	RGE.	COUNTY
SE/4 NW/4	35	18-S	31-E	Eddy

DISTANCE AND DIRECTION FROM NEAREST TOWN OR PROMINENT LANDMARK 16 miles Southeast of Loco Hills, NM

DATE AND HOUR OF OCCURRENCE 11:15 pm 4/2/79	DATE AND HOUR OF DISCOVERY 11:15 pm 4/2/79

WAS IMMEDIATE NOTICE GIVEN?	YES	NO	NOT REQUIRED	IF YES, TO WHOM
	X			W.A. Gressett

BY WHOM V.E. Staley	DATE AND HOUR 5:00 am 4/3/79

TYPE OF FLUID LOST	QUANTITY OF LOSS	VOLUME RECOVERED
Gas and condensate	N/A	N/A

DID ANY FLUIDS REACH A WATERCOURSE?	YES	NO	QUANTITY
		X	

IF YES, DESCRIBE FULLY**

DESCRIBE CAUSE OF PROBLEM AND REMEDIAL ACTION TAKEN**

Layed down drill pipe to run casing and well started flowing. Shut-in and started pumping into well and well blew-out through BOP. Shut down all operations. Replaced BOP, snubbed in drill pipe and killed well. Run 5 1/2" casing to TD of 11,800 x cement.

DESCRIBE AREA AFFECTED AND CLEANUP ACTION TAKEN**

Drill pad and pasture northeast of well covered with spray of condensate. Replaced caliche on drill pad and cleaned up pasture that was affected.

DESCRIPTION OF AREA	FARMING	GRAZING	URBAN	OTHER*
		X		

SURFACE CONDITIONS	SANDY	SANDY LOAM	CLAY	ROCKY	WET	DRY	SNOW
		X				X	

DESCRIBE GENERAL CONDITIONS PREVAILING (TEMPERATURE, PRECIPITATION, ETC.)**

Clear, 55°F

I HEREBY CERTIFY THAT THE INFORMATION ABOVE IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE AND BELIEF

SIGNED Randy Atkins TITLE Administrative Analyst DATE April 26, 1979

*SPECIFY **ATTACH ADDITIONAL SHEETS IF NECESSARY

O+2-NMOCD,A
1-Houston
1-RWA
1-ORW
1-LF thru VES

Amoco Prod. Co.
Greenwood Pre Grbg.Ut.Fed.A Com #1 Ut.F 35-18S-31E
SE NW

NC - 9739

(Do not use this form for proposals to drill or to deepen or plug back to a different reservoir. Use Form 9–331–C for such proposals.)

APR 1 3 1979

O. C. C.
ARTESIA, OFFICE

7. UNIT AGREEMENT NAME

8. FARM OR LEASE NAME
Greenwood Frebraybur

9. WELL NO.
12

10. FIELD OR WILDCAT NAME
Shugart Silurian-Devonian

11. SEC., T., R., M., OR BLK. AND SURVEY OR AREA
35-18-31

12. COUNTY OR PARISH Eddy | 13. STATE NM

14. API NO.

15. ELEVATIONS (SHOW DF, KDB, AND WD)
3653.9 RDB

1. oil well ☐ gas well ☒ other

2. NAME OF OPERATOR
Amoco Production Company

3. ADDRESS OF OPERATOR
P.O. Drawer "A", Levelland, TX 79336

4. LOCATION OF WELL (REPORT LOCATION CLEARLY. See space 17 below.)
AT SURFACE: 1650' FNL & 1980' FWL, Sec 35
AT TOP PROD. INTERVAL: (Unit F, SE/4, NW/4)
AT TOTAL DEPTH:

16. CHECK APPROPRIATE BOX TO INDICATE NATURE OF NOTICE, REPORT, OR OTHER DATA

	REQUEST FOR APPROVAL TO:	SUBSEQUENT REPORT OF:
TEST WATER SHUT-OFF	☐	☐
FRACTURE TREAT	☐	☐
SHOOT OR ACIDIZE	☐	☐
REPAIR WELL	☐	☐
~~PULL OR~~ ALTER CASING	☒	☐
MULTIPLE COMPLETE	☐	☐
CHANGE ZONES	☐	☐
ABANDON*	☐	☐

(other) Propose to change production string from 7" to 5 1/2"
Subsequent report of blow out.

(NOTE: Report results of multiple completion or zone change on Form 9–330.)

U. S. GEOLOGICAL SURVEY
ARTESIA, NEW MEXICO

17. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details, and give pertinent dates, including estimated date of starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.)*

Drilled to TD of 11,185' and ran DST #1 11,035'-11,140' Atoka. DST results attached. Drilled to TD of 11,617' and ran DST #2 11,515'-11,580' Morrow. DST results attached. Drilled to TD of 11,800'. Circulated and logged. Circulated to run casing. Pulled out of hole to lay down drill pipe and drill collars. Mud began flowing to pit. Attempted to circulate off gas bubble and pump into well with mud and brine water. Pressure increased to 3200# and BOP began to leak. Shut down and cleared location. Notified NMOCD and USGS at 6:00 AM(NM) 4/3/79 of blowout. Red Adair on location at 2:00 PM. After surveying well, opened BOP. Cleared location of loose equipment. Shut-down operations at 5:00 PM All entry roads guarded by armed guards. Two Amoco supervisors at location during night. Commenced operations at 7:00 AM 4/4/79. Built access road to well from the south. (Over)

Subsurface Safety Valve: Manu. and Type ______ Set @ ______ Ft.

18. I hereby certify that the foregoing is true and correct

SIGNED Kay Cox TITLE Admin. Supervisor DATE April 6, 1979

(This space for Federal or State office use)

APPROVED BY (Orig. Sgd.) ALBERT R. STALL TITLE ACTING DISTRICT ENGINEER DATE APR 1 2 1979

CONDITIONS OF APPROVAL, IF ANY:

0+4-USGS,A
1-RWA
1-Houston
1-Susp

*See Instructions on Reverse Side

Texas roundup

2 dead, 2 critical in gas well accident

ANDREWS, Texas (AP) — Two men remained in critical condition Sunday as a result of exposure to poisonous hydrogen sulfide gas that killed two other men when it leaked Saturday from a well being drilled southeast of Andrews.

Three other men, including two Andrews police officers, also were hospitalized.

The poisonous gas leaked from the well when the Sierra Drilling Co. rig No. 1 apparently "hit a pocket" of hydrogen sulfide at about 9:15 p.m. Saturday, a spokesman for the Texas Department of Public Safety said.

DELTA DRILLING COMPANY

Box 2012 TELEPHONE 214 595-1911

TYLER, TEXAS 75710

RECEIVED

JAN 26 1978

O. C. C.
ARTESIA, OFFICE

January 24, 1978

New Mexico Oil Conservation Commission
Drawer DD
Artesia, New Mexico 88210

RE: Report of Blowout
South Culebra Bluff No. 1 Well
Eddy County, New Mexico

Gentlemen:

This letter will confirm the prior notification given to Mr. Bill Gressett (Artesia office) and Mr. Dan Nutter (Santa Fe office) on January 4, 1978, concerning the blowout and subsequent fire at the Delta Drilling Company South Culebra Bluff No. 1 Well located 1980' FNL and 1650' FEL of Section 23, T23S, R28E, NMPM, Eddy County, New Mexico.

The South Culebra Bluff No. 1 Well was spudded by Amoco Production Company on November 6, 1977, pursuant to a Drilling Contract between Amoco Production Company, as Operator, and Brahaney Drilling Company, Inc., whose address is P. O. Box 1694, Midland, Texas, 79701, as Drilling Contractor.

On November 17, 1977, at 12:00 noon, Delta Drilling Company assumed operation of the well at a depth of approximately 4400' below the surface. Rig No. 7 of Brahaney Drilling Company, Inc. continued the drilling of such well until January 3, 1978, on which date such well, at a depth of 11,769' below the surface, encountered a gas kick, blew out and subsequently caught fire.

Operations for the drilling of a relief well and efforts to gain control of the well at the surface were commenced immediately. Control equipment has been installed on the wellhead and at present gas is being flared through two lines. Arrangements have been made to sell such gas to El Paso Natural Gas Company pursuant to an emergency gas sales contract, and it is anticipated that deliveries of such gas will be commenced on or about January 25, 1978.

Additional information concerning such well is being furnished to the New Mexico Conservation Commission pursuant to your forms C-103 and C-104.

Very truly yours,

Carl E. Haskett

Carl E. Haskett
Mgr. Corporate Engineering
and Research

cc: New Mexico Oil Conservation
Commission
P. O. Box 2088
Land Office Building
Santa Fe, New Mexico 87501

ATTACHMENT

DRILLING AT 11,769 FEET, A HIGH PRESSURE GAS ZONE WAS ENCOUNTERED. BOP AND HYDRIL WERE CLOSED AND KICK WAS BEING CIRCULATED OUT WHEN THE AUTOMATIC CHOKE FAILED FOR REASONS UNKNOWN AT THIS TIME, ALLOWING THE FULL PRESSURE TO ENTER SEPARATOR.

THE SEPARATOR WAS UNABLE TO HANDLE THE FULL PRESSURE AND SUBSEQUENTLY FAILED, WHICH IN TURN DISABLED THE CHOKE AND KILL MANIFOLD. AT THIS TIME THE WELL WAS STILL UNLOADING WATER AND GAS. THE RIG CREW STATED THAT THEY WERE UNABLE TO REACH ANY OF THE FOUR VALVES GOING TO THE MANIFOLD FROM THE BOP TO SHUT THE WELL IN. THE CREW THEN LEFT THE LOCATION FOR A PLACE OF SAFETY. THE WELL CONTINUED TO BLOW GAS AND CONDENSATE UNTIL APPROXIMATELY 5:10 A.M. THE FOLLOWING MORNING, AT WHICH TIME IT IGNITED ITSELF.

Sun Puts Damaged Platform Back on Line Following Blowout

Sun Exploration and Production Co. resumed production of natural gas last week from West Cameron Block 648 platform in the Gulf of Mexico. The platform was damaged by a blowout and subsequent fire last December.

The platform's output has reached 36 MMcfd from six wells that have been reworked since the blowout. The 13-well platform, which had a gross producing capacity of 95 MMcfd, was producing only 64 MMcfd prior to the blowout due to reduced sales to pipelines. Well A-1, which blew out, had been producing 8-12 MMcfd. There are no plans currently to redrill the well, which was capped, plugged and abandoned.

On completion of repairs the gross producing capacity of the platform from the 12 undamaged wells is expected to be 75 MMcfd, with production averaging 55 MMcfd, operator Sun says. Diamond Shamrock Offshore Partners Limited Partnership, which has a 38.333% interest in the platform, says capacity will be 85 MMcfd. Repairs on damaged portions of the platform's deck section are expected to be finished by year-end.

Well A-1 blew out last Dec. 4 during workover operations. The fire that ignited four days later destroyed the workover rig and drilling quarters. It was extinguished Dec. 31. The blowout was capped on Jan. 22.

Sun, with a 61.667% interest, has a temporary agreement to sell 16 MMcfd to Texas Eastern Pipeline Co., which was buying production from the platform prior to the blowout. Diamond Shamrock is selling 20 MMcfd to Bethlehem Steel Corp. and to Panhandle Eastern Pipe Line Corp., also a previous purchaser of gas from the platform.

Sun won't release information on the cost of repairing the platform and said it has no estimate as to how much gas was lost as a result of the blowout and resulting fire.

—CURRENT-ARGUS, Carlsbad, N.M., Monday, August 5, 1985

...and obtained from New Mexico ...versity is expected to handle an ... 44,000 takeoffs and landings an-

... for the airport was assured ... when Congress approved the 1985 ...ntal Appropriations Bill. The mea-...h now goes to President Reagan ...proval, includes $2.2 million that ...ill receive in return for the 1,667 ... university-controlled land at the ...on site.

recreation area is concerned," White said.

Sen. Pete Domenici, R-N.M., and Rep. Joe Skeen, R-N.M., issued a joint statement Friday announcing the plans for the airport would proceed following passage of the Supplemental Appropriations Bill.

Skeen said both the Ruidoso community and New Mexico State would benefit from the land transfer that clears the way for the airport's construction.

"New Mexico State will have the funds needed to continue its important range and

Fred Heckman, chairman of the Sierra Blanca Airport Commission.

Heckman said a bipartisan campaign that included Skeen, Domenici, Gov. Toney Anaya and even the Texas congressional delegation had made the new airport possible.

Domenici said months of negotiations were required at the local, state and federal levels to assure a fair agreement between NMSU and Sierra Blanca Airport Commission.

...hite Sands Rocket Test ...ted For Launch Today

...E SANDS MISSILE ... (AP) — One of two ... designed to conduct ...sics experiments in ...on with the space Challenger was sched-... launched today, offi- White Sands Missile ...d.

...ally, the two rockets ...e launched Saturday ... aborted due to tech-...blems.

...ls at WSMR said the ...k Brant rocket lifted ...ssfully at 4 p.m. Sat-...owever, the missile's path carried it east, instead of straight up as programmed.

"The first one had to be brought down three seconds before its payload would've been deployed," said Don Montoya of the WSMR information office.

The second Black Brant, with a Nike booster, did not even leave the launch pad. The rocket's flight was scrubbed just minutes before its 5:30 p.m. scheduled launch, Montoya said, because of some problems with pressure loss.

Oil Rig Blast Leaves Four In Critical Condition

BLOOMFIELD (AP) — Four workers of the Arapahoe Drilling Company were critically injured when an oil rig near the community of Turley exploded Sunday.

Three Farmington men were taken from the San Juan Regional Medical Center in Farmington to the University of New Mexico Hospital in Albuquerque.

Hospital officials said John Murphy, 57, was listed in critical condition with burns over 90 percent of his body. Steve Lavacek, 24, is also in critical condition with burns covering 80 percent of his body.

The third man, Ernest Jeter, 50, was listed in guarded condition with burns covering 64 percent of his body.

A fourth man was taken by emergency air transport to a Maricopa County burn center in Phoenix, Ariz. Dennis J. Martinez, 25, was reported in critical condition. A Maricopa County Medical Center spokeswoman said Martinez suffers from second- and third-degree burns on 55 percent of his body.

Company officials say they are not sure what caused the 6 p.m. explosion east of Bloomfield.

Arapahoe spokesman John Ahlm said the oil well was being allowed to burn.

...ents Choose Dude Ranch Work

...rage of 800 students work at Colorado ...anches each summer.

Catlow said students have been work-...g at ranches for as long as he can re-...member. Although ...

dreds of aspens and ponderosa pines and the north fork of the South Platte River, which is just 100 feet from the main lodge ...

on her day off, she said the experience has been worthwhile.

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items which

...ll; stipends for three ... January 1986 scholarship application workshop for seniors; purchase of computer software for elementary schools; and purchase of computer equipment and software in vocational and professional programs.

• A grant of $2,000 to the United Way toward the purchase of a computer-word processor for the UW office. The estimated cost of the equipment is $4,470 and the board was told UW had already raised about $1,250. In addition to the grant, the board authorized an interest-free loan to UW to make up any shortfall so the equipment can be put on-line this year.

• A grant of $2,000 to the Chamber of Commerce Retirement Committee toward the cost of hiring a part-time employee to coordinate retirement efforts in the community. The estimate cost to staff the position is $10,000 a year and the board was informed that Guadalupe Medical Center had already ment.

• A loan of $9,100 t... ntral Rural de Salud, Inc., in Loving for ... aterials for exterior renovation of a building in Loving for a medical diagnostic and treatment center. The interior renovation of the structure has been covered by federal funds, but the federal grant prohibits use of those funds for exterior work. The funds would also be used for materials for exterior renovation of three structures owned by the corporation which are part of a land trust being developed for the purpose of eventually making the clinic self-sufficient. Labor for the projects will primarily be voluntary.

• The board also approved a matching-fund scholarship in the name of long-time Carlsbad educator Sara B. Hanten. Establishment of the scholarship has been in the works for some months. Mrs. Hanten died here Monday.

Wed, Aug 7, 1985

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Associates in Albuquerque, but he lived in Santa Fe with his wife, Helen, an employee of the state Information Systems Division.

Dawn Parker of Wolfe & Associates said Clark joined the firm in April and had done very well.

"We referred to him as 'The Superstar,'" Parker said.

Clark was a computer software specialist for the state Highway Department between September 1980 and January 1982.

His family requests that donations be made to the James P. Clark Scholarship Fund at Southeastern Oklahoma State.

Oil Rig Fire Snuffed

BLOOMFIELD (AP) — A fire at an oil rig near Turley that killed a Farmington man has been extinguished, authorities said.

Authorities said Tuesday the fire burned for two days. It was caused when a drill bit punched through a pocket of natural gas and the gas exploded.

John Murphy, 57, died Monday at University of New Mexico Hospital in Albuquerque from burns he suffered in the blowout of the Arapahoe Drilling Co. rig Sunday evening.

The explosion injured three other workers, officials said.

Steve Navacek, 24, and Ernest Jeter, 50, both of Farmington, were being treated Tuesday at UNM Hospital.

Navacek was listed in serious condition with burns covering 78 percent of his body and Jeter was in critical condition with burns over 56 percent of his body, a hospital spokeswoman said.

Dennis J. Martinez, 25, was taken by emergency air transport to the Maricopa County Medical Center in Phoenix, Ariz., where he was listed in critical but stable condition Tuesday, officials said.

Martinez suffered second- and third-degree burns over 38 percent of his body, said Mary Helen Valenzuela, a spokeswoman for the medical center.

John Ahlm, an Arapahoe Drilling spokesman, said the flames engulfed half of the 100-foot drilling tower.

Ahlm said although the fire was out, natural gas still was spewing from the well. "The well's iron is still hot but we're trying to get it cooled down."

-CURRENT-ARGUS, Carlsbad, N.M., Wednesday, August 7, 1985

C 1

 Open-File Report 82-968

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

EVALUATION OF BRECCIA PIPES IN SOUTHEASTERN NEW MEXICO AND THEIR RELATION TO THE WASTE ISOLATION PILOT PLANT (WIPP) SITE, with a section on DRILL-STEM TESTS

Open-File Report 82-968

1982

Prepared by the U.S. Geological Survey
for the
Albuquerque Operations Office
U.S. Department of Energy
(Interagency Agreement E(29-2)-3627)

Open-File Report 82-968

Open-File Report 82-968

EVALUATION OF BRECCIA PIPES IN SOUTHEASTERN NEW MEXICO AND THEIR RELATION TO THE WASTE ISOLATION PILOT PLANT (WIPP) SITE

By

R. P. Snyder and L. M. Gard, Jr.

with a section on DRILL-STEM TESTS, WIPP 31, by J. W. Mercer

CONTENTS

ILLUSTRATIONS--Continued

TABLES

EVALUATION OF BRECCIA PIPES IN SOUTHEASTERN NEW MEXICO AND THEIR RELATION TO THE WASTE ISOLATION PILOT PLANT (WIPP) SITE, with a section on DRILL-STEM TESTS, WIPP 31, by J. W. Mercer

By

R. P. Snyder and L. M. Gard, Jr.

INTRODUCTION

The Waste Isolation Pilot Plant (WIPP) site is located about 40 km (25 mi) east of Carlsbad, N. Mex. (fig. 1). The site geography has been described in detail by Powers and others (1978) and U.S. Department of Energy (1980, 1981). Site selection was based principally on the existence of a thick section of Permian evaporites, mainly halite. The purpose of establishing this site is to demonstrate whether or not an evaporite environment is acceptable for the disposal of trans-uranic waste generated by the Nation's defense programs.

The primary concern regarding safe disposal of nuclear waste is to isolate the waste from the biosphere until it is no longer a danger to mankind. One of the most probable methods of accidental release of radiation from nuclear waste isolated in a geologic medium is leaching and transport of the waste by moving ground water. It is therefore of primary importance to identify any potential channelways that might allow water to enter a repository site located in bedded salt of the Salado Formation of southeastern New Mexico. The presence of the thick Permian (225 m.y.) rocks attests to the fact that major dissolution of the halite by unsaturated ground water has not occurred at the WIPP site.

Focus of Current Study

This report describes several dissolution features in the Delaware Basin and elsewhere that have been referred to as breccia pipes. Breccia pipes (also called breccia chimneys) as they occur in evaporites are vertical cylindrical pipes or chimneys that may or may not involve more than one geologic formation. The chimneys are filled with downward-displaced brecciated rock. In this context, the rock is brecciated by having collapsed into a void at depth that was probably created by ground-water solution and removal of deep-lying evaporite or carbonate rocks in an underlying aquifer system (Anderson and Kirkland, 1980; Bachman, 1980). Such features have been described in evaporite deposits in many areas of the world.

The current study was done for the U.S. Department of Energy (DOE) in response to a suggestion that because breccia pipes are thought to be the result of deep dissolution, they may represent channelways for future ingress of ground water, and that they should be considered in risk assessment programs for the evaluation of proposed waste repositories in bedded evaporite rocks. To this end, features referred to as breccia pipes in southeastern New Mexico have been assessed in relation to the integrity of the WIPP site. Reports by Anderson (1978), Bachman (1980), and Vine (1960) described dissolution and karst features in the Pecos region of southeastern New Mexico and discussed the origin and history of breccia pipes. The present report is intended to supplement these studies and provide detail that was not available to them at the time their reports were written.

Using the data from exploratory work, answers may be found to the following questions concerning breccia pipes:

1. Do breccia pipes penetrate through the evaporite section?
2. What is the physical description of a pipe?
3. How are they formed?
4. How deep do they go?
5. When are they formed, and are they forming at present?
6. Are they permeable?
7. Where are they formed, can they form at the WIPP site?
8. Do they represent a threat to the WIPP site?

Acknowledgments

We thank James Walls, vice-president and general manager of Mississippi Chemical Corp., Eddy County, N. Mex., for his generous assistance and cooperation and for allowing us access to the mine. Discussions with C. L. Jones (USGS, retired) and Dennis W. Powers of Sandia National Laboratories (SNL) helped to clarify initial ideas into explainable processes.

STRATIGRAPHIC SETTING OF THE WIPP SITE

The WIPP site is at the northern end of the Delaware Basin of New Mexico and Texas, a sedimentary basin of Permian age which is surrounded by the Capitan Reef. The geology of the area has been described in detail by Jones (1973), Powers and others (1978), and Bachman (1980) and is only summarized here.

The stratigraphic sequence and time divisions of the rocks of southeastern New Mexico pertinent to this discussion are shown in table 1.

Permian Rocks

Permian rocks in the Delaware Basin are all of marine origin and they are divided into four provincial series, which are in ascending order: Wolfcampian, Leonardian, Guadalupian, and Ochoan. Only rocks of the Guadalupian and Ochoan Series are pertinent to this report.

Capitan Limestone and Backreef Equivalents, Tansill and Yates Formations

The Capitan Limestone and its backreef equivalents, the Tansill and Yates Formations, comprise the Guadalupian Series rocks. The Capitan is the reef limestone that surrounds the Delaware Basin. The limestone is generally porous and permeable (Bachman, 1980). Submarine canyons cut through the reef and were later filled with fine-grained carbonate-cemented sand (Hiss, 1975). These deposits are much less permeable than the reef limestone and they tend to retard the migration of ground water (Hiss, 1975).

The backreef correlatives of the Capitan, the Tansill and Yates Formations, are present in the areas of Hills A, B, and C, and the Wills-Weaver pipe, but are not present at the WIPP site. These formations consist mainly of bedded limestone and interbedded sandstones over the reef in the report area.

Castile Formation

The Castile Formation consists of several thick halite and anhydrite members (Anderson, 1972). In the basin, the Castile conformably overlies the Bell Canyon Formation and is, in turn, overlain by the Salado Formation. The Castile is about 412 m (1350 ft) thick at the WIPP site.

Salado Formation

The Salado Formation consists of halite units interstratified with thinner beds of anhydrite, polyhalite, beds of glauberite, and potash minerals. The halite beds contain varying amounts of silt and clay and are considerably "dirtier" than the halite beds of the Castile. Many of the anhydrite and polyhalite beds are persistent throughout the basin. These have been numbered (Jones and others, 1960) and are used as marker beds for correlation purposes. The basal unit of the Salado, where it overlies the Capitan Limestone, is the Fletcher Anhydrite of Lang (1942). Locally, the thickness of the Salado varies as the result of dissolution at the top of the formation. At the WIPP site the Salado is 603 m (1976 ft) thick.

Rustler Formation

Where no dissolution has occurred at the top of the Salado it is overlain conformably by the Permian Rustler Formation which is also part of the Ochoan evaporite sequence. The Rustler is divided into five members which are, in ascending order, the lower unnamed member, Culebra Dolomite, Tamarisk, Magenta Dolomite, and Forty-niner Members.

The lower unnamed member is composed primarily of siltstone. The Tamarisk and Forty-niner Members are similar to each other and where unaffected by dissolution, are composed of anhydrite and minor siltstone beds. Halite is present in all three members except where it has been removed by dissolution. This dissolution is progressing from west to east across the WIPP area. These three members vary in thickness depending on the amount of halite removed by dissolution. Where dissolution has occurred, a reddish-brown silty residue remains. This dissolution has created most of the karst features described by Bachman (1980).

The Culebra Dolomite and Magenta Dolomite Members are distinctive marker beds in the Rustler Formation. The Culebra, about 8 m (27 ft) thick, is a yellowish-gray, thin-bedded, finely crystalline dolomite. Many layers contain distinctive vugs about 2-10 mm (0.08-0.39 in.) in diameter which sometimes contain selenite crystals. The Culebra is the most significant aquifer in the basin area. The Magenta is composed of alternating thinly laminated reddish-brown dolomite and gray anhydrite layers. The laminae display distinctive undulatory bedding. The Magenta is about 7.6 m (25 ft) thick in the area and is also an aquifer, although to a lesser extent than the Culebra.

Ogallala Formation

The Ogallala Formation in southeastern New Mexico consists mainly of windblown sand on which the well-known "Caliche caprock" of the High Plains has formed. The Ogallala is not present at the WIPP site and was either never deposited or more likely has been removed by erosion. The closest outcrop of Ogallala is at "The Divide" 11 km (7 mi) east of the WIPP site.

Gatuna Formation

The Gatuna Formation of middle Pleistocene age or older (Bachman, 1980, p. 38) unconformably overlies the Permian and Triassic rocks in the area except where absent owing to erosion or nondeposition.

The Gatuna, mainly of fluvial origin, consists of unconsolidated beds ranging from silt to gravel. Much of the Gatuna is locally derived, especially from reworking of Triassic conglomerates and caliche of the Ogallala caprock.

Mescalero Caliche

The Mescalero caliche (an informal name) caps many of the older rocks of the area. According to Bachman (1980, p. 42) it appears to have accumulated as the C horizon of an ancient soil after deposition of the Gatuna Formation. Bachman reports that dates derived by the uranium series disequilibrium technique show that the Mescalero formed between 510,000 and 410,000 years ago.

PREVIOUS WORK ON BRECCIA PIPES IN SOUTHEASTERN NEW MEXICO

Numerous surficial features in and near the Delaware Basin have been described as being related to dissolution of the evaporites of the Ochoan Series. Vine (1960) described four domelike features as possible pipe structures. Later work done under the direction of personnel of the SNL and the USGS during studies for the WIPP site showed that two and probably three of the four domal structures are indeed breccia pipes.

Additional surficial features have been mentioned as possible pipe structures. Reports by Reddy (1961), Vine (1963), and Anderson (1978) mention several domal structures in the basin. Vine (1963, p. B40-B41) cites 11 of these to the west of the WIPP site. Many of these domal structures were found by Bachman (1980) to be no more than caliche-capped hills carved prior to Mescalero time. The hill in the SE 1/4 sec. 24, T. 23 S., R. 29 E. was mapped in detail by Bachman (1980, fig. 20) and described as an example of ancient solution and fill structure. Another structure cited by Vine (1963) in secs. 33-34, T. 22 S., R. 29 E. was mapped by Bachman (1980, fig. 18) and drilled (WIPP 32) as part of the studies for the WIPP site (Snyder and McIntyre, 1980). No indication of dissolution in the Salado below the Vaca Triste Sandstone Member (Adams, 1944) was found. The structure is related to shallow dissolution in the Rustler and Salado Formations and not to deep dissolution. A nearby drill hole, WIPP 29 (Snyder and McIntyre, 1979), drilled to gain information for hydrologic studies in Nash Draw also showed no dissolution below the Vaca Triste.

per kilometer (100 feet per mile) and because this is the present regional dip, there is no allowance for post-Cretaceous uplift.

GEOPHYSICAL STUDIES

Numerous geophysical studies have been carried out on and around the WIPP site specifically to gain subsurface information concerning the site. Some of these surveys were designed to search for possible breccia pipes. Among these were magnetic and gravity surveys by Ferruccio Gera (1974) of Oak Ridge National Laboratory (ORNL) in conjunction with R. Hopkins of the Tennessee Valley Authority (TVA), and gravity and electrical resistivity surveys by Mining Geophysical Surveys (West and Wieduwilt, 1976) interpreted by Elliot Geophysical Company (Elliot, 1976a,b; 1977).

The resistivity surveys interpreted by Elliot (1976a,b) were run over eight suspected or known pipes. Table 2 lists the names or areas involved and the locations. Resistivity profiles across selected sites are shown in figs. 2, 3, 4. and 5. Complete profiles and technical data for all eight locations are given by Elliot (1976a). The resistivity data across Hill A shows a definite anomaly. The central part of the breccia pipe has a low resistivity that is bounded by high resistivity peaks as the survey line crosses the circular ring fault. Interpretations of the resistivity profiles along with additional data discussed later in this report have led us to the conclusion that the following are breccia pipes: (1) Wills-Weaver, (2) Hill C, (3) Hill A, and (4) Hill B. The remaining four sites are not interpreted as pipes.

Gravity surveys by Mining Geophysical Surveys (West and Wieduwilt, 1976) were run across the Wills-Weaver site, and Hills A, B, C, and D. The data were interpreted by Elliot Geophysical Company (Elliot, 1976b). Reasoning behind the belief that gravity surveys across breccia pipes would show anomalous readings is as follows:

> If the brecciated material in the pipe was not well consolidated, the additional porosity as compared to the porosity of the surrounding rocks would cause the instruments to record a gravity low across the pipe, and if the material is denser than or better cemented than the surrounding rock, a gravity high would be recorded.

Figures 6, 7, and 8 show the gravity and topographic profiles across the Wills-Weaver area, and Hill C and Hill A, respectively. Figures 6 and 8 show a definite gravity low at the Wills-Weaver and Hill A sites, but there is no such low at the Hill C site (fig. 7). Elliot (1976b, v. 1, p. 22) states that gravity data do not give a consistent gravity response across known breccia pipes; and that gravity surveys are not a definitive method for locating these breccia pipes.

Seismic-reflection data (Hern and others, 1978) were obtained across the Wills-Weaver and Hills A-B locations. Generally uninterpretable reflections came from the center of these features.

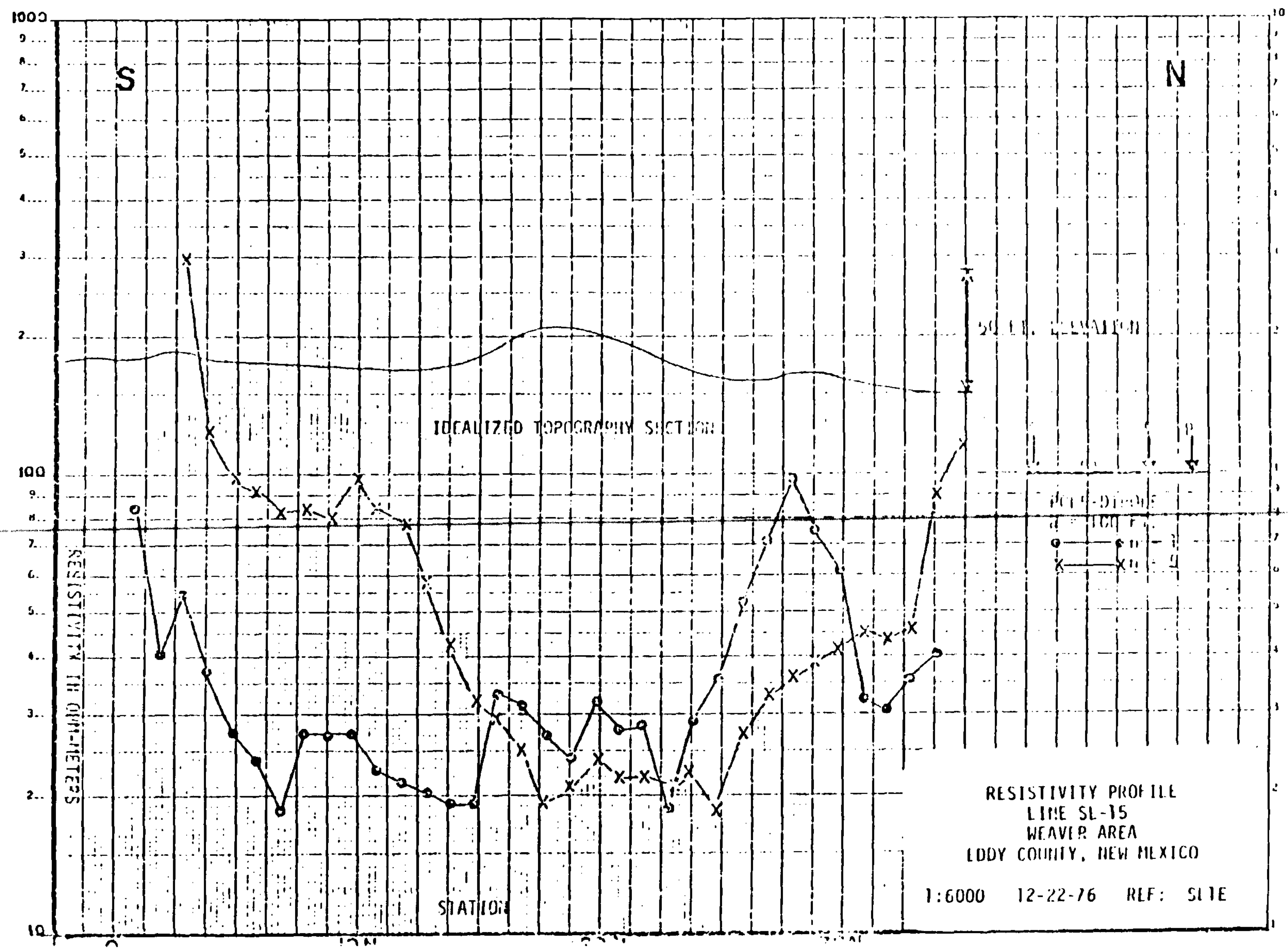

Figure 2.--Resistivity profile line SL-15, Wills-Weaver area, Eddy County, N. Mex. (from Elliot, 1976a).

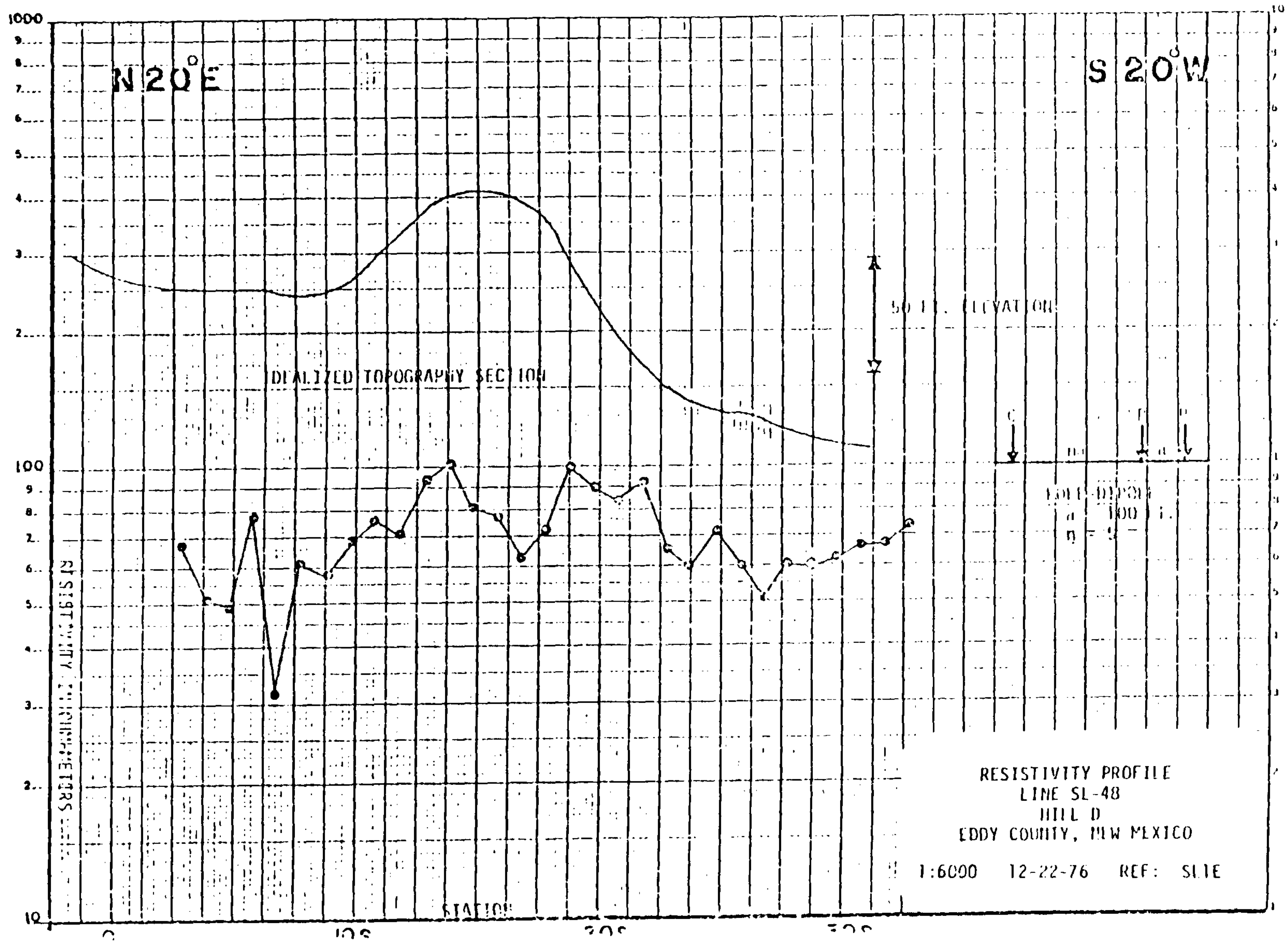

Figure 4.--Resistivity profile line SL-48, Hill D, Eddy County, N. Mex. (from Elliot, 1976a).

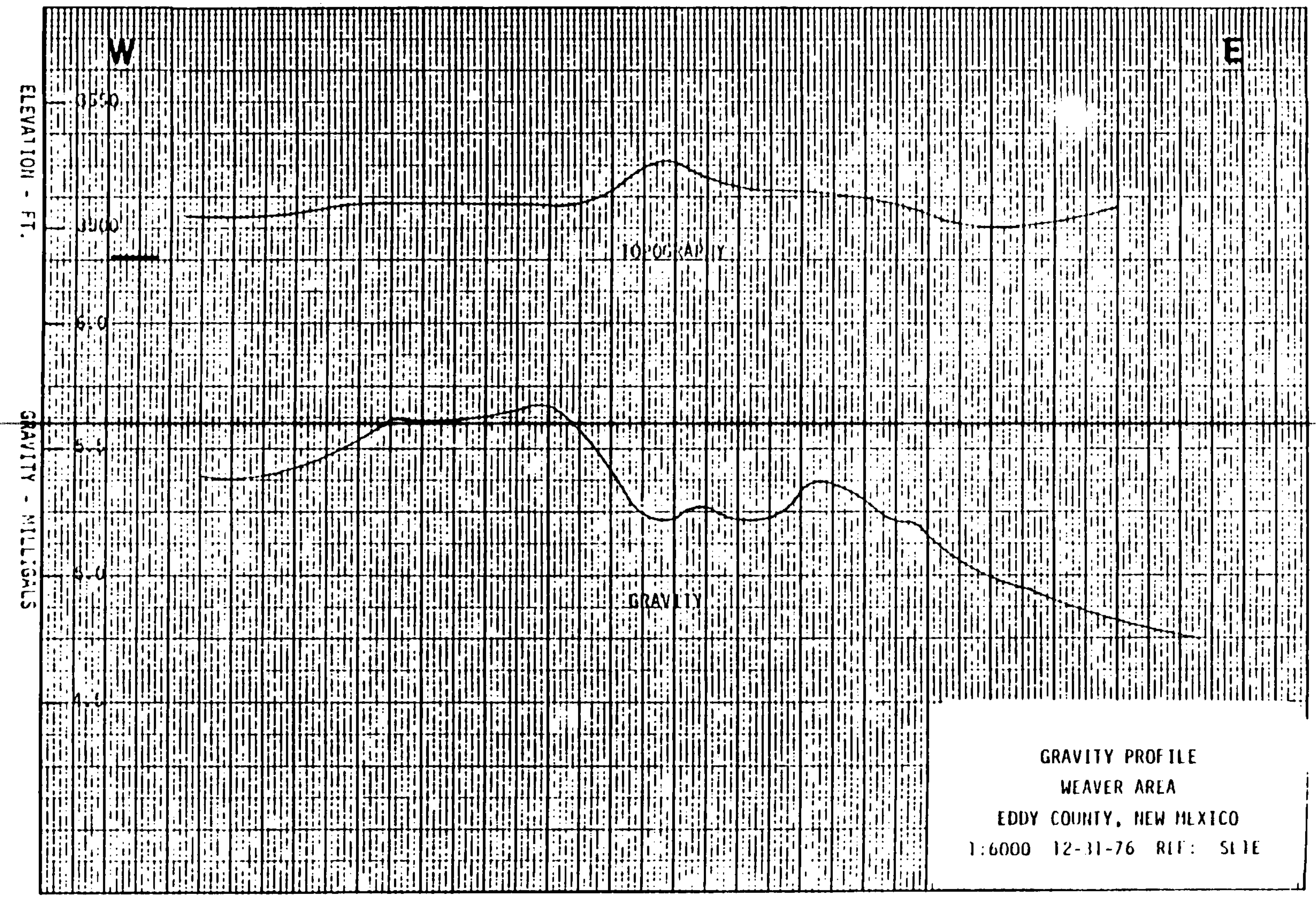

Figure 6.--Gravity profile Wills-Weaver area, Eddy County, N. Mex. (from Elliot, 1976b, v. 1).

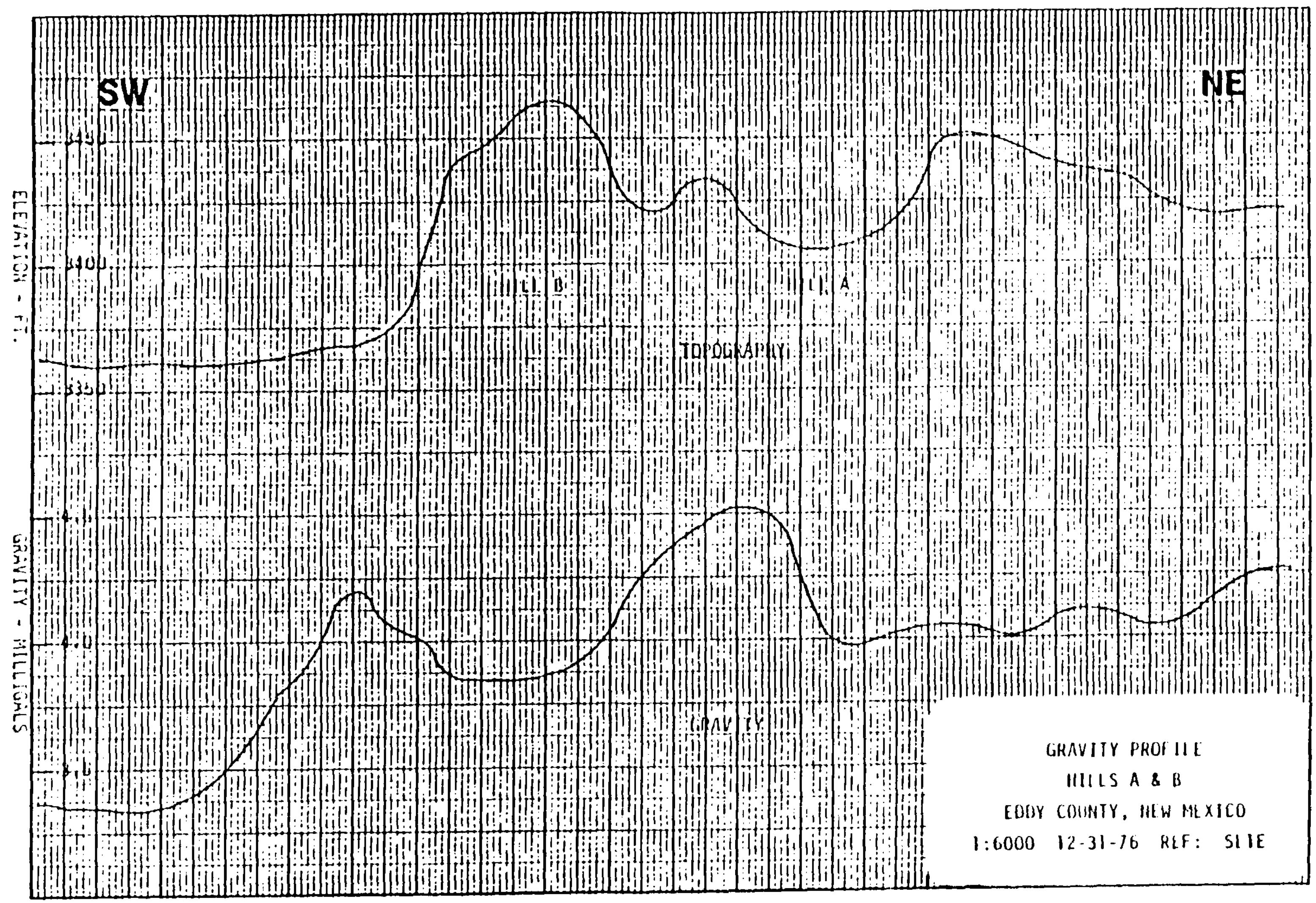

Figure 8.--Gravity profile Hills A and B, Eddy County, N. Mex. (from Elliot, 1976b).

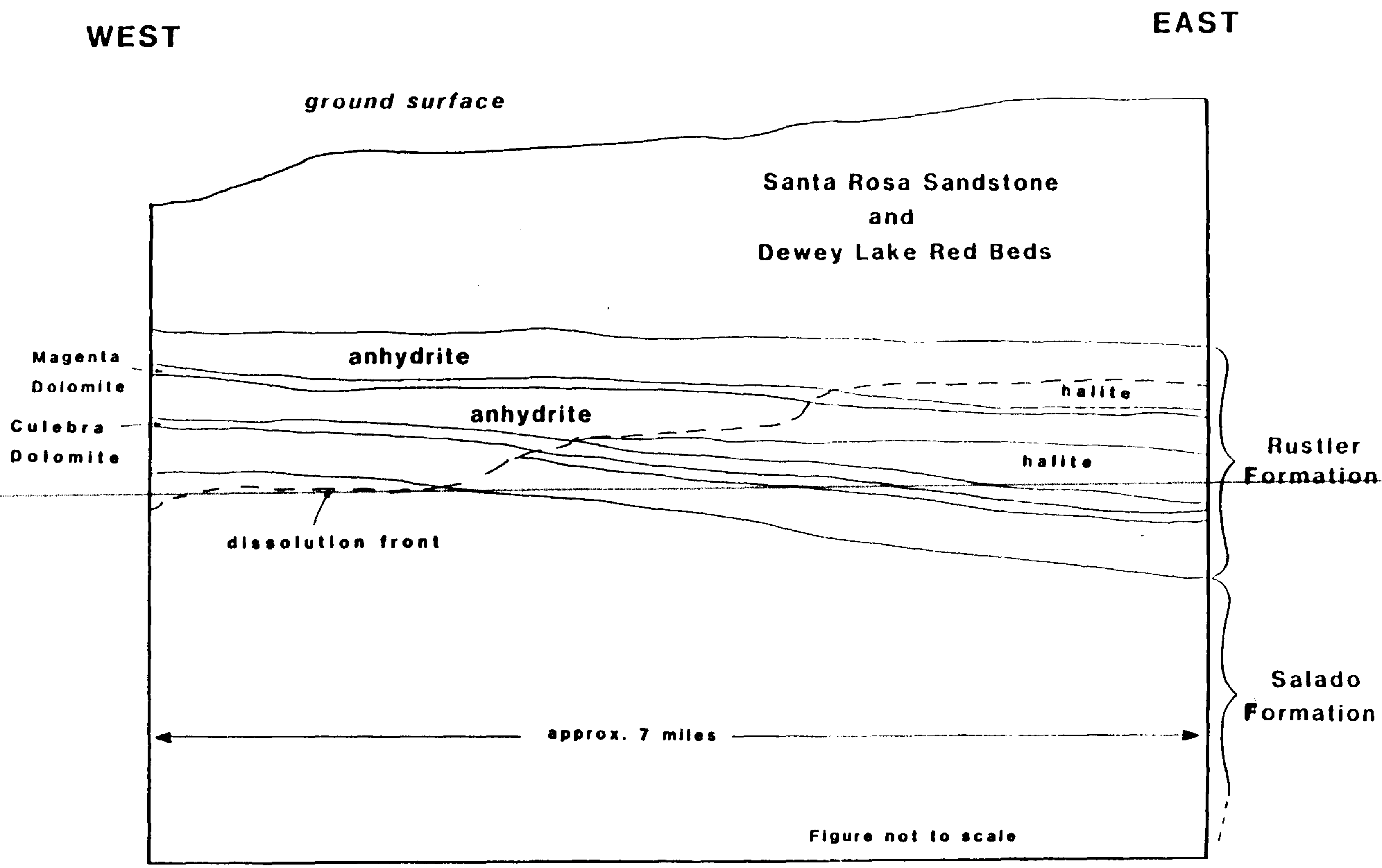

Figure 9.--Diagrammatic sketch west to east across WIPP site showing downward progression of dissolution front. Front is migrating from west to east, removing successively lower halite beds.

Drill hole WIPP 31, Hill A

Drill hole WIPP 31 was sited inside the ring fault zone mapped by Vine (1960) and Bachman (1980). The hole was drilled in two stages. The first 247 m (810 ft) were drilled during September and October 1978, and the hole was later (July-August 1980) deepened to 604 m (1981 ft). Only a few feet of core were taken in the upper 247 m (810 ft) of the hole. One core, from 229 to 230 m (750-756 ft), was anhydrite of the Rustler Formation, the first indication of this formation and somewhere between 8 and 94 m (25-310 ft) below its normal stratigraphic position. Table 3 describes in general the lithology of cuttings and core from WIPP 31.

It should be pointed out that although a specific rock, identifiable as the Rustler Formation, was first found at a specific depth, it does not imply that the stratigraphy is normal from that depth downward (fig. 11). In fact, rocks of the Dewey Lake Red Beds were found as deep as 503 m (1650 ft), which is about 366 m (1200 ft) below the base of the unit in the surrounding area. Fragments of the Magenta (fig. 12) and Culebra Dolomite Members (fig. 13) of the Rustler Formation were found 274-366 m (900-1200 ft) below their normal positions.

One part of the Salado Formation halite (about 12 m or 40 ft; true thickness) was the only thick recognizable part of that formation cored, but many of the anhydrite fragments and much of the reddish-brown clay probably are Salado rocks. The anhydrite, starting at a depth of 580 m (1903 ft) and continuing to a total depth of 604 m (1981 ft) is tentatively assigned to the Fletcher Anhydrite, or the base of the Salado Formation. It is the only known anhydrite in this area that is thick enough to account for the amount cored. The 50° dip noted on the laminations would give the cored interval of 24 m (78 ft) a true thickness about 15 m (50 ft). It is estimated that about 3-9 m (10-30 ft) of the Fletcher remains below total depth of WIPP 31.

Because the Tansill and Yates do not contain water-soluble evaporites, they are probably not the cause of the collapse of the overlying rocks. Below these formations is the Capitan Limestone, a somewhat soluble rock known to contain large caverns (Carlsbad Caverns). The most reasonable explanation for collapse of the rocks cored in WIPP 31 is that a large cavern formed in the Capitan, and the overlying rocks, as young as the Triassic Dockum Group, collapsed into the void. The Fletcher Anhydrite probably acted as a supporting beam over the collapse for some time, but as the cavity in the Capitan grew wider, the width exceeded the ability of the Fletcher to serve as a support, and collapse occurred. Another possible method to consider is that the cavity was filled with water to the base of the Fletcher, and declining water levels removed the bouyant support on the Fletcher. This would cause an apparent increase in weight of ±50 percent of the Fletcher that would increase the stress and exceed the rock strength. The Fletcher is considered as the support beam rather than one of the units in the Tansill or Yates because of its lack of bedding and its intergrown crystalline structure. The Tansill and Yates are thin bedded granular rocks.

Most of the halite of the Salado Formation, and all of the halite in the Rustler Formation are missing in the core from WIPP 31. There is no Castile Formation present over the Capitan. In an oil and gas exploration hole (Cities Service Oil and Gas, Big Eddy unit 17) about 0.8 km (1/2 mi) southwest

Table 3.--Lithologic description of cuttings and core for WIPP 31--Continued

Description	Thickness depth (feet)	Thickness interval (feet)
Cut 4		
Siltstone, mudstone, and minor sandstone, moderate-reddish-brown (10R 4/6) and dark-reddish-brown (10R 3/4); greenish-gray (5GY 6/1) reduction spots; siltstone contains bedding planes dipping from 32° to 40°--------	695.5- 703.4	7.9
No core---	703.4- 705.0	1.6
Cuttings		
Siltstone and mudstone, same as unit at 589-695 ft-------	705.0- 750.0	45.0
Anhydrite, white (N9)-----------------------------------	750.0- 751.0	1.0
Core 5		
Anhydrite, grayish-green (5G 5/2) and dusky yellowish-green (10GY 3/2), gypsiferous; mottled; very finely crystalline; laminated; irregular argillaceous laminae at 753.8 ft; dip of laminae ranges from 32° to 40°-----	751.0- 756.6	5.6
Siltstone, dark-reddish-brown (10R 3/4) and grayish-red (10R 4/2); gypsiferous anhydrite bands at 757.0 and 757.4 ft); siltstone faintly bedded--------------------	756.6- 758.9	2.3
No core---	758.9- 759.7	.8
Core 6		
Mudstone breccia; grayish-red (10R 4/2) through dark-reddish-brown (10R 3/4) and medium-dark-gray (N4), fragments less than 3 cm; slightly calcareous matrix---	759.7- 767.5	7.8
Sandstone, dark-reddish-brown (10R 3/4) and grayish-red (10R 4/2), very fine grained, hard, friable, minor calcite cement, MnO_2 stain on bedding surfaces, gypsum filled fracture---------------------------------	767.5- 771.0	3.5
Cuttings		
Siltstone, mudstone, sandstone and gypsum, reddish-brown (10R 3/4), grayish-red (10R 4/2) and dark-reddish-brown (10R 3/4) siltstone, mudstone same with some medium dark gray (N4), sandstone same color as siltstone, gypsum, white (N9); minor chert pebbles and selenite---	771.0- 800.0	29.0
Core 7		
Breccia of mudstone and siltstone, moderate-reddish-brown (10R 4/6), dark-reddish-brown (10R 3/4), grayish-red (10R 4/2), greenish-gray (5GY 6/1); slightly calcareous; mud matrix; portions colored dark-yellowish-orange (10YR 6/6)----------------------	800.0- 809.8	9.8
No core---	809.8- 810.0	.2
No returns--	810.0- 819.0	9.0
Core		
Mudstone-siltstone breccia, moderate-reddish-brown (10R 4/6) to dark-reddish-brown (10R 3/4); mudstone fragments up to 20 cm; siltstone contains greenish-gray (5GY 6/1) reduction spots, lower 4 ft is one block, siltstone in rest of unit, fragments as much as cm, most less than 4 cm--------------------	819.0-1022	203.0

Table 3.--Lithologic description of cuttings and core for WIPP 31--Continued

Description	Depth (feet)	Thickness Interval (feet)
Halite, light-gray (N7), medium-gray (N5), pale-reddish-brown (10R 5/4) moderate-reddish-orange (10R 6/6), finely to coarsely crystalline; light-gray portions appear to be recrystallized; pale-reddish-brown portions are argillaceous, and moderate-reddish-orange portions are polyhalitic; dips measured along polyhalitic streaks range from 50° to 60°--------	1457.6-1518.7	61.1
Siltstone and anhydrite breccia; siltstone, moderate-reddish-brown (10R 4/6) and dark-reddish-brown (10R 3/4), many fragments contain greenish-gray (5GY 6/1) alteration spots; angular anhydrite fragments range from olive gray to very light gray (5Y 4/1 to N5); fragments of pitted dolomite at 1549.5-1551.2, 1559, 1578, 1586.7, 1614 to 1624 ft; laminated light-brownish-gray (5YR 6/1) dolomite fragment at 1627.2 ft; oil stains at 1629 and 1648 ft; glauberite crystals at 1628.9-1629.3 ft; halite filled fractures and vugs in lower 30 ft----------------------------------	1518.7-1651.6	132.9
Anhydrite, medium-gray (N5), speckled with dusky-yellowish-brown (10YR 2/2) specks, very finely crystalline; scattered halite crystals throughout unit--	1651.6-1658.2	6.6
Anhydrite and siltstone breccia, matrix of mud; angular anhydrite fragments medium-dark-gray (N4) ranging to 50 cm; siltstone, moderate-reddish-brown (10R 4/6) to dark-reddish-brown (10R 3/4); dark-reddish-brown (10R 4/3) mud matrix about 30 percent of unit----------	1658.2-1702.6	44.4
Mud, anhydrite, and siltstone breccia; medium-light-gray (N6) to light-bluish-gray (5B 7/1) mud is about 60 percent of unit, anhydrite and siltstone fragments as in unit above; pitted dolomite fragments at 1703 ft; scattered glauberite crystals and halite filled fractures-------------------------------------	1702.6-1762.8	60.2
Mud and anhydrite breccia; mud matrix grayish-red (5R 4/2) and some medium-gray (N5); anhydrite as in unit at 1658.2-1702.6 ft---------------------------------	1762.8-1782.8	20.0
Anhydrite and mud breccia; anhydrite as in unit at 1658.2-1702.6 ft; mud matrix, light bluish-gray (5B 7/1)--	1782.8-1802.6	19.8
Anhydrite, medium-gray (N5) to medium-dark-gray (N4), very finely crystalline; rock is brecciated and fractures are filled with medium-bluish-gray (5B 5/1) clay; some intervals contain subrounded laminated and subrounded dense anhydrite fragments as large as 4 cm in a mud matrix-------------------------------------	1802.6-1903.0	100.4

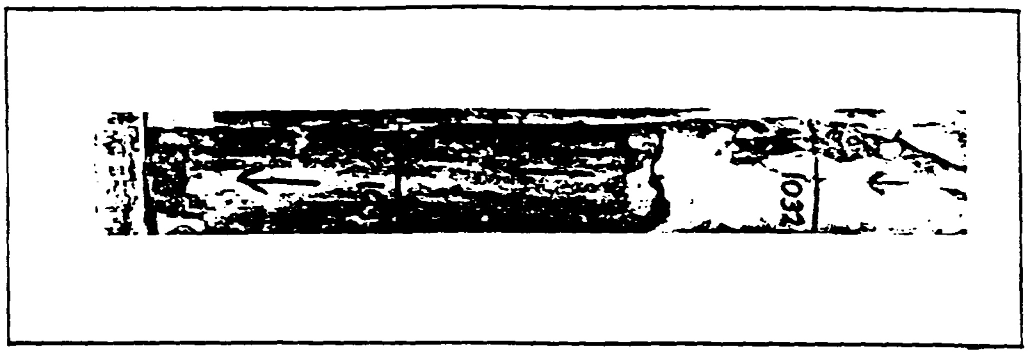

Figure 11.--Core from WIPP 31 showing block of younger Dewey Lake Red Beds underlying older fragments of Rustler Formation. The small light-gray spots in lower part of core are reduction spots. Arrows point downhole.

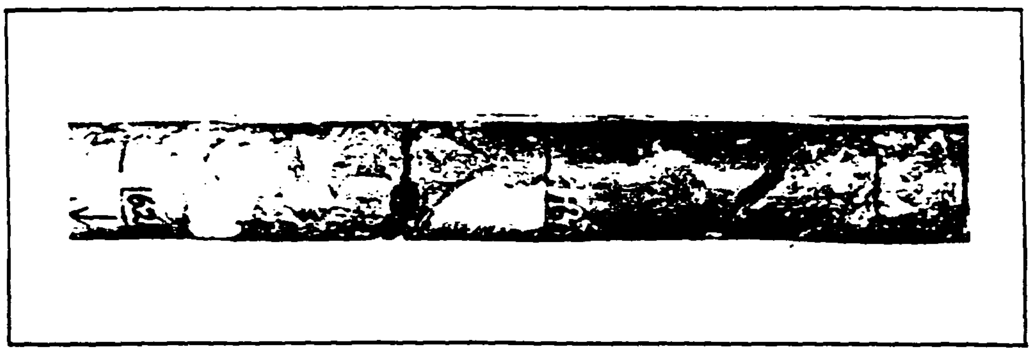

Figure 12.--Fragments of siltstone and anhydrite with a fragment of the Magenta Dolomite below 1627-footage mark in WIPP 31. Arrows point downhole.

Figure 13.--Breccia from WIPP 31 containing anhydrite and siltstone fragments. A fragment of the Culebra Dolomite has the depth number 1448 written on it. Arrows point downhole.

minor readjustments of the breccia mass (fig. 14). Unlike Hill A, only a very small area of Dewey Lake Red Beds is exposed in the gully that drains the western part of the hill. The rock exposed in the center of the hill is brecciated Triassic Dockum Group fluvial sandstones and siltstones.

Samples for palynomorph analyses were collected from the brecciated Dockum Group rocks and were studied by Robert M. Kosanke of the USGS. Kosanke reported (oral commun., 1981) on the findings as follows: The samples yielded few palynomorphs and they were poorly preserved. Palynomorphs are usually not found in red or oxidized rocks and the presence of calcareous matter does not normally help with the preservation. The samples did, however, yield a few poorly preserved palynomorphs. Kosanke states (written commun., 1981) "The most abundant of these would be the remains of the alga Botryococcus cf. B. braunii. Botryococcus is known to occur from early Paleozoic time to the present day where it is a member of the freshwater plankton, is widely distributed throughout the lakes of the United States, but is rarely abundant. Botryococcus is abundant and the primary constituent of boghead or algal coals known to occur in Alaska, Australia, France, Scotland, South Africa, and mainland United States. It is not so much an indicator of age as it is an indicator of freshwater environment. A single pollen grain, probably related to the Compositae was found together with two tricolpate pollen grains, and several winged pollen grains assignable to Pinus. In addition, several spores referable to the fungi were observed. This is not an assemblage--there is not enough evidence to evaluate with any degree of confidence. If what was found is valid and not modern contamination, the presence of the Compositae would suggest Oligocene or younger."

The rocks, as mentioned above, have been dated by field mapping as Triassic; thus indicating the likelihood of contamination of the samples precluding the use of palynomorphs, in this case, to date the exposed rocks in the central surficial part of Hill C.

The breccia pipe at Hill C provided an unparalleled opportunity to study a pipe in three dimensions. Prior to our investigation, this was the only breccia pipe that was known to contain brecciated rock at depth. During mining operations in 1975, in the 7th ore zone (see Jones and others, 1960, for stratigraphic location of ore zones) in the MCC potash mine one of the mine entries encountered the edge of this pipe. Not only were the rocks adjacent to the pipe exposed 366 m (1200 ft) below the surface, but also some of the breccia in the pipe itself could be studied.

The objectives of investigating Hill C were to explore and define the horizontal dimensions of the breccia pipe at mine level, and study the effects of the collapse on the adjacent rock in the MCC potash mine. Additionally, it was planned to match the underground pipe boundary with its surface expression and to identify the stratigraphic origin of the displaced rock fragments in the pipe at mine level. Additional objectives were to determine the permeability and porosity of the pipe and, if possible, the origins and ages of mineral phases associated with dissolution.

It was planned to drill horizontal core holes across the breccia pipe from the mine level to examine the breccia, determine the pipe dimensions, and collect samples that might be useful for age determination. Before these holes were to be drilled, it was thought advisable for safety reasons to drill a vertical hole from the surface to ascertain whether the breccia contained fluids or gases that might endanger the mine if intercepted by horizontal holes. Borehole WIPP 16 was designed for this purpose and was located on Hill C (NW1/4 SW1/4 sec. 5, T. 21 S., R. 30 E.). The hole was cored from 37.5 m (123 ft) to a total depth of 396 m (1300 ft), about 27 m (88 ft) below the mining horizon. A summary of the stratigraphy for rocks recovered from WIPP 16 is given in table 4, and an abbreviated lithologic log is given in table 5.

Exploratory drill holes for potash are located in the immediate vicinity of the breccia pipe (fig. 14), and two of these are combined with borehole WIPP 16 to construct a cross section across the pipe and into the surrounding rock (fig. 15).

WIPP 16 penetrated brecciated rock of the Triassic Dockum Group, and the Permian Dewey Lake Red Beds and part of the Rustler Formation. Although the Rustler has been downdropped and shattered, the beds, unlike the overlying rocks, were in recognizable stratigraphic order. The contact of the Rustler and the overlying Dewey Lake has been downdropped about 189 m (620 ft) (fig. 15), as has the Culebra Dolomite Member of the Rustler. Halite below the Culebra was cored in WIPP 16, and this differs markedly from drill hole WIPP 31 at Hill A where no halite and no recognizable stratigraphic sequence of rock was found to represent the Rustler.

The explanation for the nearly intact Rustler, minus halite in the Forty-niner and Tamarisk Members, in WIPP 16 is a problem. At Hill A (WIPP 31), the sequence of deposition, collapse of material in pipe, erosion, deposition of caliche, and dissolution of halites in the Rustler and upper Salado seems reasonable. To preserve Rustler halite in the pipe at WIPP 16, and arrange a plausible sequence of events for the formation of the pipe at Hill C, calls for stages of dissolution of the Rustler and upper Salado halites that suggest an unreasonable timing for the dissolution of these halites. It is probable that the formation of the pipes at Hills A and C occurred at widely spaced times.

The dipping beds shown abutting the pipe in figure 15 are explained by the following evidence. The surface dips of the undifferentiated Triassic rocks are mappable at the surface. The inward dipping rocks of MB 121 are mapped in the potash mine drift (fig. 23). Dips of beds between these two horizons and below MB 121 are hypothetical, but a reversal between the surface and MB 121 is true, and somewhere above the base of the dissolution of halite in the Salado (MB 109) is a reasonable place to put it.

Oil smears were found on core from WIPP 16, just as they were in WIPP 31. In WIPP 16 the rocks containing these smears were anhydrite, halite, and dolomite of the Rustler Formation. (Analysis of this oil was reported by Palacas and others, 1982.)

Hydrologic testing of WIPP 16 was not done because of the instability of the hole walls. A neutron log run by USGS personnel, Albuquerque, N. Mex., did not indicate the presence of water. Morco Geological Services continuously logged drilling fluids to detect CO_2, hydrocarbons, nitrogen, and

Table 5.--Abridged lithologic log of borehole WIPP 16

[Color designation from Rock-Color Chart (Goddard and others, 1948). Cuttings 40-120 ft, core 123-1300 ft; depths from driller, not matched to geophysical logs; to convert multiply footage by 0.0348; depths are from ground level]

Description	Thickness depth (feet)	Thickness interval (feet)
No cuttings logged	0 - 40	40.0
Sandstone, siltstone, and clay; sandstone is grayish red (10R 4/2), very fine to fine grained and ranges from 10 to 60 percent of sample; siltstone is moderate reddish brown (10R 4/6) and light olive gray (5Y 6/1) with traces of greenish-gray (5GY 6/1) reduction spots, 40 percent of sample; clay is medium light gray (N6), 0-30 percent of sample; some (10 percent) moderate-reddish-brown (10R 4/6) to dark-reddish-brown (10R 3/4) mudstone in lower (25 ft)	40.0- 120.0	80.0
No returns	120.0- 123.0	3.0
Siltstone breccia, moderate-reddish-brown (10R 4/6) and dark-reddish-brown (10R 3/4); scattered blebs and patches of greenish-gray (5GY 6/1) alteration zones; core consists of unbroken blocks as large as 0.3 m (1 ft) as well as angular and rounded fragments of recemented siltstone; alteration spots do not cross fragment boundaries; dips, where bedding apparent, are as steep as 71°, but there is no regular pattern; some mud matrix between siltstone in places; core loss from 125.4-126.4, 130.0-132.1, 135.7-136.7, 151.0-153.3, 153.6-154.0, 163.7-164.0, 169.2-170.2, 172.1-176.0, 180.6-181.0, 185.3-186.0, and 189.0-191.0 ft	123.0- 191.7	68.7
Sandstone, grayish-red (10R 4/2), moderate- and dark-reddish-brown (10R 4/6-10R 3/4), fine grained; fractures rehealed with calcite and selenite; dips of crossbedding range from 50°-80°, no core from 59.7 to 59.7 m (195.8-196.0 ft)	191.7- 201.4	9.7
Siltstone and mudstone breccia, moderate-reddish-brown (10R 4/6) siltstone; dark-reddish-brown (10R 3/4) mudstone; fragments are subangular to subrounded and range in size from 0.5 to 4 cm (1/2-1 1/2 in.)	201.4- 203.0	1.6
Sandstone, siltstone, and breccia consisting of sandstone, siltstone, and mudstone, moderate-reddish-brown (10R 4/6), and dark-reddish-brown (10R 3/4); some greenish-gray (5GY 6/1) zones and spots; dips of crossbedding in sandstone range from 50° to 75°; fractures in sandstone and siltstone rehealed with calcite and selenite; much of breccia has a matrix of mud; no core recovery at 220.6-221.0, 224.0-226.0, 244.9-247.0, 247.8-251.0, 260.4-261.0, and 265.6-265.8 ft	203.0- 265.8	62.8

Table 5--.--Abridged lithologic log of drill hole W-16--Continued

Description	Thickness Depth (feet)	Interval (feet)
Siltstone and mudstone breccia, dark-reddish-brown (10R 3/4) and moderate-reddish-brown (10R 4/6), much of unit consists of fairly undisturbed rock, except for its steep dip. Scattered subrounded fragments of moderate-reddish-brown (10R 4/6) sandstone and greenish-gray (5GY 6/1) mudstone and clay fillings between fragments; dips of 30°-65° on bedding planes; scattered fractures rehealed with gypsum and selenite; core loss at 659.0-661.0, 685.9-686.0, 703.6-706.0, 706.6-709.5, 719.4-720.7, 730.9-731.0, 734.7-735.3, 747.0-747.5, 755.0-755.5, 762.7-767.9, 774.6-776.0, 777.1-781.0, 783.6-786.0, 790.3-791.0, 791.8-796.0, 797.7-798.2, 805.4-805.6, 810.2-810.6, 833.6-833.8, 850.8-851.0, 853.4-857.0, 938.9-939.0, 945.6-946.0, 960.8-961.0, 977.8-978.0, 1070.6-1071.0, 1078.5-1079.0, 1084.7-1086.0, 1123.6-1124.2, 1138.0-1139.5, and 1144.0-1145.3 ft--	657.3-1145.3	48.80
Anhydrite, medium-gray (N5) and olive-gray (5Y 4/1) laminated in part with brownish-gray (5YR 4/1) and moderate-brown (5YR 4/4), partly brecciated, fractures filled with clay; dolomitic band 3 cm (1 in. thick) at 355.7 m (1167.0 ft); laminae dip from 20° to 36°; oil bleeding from brecciated zone at 352.3-353.0 m (1156.0-1158.2 ft)-----------------------	1145.3-1168.9	23.6
Mudstone, moderate-reddish-brown (10R 4/6), containing siltstone fragments and reduction spots----------------	1168.9-1172.0	3.1
No core--	1172.0-1175.0	3.0
Anhydrite, olive-gray (5Y 4/1) and medium-bluish-gray (5B 5/1), argillaceous filling in hairline fractures---	1175.0-1177.7	2.7
No core--	1177.7-1178.0	.3
Anhydrite, brownish-gray (5YR 4/1), light-bluish-gray (5B 7/1), light-greenish-gray (5GY 6/1) and grayish-yellow (5B 8/4), very finely crystalline, dips 38°-40°; fractures filled with clay----------------------------	1178.0-1186.3	8.3
Anhydrite, dolomitic, greenish-gray (5Y 6/1) and light-brownish-gray (5YR 6/1)-------------------------------	1186.3-1186.6	.3
No core--	1186.6-1186.9	.3
Anhydrite, dolomitic, same as unit at 1186.3-1186.6 ft, brecciated and recemented; laminae dip 36°-------------	1186.9-1192.6	5.7
Dolomite, greenish-gray (5GY 6/1), light-olive-gray (5Y 6/1), and light-brownish-gray (5YR 6/1) wavy olive-black (5Y 2/1) laminae, gypsum along some laminae; brecciated and rehealed in part---------------	1192.6-1198.6	6.0

Table 5--.--Abridged lithologic log of drill hole W-16--Continued

Description	Thickness depth (feet)	Thickness interval (feet)
Anhydrite, same as unit at 1287.3-1293.5 ft, halite bands parallel to anhydrite laminae diping 40°-45°-----------	1294.0-1297.7	3.7
Mudstone, anhydritic, dark-reddish-brown (10Y 3/4), gypsiferous and halitic-------------------------------------	1297.7-1300.0	2.3
Total depth-----------------------------------	1300.0	

hydrogen sulfide. Between depths of 362 and 367 m (1188 and 1204 ft), hydrogen sulfide was detected; the readings indicated as much as 6 parts per million between 365 and 366 m (1198 and 1200 ft). No other gases were detected in the drill hole.

In WIPP 16, all of the breccia above the Rustler Formation is composed of Triassic Dockum Group and Permian Dewey Lake Red Beds. Some idea of the minimum thickness of these units at the time of collapse of the material into the pipe can be estimated. The present thickness of these two units in the pipe is about 350 m (1150 ft). These units without collapse are about 145 m (475 ft) thick in nearby drill holes. Using an approximate bulking factor of 1.25, averaged from those of Houser (1970) for alluvium and zeolitized bedded tuff at the Nevada Test Site, the expected thickness of the brecciated rock in the pipe would be about 181 m (595 ft). This is about half (181 versus 350 m; 595 versus 1150 ft) of what is present. Apparently there was another ±145 m (±475 ft) of Dockum Group rock overlying the present Dockum Group. Following this line of reasoning, the collapse may have occurred at a time when a more complete sequence was present. The core from WIPP 16 contained no voids, but rather a great deal of fine sediments, mostly clay and silt-size material. This filling would have been obtained from disintegrated fragments of collapse material, and this would lower the bulking factor to something less than 1.25 and thereby require an even thicker section of rock than the extra ±145 m (±475 ft) at the time of collapse.

This estimation technique cannot be used in WIPP 31 because the loss of halite in the Salado and Rustler Formations adds too many variables to the calculations. Unfortunately, there is no way of estimating the erosional rate of the Dockum Group rock, but it must have taken hundreds of thousands of years to remove most of the rock. The Dockum Group is about 220 m (720 ft) thick 26 km (16 mi) to the east of Hill C, and thicknesses of over 457 m (1500 ft) are found farther east.

During this stage of the collapse, a depression probably formed at the surface allowing surrounding Triassic surface material to be washed into the depression. This material, especially the smaller fragments of sandstone and siltstone, was carried downward to form the matrix of the brecciated material now found in the pipe.

Underground Exploration

In doing development work to open another area of the 7th ore zone in the MCC potash property for mining, entries were driven to the northwest from the main haulage entry (fig. 14). In the MCC mine, the 7th ore zone dips gently northeast. As the new entries were advanced northwestward and approached the breccia pipe, the ore zone began to dip down at a steeper angle than the mining machine could follow, so the machine mined progressively higher and higher beds (figs. 16 and 17) until the edge of the pipe was reached (fig. 18). Mining exposed about 19 m (63 ft) of stratigraphic section above the 7th ore zone in a horizontal distance of 44 m (145 ft) (fig. 8). Mining was advanced about 5.5 m (18 ft) into the breccia pipe and a horizontal exploratory hole was drilled 10.7 m (35 ft) into the pipe and still encountered breccia. The hard polyhalite marker beds above the 7th ore zone

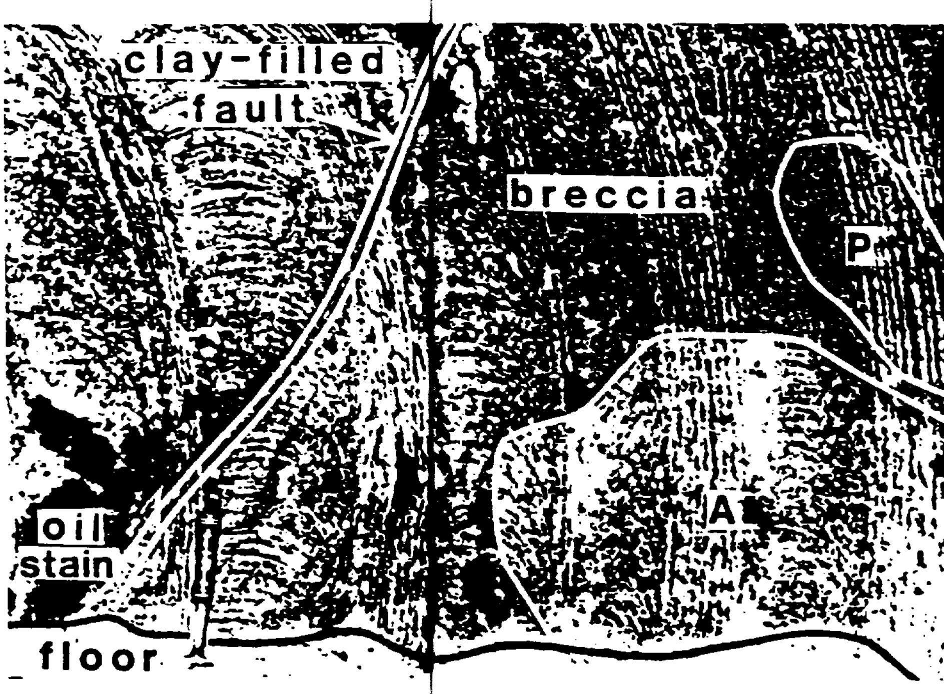

Figure 18.--Left rib 16-L drift. Pick leaning on breccia pipe material. Boundary of inplace halite and breccia of pipe is line that starts at base of oil stain in lower left corner, passes just above hammer handle and reaches top of photo near center. The line is a clay-filled (not gouge) fault zone. The fragments of anhydrite, polyhalite, and halite to the right of the fault show as various shades of gray. P=polyhalite, A=anhydrite.

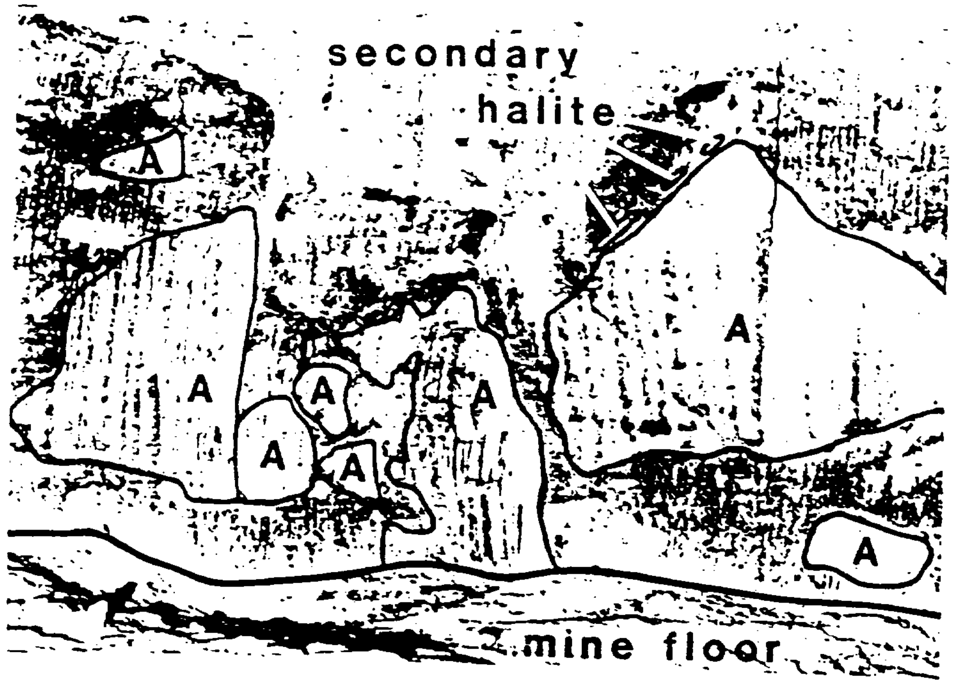

Figure 19.--Left side of exposed breccia pipe at end of 16-L drift showing numerous anhydrite blocks and matrix of clay and halite and anhydrite fragments. A=anhydrite.

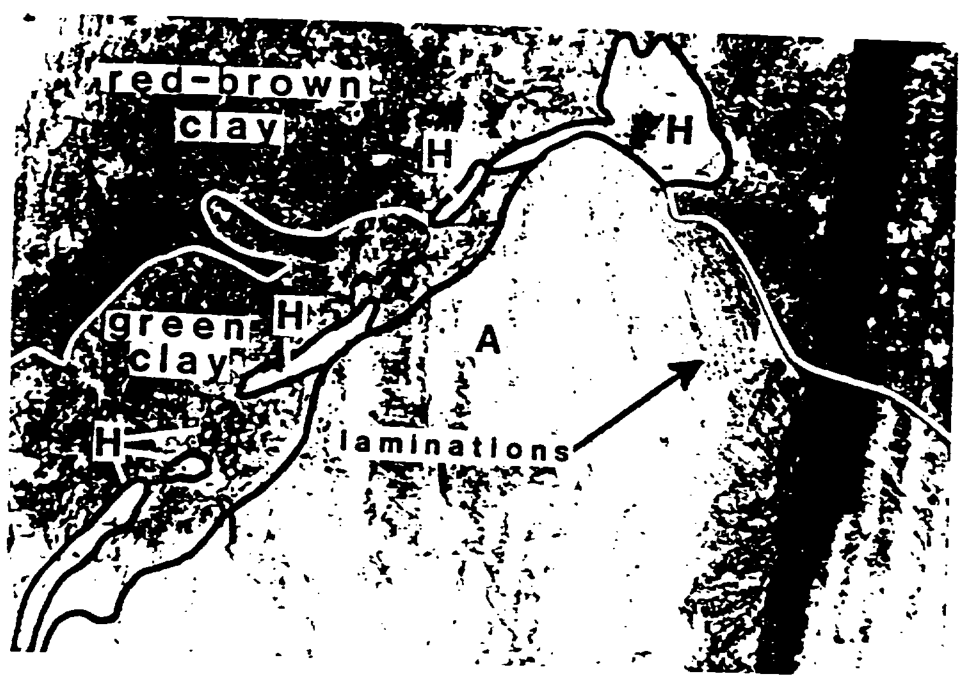

Figure 20.--Enlargement of upper right portion of figure 19. Light streaks along left side of anhydrite block are secondary halite seam cutting through greenish clay. Above greenish clay in upper left is reddish-brown clay. Laminations apparent on upper right side of anhydrite. Dark streak on right is shadow. A=anhydrite, H=halite.

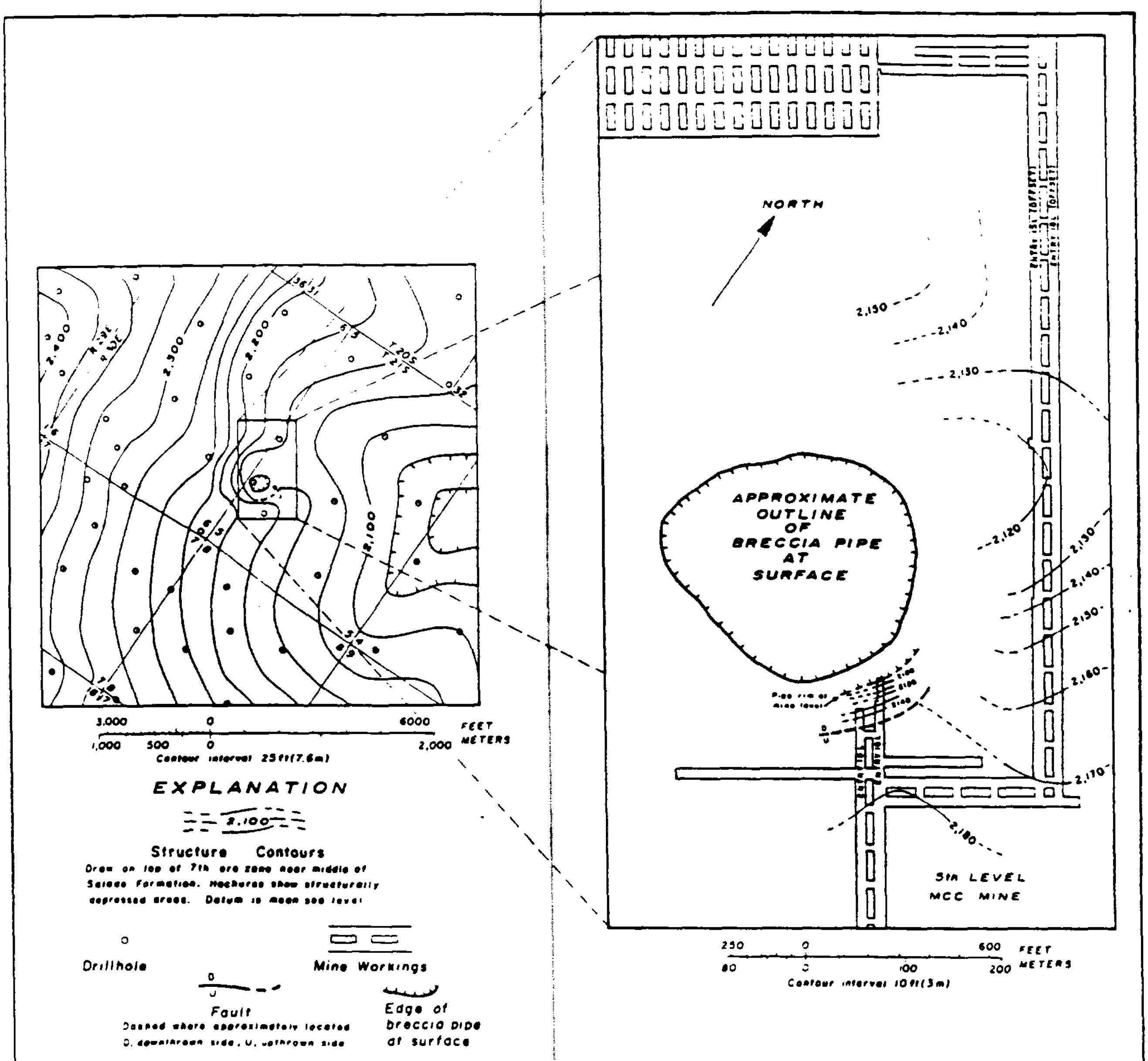

Figure 22.--Structure of salt beds (top of 7th ore zone) in vicinity of Hill C breccia pipe.

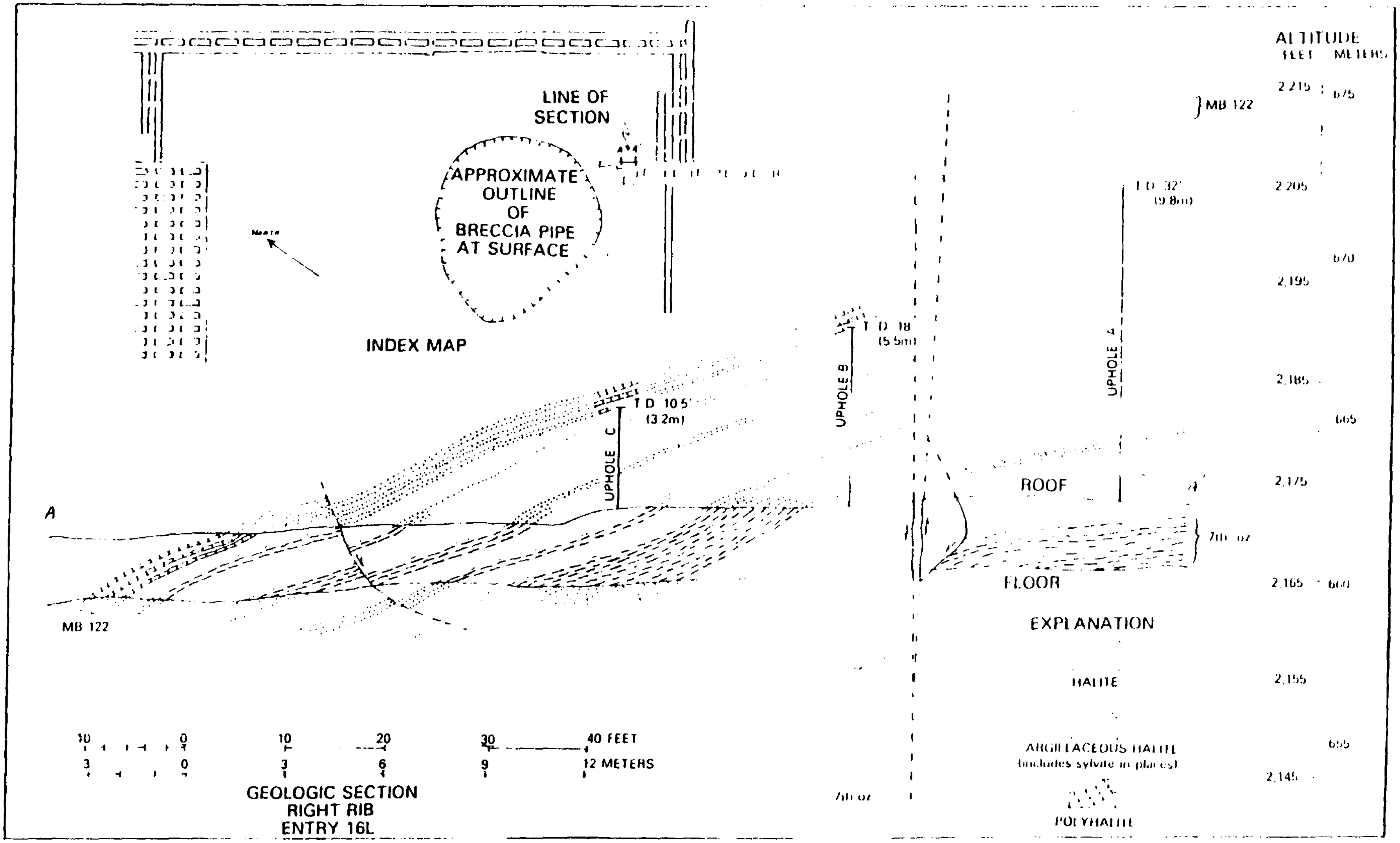

Figure 24.--Displacement of salt beds by faults near southeast flank of Hill C breccia pipe in mine workings, Panel 4A, 5th level, MCC mine.

holes were cored in alphabetical order (A, B, C); the core was 2.5 cm (1 in.) in diameter. Hole A penetrated the pipe boundary. Figure 26 shows about 1.8 m (6 ft) of core at the "bottom" of drill hole A. The discing of the core was caused by torque and direct pressure on the bit face and the discs varied from about 3 mm to 10 cm (1/8 to 4 in.) in length. Argillaceous halite and anhydrite layers made up the longest lengths.

In the next to the bottom row of core in figure 26, just in from the left side is the clay seam contact 24.7 m (80.9 ft) between the normal stratigraphy and the breccia pipe. In the bottom row of core, the shades of gray are fragments of halite and anhydrite in a brown clay matrix. The black disc in the second row left is an oil-stained halite. Figure 27 is a geologic cross section of the hole.

Hole B (fig. 25) was cored to a length of 18.3 m (60.1 ft). The core in the first four rows in figure 28 was shattered during drilling, less pressure was applied to the bit during coring of the rock in the last two rows. Oil stained the lower 0.4 m (1.4 ft). The oil caused a lack of circulation of the air cooling the bit and hindered removal of the cuttings below 17 m (56 ft) and the bottom 1.2 m (4.1 ft) of core was lost. The pipe boundary was not reached. Oil from this hole was described in Palacas and others, 1982. Figure 29 is a geologic cross section of the hole.

Hole C (fig. 25) was drilled slightly up from horizontal to a length of 19.6 m (64.15 ft). No recognizable lithologic units were penetrated. Clay was penetrated in the last 0.6 m (2 ft) of the hole and the bit and pipe were jammed in place. A total of 14.6 m (48 ft) of drill pipe was recovered, leaving 7.3 m (24 ft) in the hole. It is not certain whether or not this clay represents the pipe boundary; the SNL drillers believe that the rock being cored just before the pipe became stuck was drilling like halite and not like the breccia material in drill hole A. The pipe boundary was predicted several tens of feet beyond the end of drilling. Figure 30 is the geologic cross section of hole C.

The question of whether or not the walls of the breccia pipe are vertical or the pipe is a cylindrical-shaped body cannot be fully answered with the available data. Superimposing the surface trace of the pipe with the one area underground shows that the underground boundary of the pipe is about 30 m (100 ft) further to the southeast than the corresponding part of the pipe at the surface. This could indicate that either the pipe does increase in diameter with depth or if it is a cylinder, then the cylinder is not in a vertical orientation.

In studies done by Piper and Stead (1965, p. 34), it was found that most collapse structures over underground nuclear tests are roughly cylindrical. In additional studies on the same subject, Houser (1970) used a cylindrical shape in his interpretations, although he states (p. 51) that while evidence points to the cylindrical shape in some cases, other cases indicate an inverted cone (opening downward).

Landes and Piper (1972) in studies of brine cavity subsidence in Michigan, state that surface features outside the collapse area do not extend

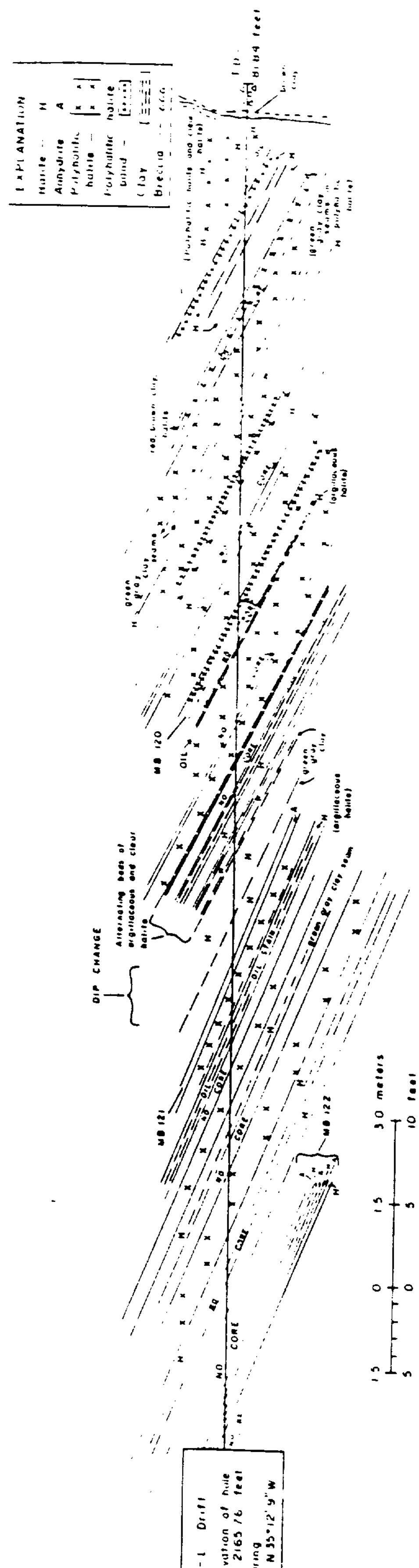

Figure 27. -- Cross-section, drill hole A, Mississippi Chemical Corp Mine breccia study

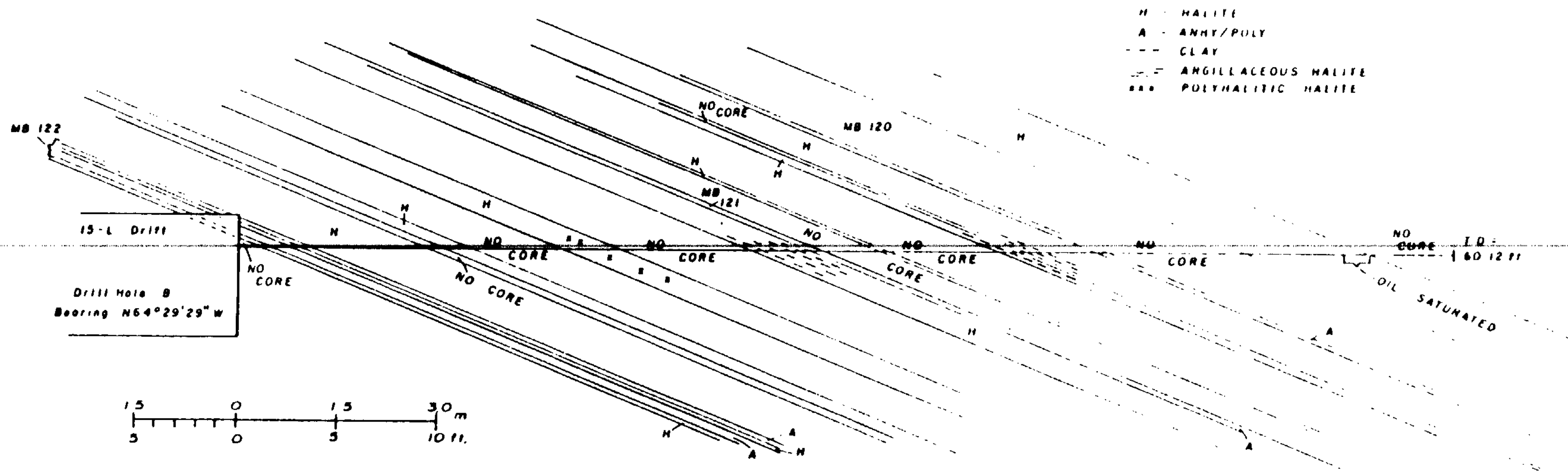

Fig. 29--Cross-section, drill hole B, showing lithology and structure

outward farther than the underground solution cavity. This implies that the possible shape of the collapse structure is an inverted cone or a nearly vertical cylinder.

Eck and Redfield (1963) in their study on the Sanford Dam near Borger, Tex., report numerous filled chimneys having irregular vertical sides (p. 56). The upper portions of these chimneys have funnel shapes.

The general shapes of the breccia pipes at Hills A and C are believed to be near-vertical cylinders, possibly widening slightly with depth.

OTHER SUSPECTED PIPES IN DELAWARE BASIN

Wills-Weaver Pipe

In the earlier discussion of geophysical studies carried out in the basin for the WIPP site, the Wills-Weaver area was mentioned. A hole was drilled in sec. 12, T. 20 S., R. 29 E. and penetrated 250.2 m (821 ft) of brecciated rock. Interpretation of geophysical surveys, namely electrical resistivity (Elliot, 1976a) and gravity surveys (Elliot, 1976b), were run across the area and both gave anomalous readings across the suspected pipe. No other work has been done at this site. It is believed to be a breccia pipe. The hill over the pipe has not been breached by erosion and no near-surface structure can be seen.

Hill B

Hill B lies immediately south of Hill A (fig. 9) and rises 28 m (93 ft) above the surrounding terrain. It is round in plan, dome shaped and caliche capped. The hill is only slightly eroded on the west and south sides where some brecciated Triassic rocks (Bachman, 1980) are exposed, but no ring fault has been seen.

Electrical resistivity (Elliot, 1976a) and gravity (Elliot, 1976b) surveys give anomalous readings across the hill much like at Hill A. No drilling was done on Hill B, but the data of Bachman and Elliot strongly suggest that this hill marks the location of a breccia pipe.

WIPP 13 Area

An electrical resistivity survey (Elliot, 1977) across an area about 2.4 km (1 1/2 mi) north-northwest of the center of the WIPP site indicated a possible breccia pipe area. The resistivity signature across this area appeared much like those signatures across Hills A and C. In 1978, interpretation of a gravity survey across the area indicated a gravity low centered on the WIPP 13 site (L. J. Barrows, SNL, oral commun., 1981). There is no topographic expression, of either a hill or a depression; but because of the closeness of this area to the actual repository location, further exploration was needed. Drill hole WIPP 13 is located near the center of the resistivity anomaly. Core and cuttings, along with downhole geophysical logs indicate that no buried structural anomalies exist at the WIPP 13 location (Gonzales and Jones, 1979) to account for the resistivity anomaly. The probable cause for the anomaly is an increase of sandy, more porous material in the Dewey Lake Red Beds containing more water than is found in the

In a report by Brobst and Epstein (1963, p. 331), pipes "tens to hundreds of feet in diameter" and 61 m (200 ft) deep were mapped in the Fanny Peak quadrangle of Wyoming and South Dakota. The authors attribute the pipe formation to the solution of anhydrite and gypsum in the Minnelusa Formation. Fragments of overlying Permian rocks are incorporated in the breccia in the pipes. The formation of these pipes started after the Black Hills uplift (Late Cretaceous-Early Triassic), and the dissolution is continuing to the present.

In the Wyoming-South Dakota area, the anhydrite-gypsum layers of the Minnelusa and overlying Opeche and Spearfish Formations are the rocks involved in the dissolution. Halite also was and is being dissolved from the formations as indicated by analysis of well water in the area. Brobst and Epstein (1963, p. 336) attribute the near-vertical orientation of the pipes to their formation at intersections of joints. They also postulated that most of the pipes have their roots in the Minnelusa, although some may be rooted in the underlying Pahasapa. The breccia in the pipes has been well-cemented by $CaCO_3$, and the pipes stand out on cliff faces and as small hills above the surrounding terrain.

Michigan

Michigan also contains breccia pipes. Landes and others (1945) describe the occurrence and possible formative history of these pipes in the Mackinac Straits area. They attribute formation of the pipes to cavity forming in the evaporite-rich Pointe aux Chenes Formation (usage of the Michigan Geological Survey) of Silurian age. In the subsurface the formation is called the Salina. No brecciated rocks have been found in the underlying Niagara Formation, and Landes and others put the base of the pipes in the Pointe aux Chenes.

Several previous explanations for the forming of the breccias are given in the Landes report. He and the other authors favor a solution to-cavity to-collapse of overlying rocks theory. Whether or not the collapse was catastrophic and occurred as a single event is unknown. Landes believes that some of the process involved catastrophic collapse, because brecciated rocks of much younger age are found in the breccia mass. Downward displacements of from 183 to 457 m (600 to 1500 ft) are recognized in a quarry at Calcite, Mich. (Landes and others, 1945, p. 129). Landes and others (p. 134) described these breccias as a conglomeration of rock fragments of every degree in size with interstices between the larger fragments filled with smaller fragments which range downward from a few inches to dust size.

Where calcium carbonate was available in the water moving through the brecciated rocks, they are firmly cemented by calcite. Other pipes have little cement if their matrix contains shale which filled the interstices between the limestone blocks and impeded the flow of ground water.

The age of the brecciation has been estimated by Landes and others (1945, p. 136-137). The youngest rock found in the breccia masses is the Detroit River Formation of Devonian age. These rocks must have solidified prior to collapse or they would not form discrete blocks in the breccia. At a quarry in Calcite, Mich., the flat-bedded Dundee Limestone (Devonian) can be seen overlying the brecciated Detroit River Formation. Collapse and brecciation must have been completed before the Dundee was deposited. Collapse could have

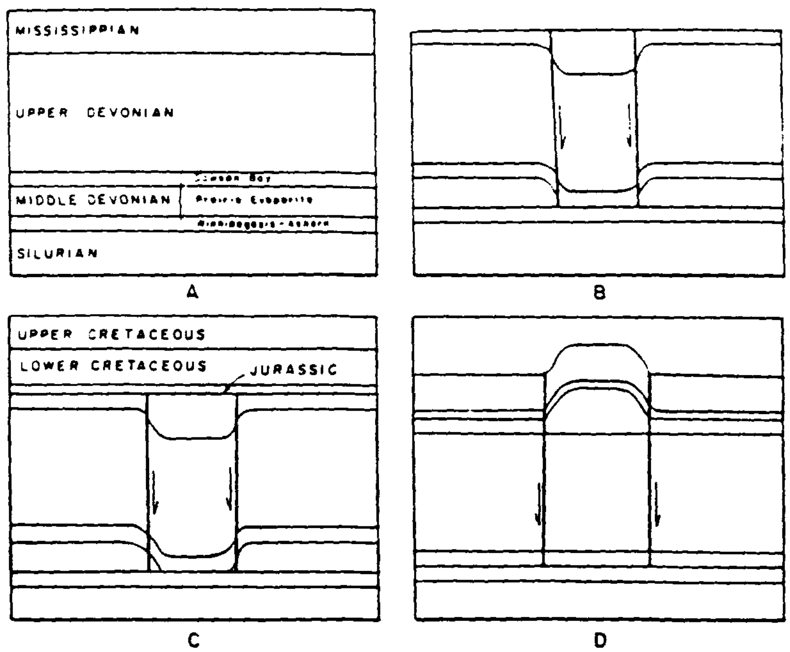

Figure 31.--Formation of anomalous Mississippian thicks and coincident structural highs in younger strata. (A) Post-Mississippian erosion; (B) Later stage during post-Mississippian peneplanation following removal of Prairie Evaporite salt section by solution; (C) Subsequent deposition of uniform thicknesses of Jurassic and Cretaceous beds on smooth Mississippian surface; (D) Final stage following solution of remaining Prairie Evaporite salt (modified from Gorrell and Alderman, 1962).

dissolution of anhydrite and possible minor amounts of halite from the Röt facies of the Bundsandstein (possibly as much as 100 m or 328 ft of evaporite rocks). Bernard believes that the Zechstein at the locations of these pipes contains little halite; the edge of the Zechstein is in this area, and therefore could not be the root zone for the pipes. He does acknowledge the existence of Zechstein rooted sinks 25 km (16 mi) to the north of Kassel in the "Cloudburst" area of Tendelburg. Bernhard (1973) dates the formation of the pipes near Kassel as late Tertiary to early Quaternary on the basis of the sink-fill material containing Keuper rocks (Upper Triassic).

CONCLUSIONS

Method(s) of Formation of Breccia Pipes and Age of Formation of Known Pipes in Basin Near the WIPP Site

The understanding of the method(s) of formation of breccia pipes in the Delaware Basin is critical to the placement of a repository for radioactive waste at the WIPP site. The principal question is: Can a pipe develop under the repository and cause a breach in the system that will allow access of fluids to the waste canisters? A secondary question is: Could a nearby developing pipe adversely affect the repository? Investigations at and near the WIPP site have helped to define what a breccia pipe is and how a pipe develops, but not what governs its location--see below. Another question is: Can dissolution of beds affect the integrity of the repository?

Examples of pipes in Michigan show that at some stage in the development of those pipes there was catastrophic collapse. In the Mackinac Straits region of Michigan, breccia fragments have been identified 183-229 m (600-750 ft) below their normal stratigraphic horizon (Landes and others, 1945, p. 129). Limestone beds above the cavities where halite had been dissolved could have formed support beams which held until increasing widths of the cavities caused failure of the beams, at which time the material above the existing cavities could collapse rapidly, causing a jumbling of material in the collapse chimney.

Rock in core from WIPP 16 and WIPP 31, drilled into known or expected breccia pipes north of the WIPP site in southeastern New Mexico, also shows a great deal of intermingling of various strata. Dolomite fragments have been found 335 m (1100 ft) below their normal stratigraphic position in WIPP 31. Siltstone fragments in WIPP 16 are found 183 m (600 ft) below their expected level.

Depending upon the type of rock above the solution cavities, the downward movement of the overlying rocks can be catastrophic as in the above cases, or slowly as in many salt mines (actually as salt flowage). If the movement is slow or in the catastrophic cases if the drop is not far, the falling rocks will fracture but not be mixed and jumbled with surrounding lithologies.

The only known breccia pipes in the Delaware Basin in the vicinity of the WIPP site are located 19-32 km (12-20 mi) northwest of the center of the site. Two pipes, and probably a third, have surface expressions which are nearly circular, rounded and breached hills 15-30 m (50-100 ft) in elevation. These are Hills A, B, and C of Bachman (1980) (domes A, B, and C polyhalite beds of the Salado Formation to drop with it. Rocks of the overlying Rustler Formation, Dewey Lake Red Beds, and Dockum Group may have also dropped.

The cavity would be filled with unsaturated water and as the mass of rock dropped nearly instantaneously into the cavity, the water would be forced out. The easiest path would be upward into the void and fractured rocks created by the collapse. Much of the halite would be dissolved by this water and eventually the now saturated water would move downward and out through the existing paths in the reef.

It is doubtful if collapse to the surface occurred all at one time. The mixture of rock units, with some rocks dropping as much as 335 m (1100 ft) to be mixed with rocks from a lesser vertical drop, implies that there were several stages of collapse as the pipe stopped its way to the surface.

Boulders of Dockum Group conglomerate now present on the surface overlying the pipe are believed to come from a higher stratigraphic position (Bachman, 1980, p. 67). The presence of these younger rocks implies that the Dockum Group was thicker at the time of formation of the pipe than it is now.

After the collapse to the surface, the resulting depression served as a catchment basin, and as the collecting water percolated downward, it also dissolved halite, potash, and other soluble rocks. Nearly all of the Salado halite and all of the Rustler halite was removed by this process aiding additional collapse in the pipe. This process also transported clay, silt, and sand downward and these particles became the matrix of the brecciated rock in the pipe.

Complete removal of soluble rocks has not occurred in the pipe filling at Hill A. Evidence of this is found in the anhydrite and gypsum fragments and beds still present, and in the large block of Salado halite cored between depths of 444 and 464 m (1458 and 1522 ft). Additional evidence of the incomplete removal of solubles is found in fragments of the Dewey Lake Red Beds. Stringers of selenite (gypsum) are found cutting these fragments but not the breccia matrix. Selenite stringers are found in the Dewey Lake Red Beds where the unit has not been brecciated. These deposits are thought to be caused by downward percolating of calcium sulfate-enriched water filling bedding-plane partings and fractures caused by gentle subsidence of the rock as units below are slowly being dissolved. This process is occurring or has occurred in much of the Dewey Lake Red Beds on the western half of the WIPP site (Jones, 1978) to the south of Hill A.

Over some period of time, surface erosion removed the Dockum Group rocks and any depression over the sink was filled in by debris-carrying surface water. About 600,000 years ago the Gatuna Formation was deposited across a gently rolling terrain filling in lows in the topography. Above the Gatuna, the Mescalero caliche was deposited on a nearly flat surface (410,000-510,000 years ago, Bachman, 1980). The caliche was deposited over the pipe at Hill A. The present dip of the caliche beds away from the center of Hill A indicates removal of halite from around the pipe. Holes drilled nearby show that the Rustler halite and the upper part of the Salado halite have been removed. This removal is referred to as the dissolution front (see p. 18), a have been the rapid downward movement in this pipe, but more than 183 m (600 ft) of rock of various lithologies was let down slowly, only tilting about 35° at its final resting depth. Here the two pipes differ in the condition of the rock, Hill A containing brecciated and jumbled rock down to the Fletcher Anhydrite Member, Hill C containing these only to the top of the Rustler Formation.

The dissolution front, moving from west to east, had penetrated into the Salado Formation at Hill A, but only into the Rustler Formation at Hill C at the time of collapse of the pipe, presuming that the two pipes formed at nearly the same time.

The caliche overlying Hill C has been downdropped toward the center of the pipe in several places indicating that minor collapse occurred after the main collapse. This minor collapse can be dated as less than 410,000 years ago.

Minor amounts of oil-stained core from both WIPP 16 and WIPP 31, as well as oil seeps in the MCC drifts near Hill C, were analyzed to see if an answer could be found to account for the presence of the oil (Palacas and others, 1982). Gas chromatograph and geochemical analysis indicate that the three oils are related to the oil from wells to the north of the pipes taken from the Yates Formation. The Yates overlies the Capitan reef on the backside of the reef. It is possible that oil from this formation migrated toward the area of the breccia pipes and either entered the rocks before collapse occurred or it was forcefully emplaced during collapse, being pushed stratigraphically upward by hydrostatic pressure as the water in the underlying void was forced upward by the infalling rocks. In WIPP 31, the oil stains were in rocks of Dewey Lake Red Beds, and Rustler and Salado Formations consisting of siltstone, anhydrite, and dolomite fragments and a matrix of mud, recrystallized halite, and glauberite crystals. In WIPP 16, the oil stains were in the Rustler Formation in anhydrite above the Magenta Dolomite Member and in halite below the Culebra Dolomite Member. The oil seeping into the MCC mine appears to be coming from a nearly vertical fault about 43 m (140 ft) from the edge of the breccia pipe.

Possible Effect on WIPP Site

Numerous domes and sinks dot the landscape in the Delaware Basin. Some of these features can be shown to be remnants of near-surface dissolution or surface erosion; others are from dissolution and cavity formation in the Capitan Limestone. Known locations where deep dissolution occurs and forms structures called breccia pipes are limited to areas over the buried Capitan reef, no closer than 16 km (10 mi) to the WIPP site. The four known occurrences are Hills A, B, C, and the Wills-Weaver site.

Collapse of these structures, at least to the surface, occurred sometime before 400,000-500,000 years ago.

Locales on and around the WIPP site that were investigated for evidence of pipe formation, with none being found, include the sites of drill holes WIPP 13, WIPP 32, WIPP 33, and WIPP 34. Numerous surface features were mapped and found to be near-surface erosion and dissolution features.

DRILL-STEM TESTS, WIPP 31

By J. W. Mercer

INTRODUCTION

During drilling and coring of WIPP 31 reentry, formation tests were conducted over selected intervals of the borehole to determine the possible presence of fluids (liquids or gases) and, if present, to obtain estimates of quantity, quality, and source. The formation tests were conducted using standard drill-stem test procedures as described in Dolan and others (1957), Bredehoeft (1965), Hackbarth (1978), and in "Supplement #1 to the field operations plan for WIPP 31 Re-Entry" as discussed in a letter from W. D. Weart. SNL, to D. Schueler, DOE, dated July 25, 1980.

The drill-stem test is a temporary well completion whereby the zone of interest in the borehole is isolated by the expansion of a rubber packing element or packer attached to the drill string. These packers isolate the test interval, relieving the mud column pressure and allowing the zone to produce formation fluid (if present) to the drill pipe. In addition to these packers, the drill-stem-testing tool consists of valves, pressure-recorders, and related equipment. During each individual drill-stem test, normal procedures call for multiple opening (flow-in) and closing (shut-in) of the tester valve with subsequent recording of the pressure changes. As discussed in Bredehoeft (1965), interpretation and analyses of drill-stem tests can yield information about the undisturbed formation pressure, a coefficient of permeability for the stratigraphic interval tested, and in some cases a sample of formation fluid.

ANALYSIS

During coring of WIPP 31, seven individual formation tests were attempted over various stratigraphic intervals in the borehole. Of these seven tests, only five were successfully completed, the first two failing because of malfunction of the testing tool. The procedure prior to each drill-stem test included running geophysical logs (gamma, density, and neutron) for lithologic control as well as a caliper to select packer seats. As drilling proceeded, the core was monitored for any fracturing or lithologic changes that might indicate a zone of fluid entry.

Field data obtained during testing are included in table 6 and various packer configurations for the tests are shown on figure 33. These tests (DST-3 and -4) indicate that the zone tested from 246 to 324 m (808 to 1064 ft, DST-3) and 246 to 376 m (808 to 1235 ft, DST-4) contained some fluid, however, production rates were so low that the only fluid recovered was diluted drilling mud. Calculated permeabilities were 0.57 and 0.90 millidarcies (mD), respectively. DST-5 from 371 to 426 m (1,216 to 1,396 ft) indicated very low permeability with a calculated value of 0.11 mD. The tests for DST-6 (456-514 m or 1,495-1,687 ft) and DST-7 (451-604 m or 1,480-1,981 ft) indicated the formation was extremely tight and did not yield enough fluid to make calculations for permeability.

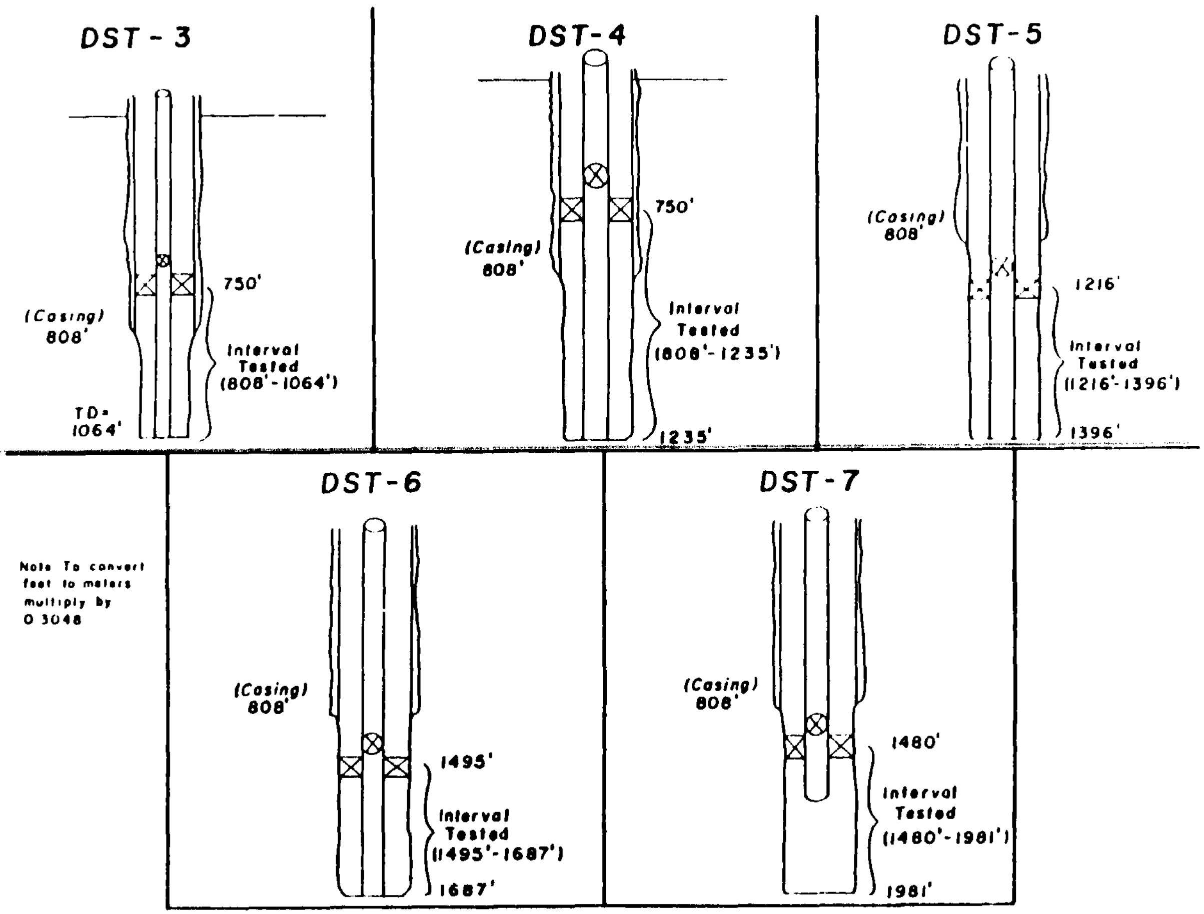

Figure 33.--Packer configuration for drill-stem tests of WIPP 31 test hole.

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To	Mr. R. H. Blackman Resident Counsel	Date	June 12, 1975
		Subject	Oil Seeps in Salt Section P.C.A. Mine Area
From	L. P. Corbin		
		File	

Two areas in the P.C.A. Mine have oil seeps in the salt section.

The first area is in Sections 5, 8, and 9, T. 20 S., R. 30 E. as shown on Figure 1. The top of the salt in this area is approximately 490' and the bottom of the salt is about 1390'. The Main South Haulage Tunnel encountered an oil seep in the tunnel heading which is at a depth of about [illegible]'. Oil flowed slowly out of a drill hole in the tunnel face. The flow was killed by tamping a wooden plug into the drill hole. As shown on Figure 1, the tunnel was rerouted at considerable expense only to encounter another seep of smaller volume. Both locations are still seeping oil at a very slow rate. A core test, PCA 107, shown in Section 5 on Figure 1, had seven zones of oil stained core over an interval of 304' in the salt section. These seeps are thought to be coming from an abandoned oil test "Continental Chase" which was drilled in the late 1920's in the NE-1/4 Sec. 8, T. 20 S., R. 30 E.

The second area of oil seeps is in the east end of our West Orebody (Figure 2). The top of the salt in this area is approximately 360' and the bottom of the salt is about 1041'. Here in Room 5, Breakthrough 13, as described by E. C. Jourdan, chief mine engineer "The seep was interesting in that it occurred in a fine vertical fracture within the ore horizon and extends for an unknown distance into the salt above and below the ore zone." This seep is approximately 600' below the surface and 1000' from the nearest abandoned oil well in the Getty Pool. In the National Potash Mine, about 900' south of our oil seep in Room 5, Breakthrough 13, another oil seep was encountered. This seep is about 700' from an abandoned oil well in the Getty Pool. PCA Core Test 74, in this same area, showed two zones of oil stains in the salt section at 549' and 565'4". Core Test 74 is located between two abandoned oil wells, one about 1000' due north, the other 1000' due south.

LPC:dt
attachments

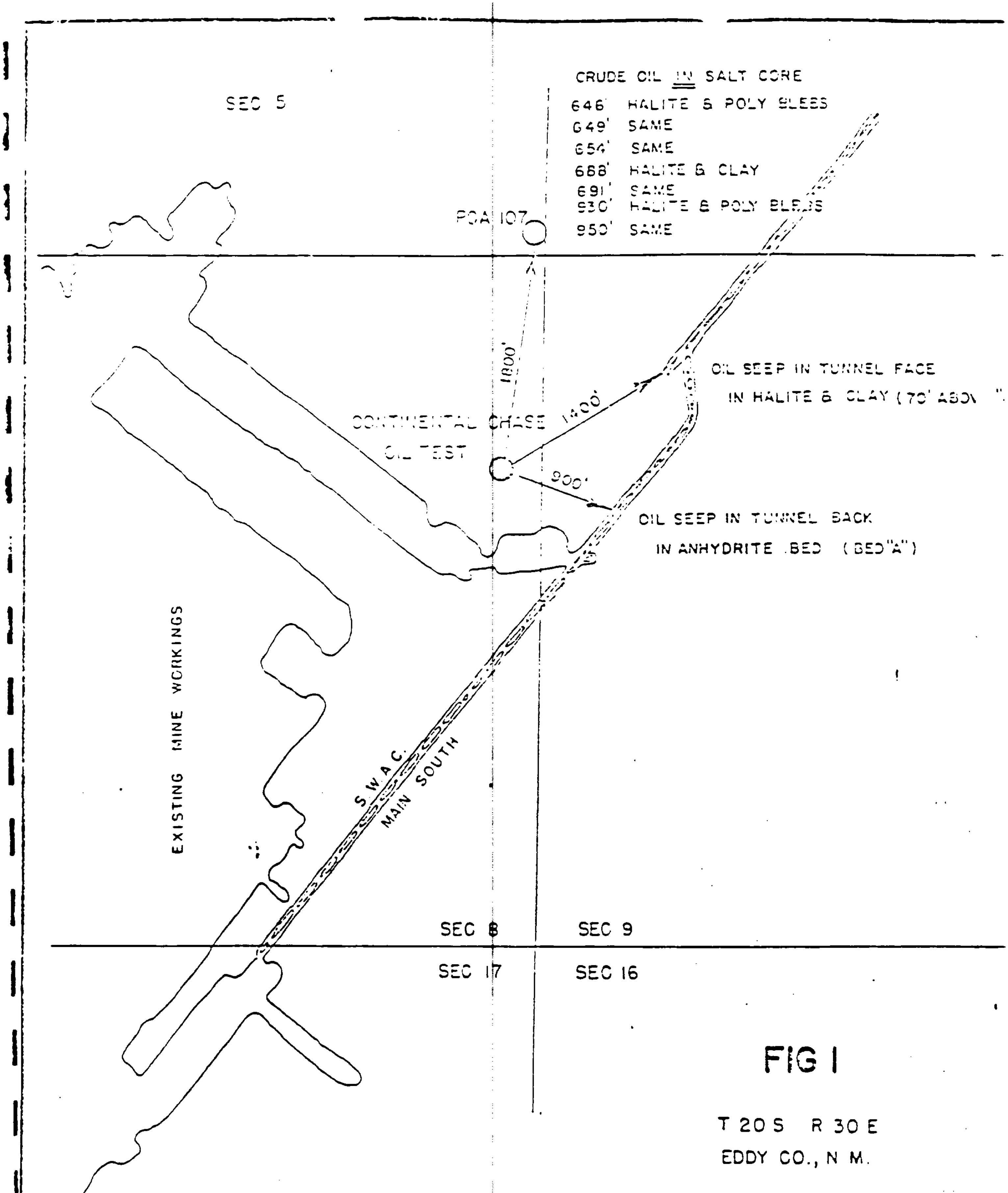


FIG I

-ROVED BY	SHOWING CONTINENTAL CHASE OIL TEST AND THE AREAS WHERE CRUDE OIL HAS BEEN ENCOUNTERED IN SALT.	POTASH COMPANY OF AMER. CARLSBAD, NEW MEXICO	
		DRAWN BY LFC	DRAWING
		CHECKED BY	
	SCALE- 1" = 1000' DATE- MARCH 64	DIRECTED BY JBC	

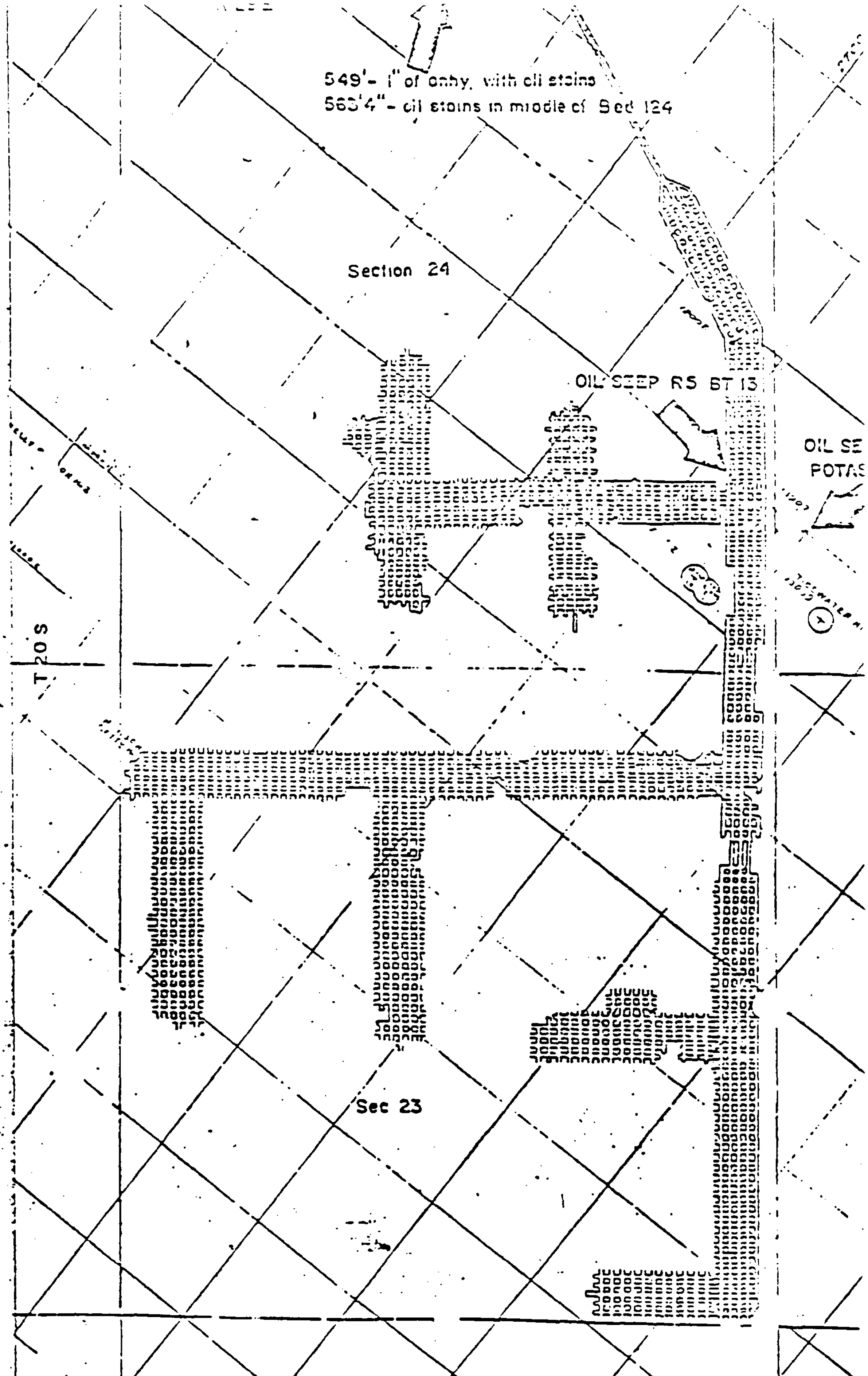


FIG 2

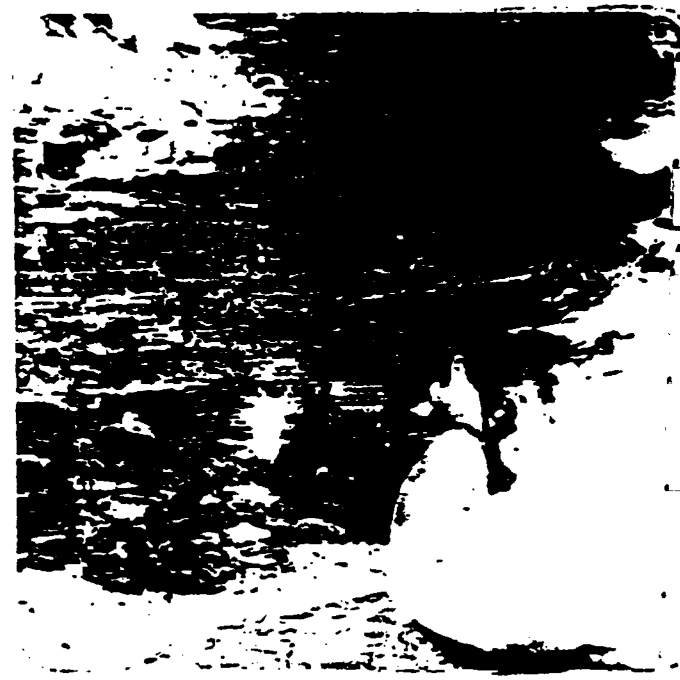
SHOWING PCA FAR WEST OREBODY & LOCATION OF OIL SEEPS IN THE SALT SECTION

POTASH COMPANY OF AMERICA

Photographs of Main South Entries Showing Oil Seep Near Abandoned Oil Well

January 18, 1962

Tension crack in anhydrite filled with salt showing oil seep in Main South.



Anhydrite bed - Main South showing oi seep.

Oil seep in rib of Main South Entry.

Face of Main South. Red is polyha and salt. Oil covers most of face.

NATIONAL POTASH COMPANY

P. O. BOX 731
CARLSBAD, NEW MEXICO

August 1, 1973

Mr. Roy H. Blackman
Resident Counsel
Potash Company of America
P. O. Box 31
Carlsbad, New Mexico 88220

Dear Mr. Blackman:

This pertains to an incident in the spring of 1965 in which we encountered evidence of oil seepage in operations at our Eddy Mine. The location where this occurred was approximately 1,000 feet from the west line and 100 feet from the north line of the NW-1/4, Sec. 25, T. 20 S., R. 29 E. Altogether there were some three or four oil stains present, and two separate entries in the panel were affected.

The material involved at the site was horizontally bedded and consisted of 5 feet of sylvinite overlaid by 1 to 1-1/2 feet of clay. No particularly unusual physical conditions were present other than the fact that it was a salt dome area in which the seeps were encountered.

Mining operations in the area were discontinued immediately in order that the seep conditions could be investigated. This, of course, necessitated transfer of operations, including removal of all equipment by the production crews involved, to another area of the mine.

Since the nearest well was the Getty No. 1, which was approximately 700 feet from the location of the seeps, it was suspected as their source. The U. S. G. S. investigated and determined that this well had not been properly and adequately sealed. So the owner was required to reseal it in an approved manner. It is my understanding that this led further to a check of several other wells in the Getty pool in which the findings of such inadequacy were essentially the same and in which similar corrective action was also taken.

If, for any reason, additional information in regard to this matter is needed, I am sure it can readily be obtained from the U. S. G. S. office in Roswell, New Mexico, as personnel from there were involved in the incident.

Very truly yours,

Orland Foster

Orland Foster
Industrial Relations Manager

OF:ca

AMAX ELECTRICAL HOLE - DRILLING PROGRESS CONT'D.

DATE	COMMENTS	FT./ACCUM FT.	HRS. & / ACCUM. HRS.
1-14-81	Drilling-Build Up Bit Water@135'	10/305'	9/198½
1-15-81	Drilling-Water @130' Hole Caving	9/314'	8½/207
1-16-81	Drilling-Water @ 130'	11/325'	9/216
1-17-81	Drilling-Hole Caving Bad Water @135'	5/330'	10/226
1-18-81	Drilling-Hole Caving Water @135'	5/335'	9/235
1-19-81	Drilling-Hole standing better Water@ 135'	5/340'	10/245
1-20-81	Drilling-Reset Socket Water @135'	5/345'	9/254
1-21-81	Drilling-Water @ 130'	5/350'	9/263
1-22-81	Drilling-Water @135' Built up bit	5/355'	10/273
1-23-81	Drilling-Water @135' (HIT SALT STRINGERS)	10/365'	9/282
1-24-81	Drilling-Water @ 130' (IN SALT)	10/375'	10/292
1-25-81	Drilling-Water @ 130'	9/384'	8/300
1-26-81	Drilling-Water @ 130'	11/395'	10/310
1-27-81	Drilling-Water @ 130' Some Hole Cave	5/400'	9/319
1-28-81	Drilling-Water @ 130' String up 10" Tools & Get Ready to Run Csg.	4/404'	10/319
1-29-81	Run 404' of new 13-3/8" Casing & Cement with 400-sxs.(Denton Cement Co.) Did not circulate	-	10/329

TOTAL DEPTH TO SET SURFACE = 404 FEET

TOTAL RIG HOURS = 329

(ABOVE WORK BILLED ON OUR INV#0118)

1-30-81 1-31-81 2-1-81	Wait on Cement to Dry-Surface 13-3/8" Casing	-	-
2-2-81	Drill out Shoe - Check for Water-None-Drilling	21/425'	10/10
2-3-81	Drilling-Dry	40/465'	9½/19½
2-4-81	Drilling - Hard	15/480'	9/28½
2-5-81	Drilling	40/520'	10/38½

AMAX ELECTRICAL HOLE - DRILLING PROGRESS CONT'D.

2-6-81	Drilling	40/560'	10/48½
2-7-81	Drilling	40/600'	10/58½
2-9-81	Drilling	40/640'	10/68½
2-10-81	Drilling	36/676'	10/78½
2-11-81	Drilling - Cut 124 Bed(Sample)	16/692'	8/86½
2-12-81	Drilling-Get ready to run 8-5/8" DID Not	4/696'	9/95½
2-13-81	Run/Cement(Circulate) 8-5/8" Csg. to 696' Denton Cmt. Co. 350-Sxs.	- Add 8-Yd^3 Cement to back-side	10/105½
2-14-81			-
2-15-81	Wait on Cement		-
2-16-81	Drill out Shoe-Drill into Mine(TD 704')	8/704'	10/115½

TOTAL DEPTH TO SET 8-5/8" = 696'

TD into Mine = 704' (base 124-bed approx. 696')

TOTAL RIG HOURS = 115½ Hrs.

(Drill Ground Cable Hole per Alan Baldridge - approximately 30' SW above hole)

2-17-81	Move & Rig-Up	-	10/10
2-18-81	Drilling	20/20'	9½/19½
2-19-81	Drilling	20/40'	10/29½
2-20-81	Drilling	20/60'	10/39½
2-21-81	Drilling	20/80'	9½/49
2-22-81	Drilling	15/95'	10/59
2-23-81	Drilling	10/105'	8/67
2-24-81	Drilling-Water @ 138'	33/138'	10/77
2-25-81	Drilling - TD=145'	7/145' TD	10/87
2-26-81	Rig-Down	-	10/97

TD on Ground Cable Hole = 145'

Water @ 138'

Total Rig Hours = 97-Hrs.

AMAX ELECTRICAL HOLE - DRILLING SAMPLES CONT'D.

DEPTH IN FEET	DESCRIPTION (As Reported by DRILLER)
295'-330'	Anhydrite & Shale
330'-360'	Gyp & Red Shale
360'-382'	Gyp & Red Shale With Salt Stringers
385'	CALL TOP OF SALT
385'-404'	Salt
404' Set 13-3/8" Surface Casing	
404-696'	Salt - Base 124 Bed approx. 696'
696' Set 8-5/8" Casing	
696-704'	Salt-Drill into Mine approx. 704'

NOTE: Use this same log for 145' Ground Cable Hole

MARNEL PIPE & SUPPLY CO.

NEW – USED OIL FIELD PIPE & EQUIPMENT
SHALLOW POOL CASING PULLING & WELL PLUGGING
PIPE THREADING & TESTING

P. O. Box 1037
401 N. 1st St.

Artesia, New Mexico 88210
(505) 746-6558

AMAX ELECTRICAL HOLE - DRILLING PROGRESS

DATE	COMMENTS	Feet/Accum Feet	Hrs. Accum. Hours
12-18-80	Moving & rigging-up	—	4/4
12-19-80	Rigging-Up	—	8/12
12-22-80	Spud Hole & Drilling	20'/20'	10/22
12-23-80	Drilling	20'/40'	9/31
12-24-80	Drilling - Shut down for Christmas	10'/50'	5/36
12-29-80	Drilling	25'/75'	10/46
12-30-80	Drilling-Lost Water & Mud in Crack	20'/95'	10/56
12-31-80	Drilling	20'/115'	9½/65½
1-1-81	Drilling	15'/130'	8½/74
1-2-81	Drilling-HIT WATER 130-145' (Fresh)	15'/145'	10/84
1-3-81	Drilling-Fresh Water 30' in hole	20'/165'	9/93
1-4-81	Drilling-Fresh Water 50' in hole	15'/180'	10/10[illegible]
1-5-81	Drilling-Fresh Water 60' in hole Put on drilling-jars	15'/195'	10/11[illegible]
1-6-81	Drilling-Fresh Water 70' in hole	20'/215'	9/122
1-7-81	Drilling-Fresh Water 90' in hole Drilling Slowed due to water	10/225'	9/13[illegible]
1-8-81	Drilling-Fresh Water 100' in hole Bailed hole for 1-hr. & could not lower water level.	10/235'	10/141
1-9-81	Drilling-Fresh Water 105' in hole	15/250'	9/15[illegible]
1-10-81	Drilling-Fresh Water 120' in hole	10/260'	10/16[illegible]
1-11-81	Drilling-Fresh Water 120' in hole	10/270'	10/17[illegible]
1-12-81	Drilling-Fresh Water 130' in hole	9/279'	10/18[illegible]
1-13-81	Drilling-Fresh Water 130' in hole	16/295'	9½/189½

(Feb. 1951)

X			

Land Office Santa Fe
Lease No. M 26573
Unit

(SUBMIT IN TRIPLICATE)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SUNDRY NOTICES AND REPORTS ON WELLS

NOTICE OF INTENTION TO DRILL	X	SUBSEQUENT REPORT OF WATER SHUT-OFF	
NOTICE OF INTENTION TO CHANGE PLANS		SUBSEQUENT REPORT OF SHOOTING OR ACIDIZING	
NOTICE OF INTENTION TO TEST WATER SHUT-OFF		SUBSEQUENT REPORT OF ALTERING CASING	
NOTICE OF INTENTION TO RE-DRILL OR REPAIR WELL		SUBSEQUENT REPORT OF RE-DRILLING OR REPAIR	
NOTICE OF INTENTION TO SHOOT OR ACIDIZE		SUBSEQUENT REPORT OF ABANDONMENT	
NOTICE OF INTENTION TO PULL OR ALTER CASING		SUPPLEMENTARY WELL HISTORY	
NOTICE OF INTENTION TO ABANDON WELL			

(INDICATE ABOVE BY CHECK MARK NATURE OF REPORT, NOTICE, OR OTHER DATA)

December 3, 1980

Well No. 181 is located 2106 ft. from {N/S} line and 1178 ft. from {E/W} line of sec. 13

SW¼, Section 13 (¼ Sec. and Sec. No.) T 19S (Twp.) R 29E (Range) NMPM (Meridian)

(Field) Eddy County (County or Subdivision) New Mexico (State or Territory)

The elevation of the derrick floor above sea level is 3310 ft.

DETAILS OF WORK

(State names of and expected depths to objective sands; show sizes, weights, and lengths of proposed casings; indicate mudding jobs, cementing points, and all other important proposed work)

AMAX Chemical Corporation plans to drill bore hole at this location to be used for an electrical power supply to our underground mine workings in the western lease area. We will drill a 16-inch diameter hole into the top of the salt and cement 12-inch I.D. casing.

We will drill a 10-3/4" hole from the top of the salt to the mine workings in the 3rd ore zone; 8-inch casing will be cemented from the mine level to surface. Cement to be circulated on both strings of casing.

Drilling is to be done by cable-tool methods.

I understand that this plan of work must receive approval in writing by the Geological Survey before operations may be commenced.

Company AMAX Chemical Corporation

Address P. O. Box 279
Carlsbad, New Mexico 88220

R E Kirby
R. E. Kirby
General Mine Superintendent

APPROVED:
U. S. Geological Survey

By

Title

GPO 862-752

SAMPLES AS REPORTED BY DRILLER

MARNEL PIPE & SUPPLY CO.

NEW – USED OIL FIELD PIPE & EQUIPMENT
SHALLOW POOL CASING PULLING & WELL PLUGGING
PIPE THREADING & TESTING

P. O. Box 1037
401 N. 1st St.

Artesia, New Mexico 88210
(505) 746-6558
Mobil: 365-2516

AMAX ELECTRICAL HOLE – DRILLING SAMPLES

DEPTH IN FEET	DESCRIPTION (As Reported by Driller)
0-10'	Top soil
10-20'	Caliche
20-35'	Gravel-Caliche
35-40'	Red Sand (hard)
40-50'	Gravel & Shale
50-60'	Brown Shale
60-65'	Red Shale
65-75'	Red Sand
75-80'	Gray Anhydrite
80-95'	Red Bed
95-105'	Red Bed (Broken) Lost Water & Mud-Cracks
105-115'	Gray Anhydrite (Hard)
115-165'	Gray Anhydrite (NOTE: 130-45' WATER SAND)
165-170'	Gyp
170-185'	Broken Anhydrite
185-200'	Red-Blue Shale
200'-215'	Broken Anhydrite
215'-225'	Sand
225'-250'	Gray & Red Shale
250'-275'	Red Shale with some sand
275'-295'	Red Sand

NO. 5 SHAFT PREGROUTING PROGRAM

The IMC pregrouting program at No. 5 Shaft consisted of trying to grout a 32-foot diameter curtain from the standing water table to the top of the salt which is at a depth of 295 feet. The purpose of which was to stop any inflow of water during the sinking of No. 5 Shaft.

In the first stage of the grouting program 276,420 pounds of grout was pumped from the surface to a depth of 100 feet, but tests showed that the water inflow would not be stopped.

Grouting was continued and this extended phase of the grout program used 1,727,985 pounds of grout.

At the completion of the pregrouting program, a total of 2,986,705 pounds of fly ash/cement grout and 99,100 pounds of chemical grout were used. The holes of the grout curtain were grouted to a final pressure of 150 psi. The curtain was then pump tested and found to have a low water inflow rate.

However, during the excavation of No. 5 Shaft, at a depth of 72 feet, the grout curtain failed. There was a 600 gpm inflow of water which caused the shaft to flood.

JP:d

8-6-86

NO. 5 SHAFT PREGROUTING

The pregrouting of No. 5 Shaft was conducted from the surface with a Drill Tech D-40K drill, an Acker diamond core drill, cement grout plant, chemical grout plant and batch plant.

The first stage of the program was to drill and grout a series of 24 holes to a depth of 100 feet. The diameter of the grout ring was 32 feet. The spacing between hole centers was approximately 4.2 feet.

The upper 20 feet of ground was cased with 6 inch pipe which was grooved for victaulic type couplings. Six holes, called primary holes or 'P' holes were drilled first. The spacing between holes was approximately 16.75 feet. These 'P' holes were drilled and grouted in stages. The method used in the first six holes was to drill with air and note when water was encountered. The holes were then drilled with water to determine any loss circulation zones. When the holes encountered bad ground, the drilling was stopped and the hole grouted with a cement and fly ash mix grout. This pattern was continued to 100 feet or until the clay seam was encountered. Water in the drill holes was blown out before grouting was started. Also a water injection test was made just before grout injection. The water injection test was made by timing the rate the grout pump could inject water into the ground at a controlled pressure. Usually 7.5 gallons of water was injected. Water was ejected from the holes by placing a two inch plastic pipe, connected to the drill compressor, into the hole and forcing the water out.

The grouting of the first six holes was done as bad ground was encountered and circulation was lost. It was anticipated that cavities could be encountered, so the first six holes were evaluating the ground from the surface to the clay at 100 feet. There were no cavities found. The second set of holes to be drilled were called 'S' holes. There were six of them located halfway between the 'P' holes. These holes would leave a spacing between holes of approximately 8.4 feet. The 'S' holes were drilled and grouted in 20 foot stages from the water table at 30 feet to the clay at 105 feet. The method of grouting these holes was to drill all six holes to the desired depth, blow out the water in the holes for 1/2 hour per hole, water test and grout each hole. No connection was observed between holes. Grout pressures were kept at or below 1 psi per foot of hole. The grout mix was altered to increase grout pressure. The mix started with 25 lbs. cement plus 25 lbs. fly ash in 50 gallons of water. After several batches of this mix, the cement and fly ash were increased to 50 lbs. each, then 75 lbs. each, then 100 lbs. each, then 125 lbs. each and finally increased to 150 lbs. each. After all holes were grouted, they were redrilled to the grouted depth plus 20 feet and grouted again.

At the completion of the 'P' holes and 'S' holes, the 'T', tertiary, holes were drilled and grouted. There were 12 'T' holes located halfway between the 'P' and 'S' holes. The final hole spacing was approximately 4.2 feet between hole centers. The 'T' holes were grouted in the same fashion as the 'S' holes.

The total grout injected in each series of holes is as follows:

P-1	10,800 lbs	S-1	42,600 lbs
P-2	6,400 lbs	S-2	11,100 lbs
P-3	14,200 lbs	S-3	5,200 lbs
P-4	11,400 lbs	S-4	10,550 lbs
P-5	8,000 lbs	S-5	58,700 lbs
P-6	15,200 lbs	S-6	21,170 lbs
T-1	18,150 lbs	T-7	2,850 lbs
T-2	8,800 lbs	T-8	3,050 lbs
T-3	2,800 lbs	T-9	5,000 lbs
T-4	3,000 lbs	T-10	2,900 lbs
T-5	5,500 lbs	T-11	4,300 lbs
T-6	3,150 lbs	T-12	1,650 lbs

Total grout injected in first stage of grouting was 'P' holes - 66,000, 'S' holes - 149,320, 'T' holes - 61,150 for a total of 276,420 lbs grout.

At the completion of grouting the 'T' holes, an effort was made to core 4 holes to the salt. These holes were not completed because the ground conditions were very poor and there was excessive water present. The core recovery from the limited coring completed was very low but a few pieces of core were recovered which had large holes without cement and small holes which the cement could not fill because of particle size.

Cementation West conducted a pump test in an effort to determine the water make a shaft could expect. Although the test was inconclusive, since no substantial drawdown could be obtained, Steve Phillips calculated the shaft water make at 1,250 gpm.

Since the pump test indicated excessive water was present and more grouting would be required, the decision was made to begin a chemical grout program in the upper 100 foot zone. Geoseal was purchased from Phillips Petroleum for a price of 35¢ per pound. A new series of 24 holes was described by Steve Phillips. These holes were to be located 3 feet inside the previous holes. The first 6 holes were called 'P' 100 holes.

The chemical grout program was designed to fill the very small voids in the ground which could not be reached by cement. An anticipated problem was the presence of brine water. The chemical grout would not set up in the presence of brine, therefore, the area had to be flushed with fresh water to dilute the brine. The fresh water was piped into the ground at approximately 50 gallons per minute. The holes would not fillup which indicated the ground was still very open. The geoseal was mixed and pumped into the ground. The mixing porportions were 50 lbs. geoseal in 35 gallons of water. One quart of sodium silicate solution (10% strength) was added to the mix water. The grout was pumped at a maximum pressure equal to 1 psi per foot of overburden. The early chemical grout holes had no pressure buildup and several injections were required before back pressure could be obtained. Samples of the grout were taken on every batch. The gel time was recorded. Excess foam was suppressed by spraying the surface with WD-40 solvent. The chemical grout was pumped into the holes in groups of 10 batches. There were occasions when 10 batches would not build up pressure so up to 10 more batches were injected. There also were occasions when the hole would not accept 10 batches without exceeding the maximum pressure. Therefore, less grout was injected. This process was continued from 30 feet to 105 feet in the 24 holes. From 20 feet to 30 feet, no chemical grout was used since it was above the standing water table. The chemical grout injected into the holes connected to nearby holes in some instances.

No. 5 Shaft Pregrouting (cont'd Page 4)

The total chemical grout injected in the zone from 30 feet to 105 feet was 99,100 lbs or 1,982 bags. The grout injected into the holes in the following amounts.

Hole No.	lbs. of Geoseal	Sub-Total Series	Avg. Per Hole lbs. of Geoseal Per foot Per Hole	Avg. Per Foot 1 Hole
P-101	3,400			
P-102	4,250			
P-103	4,250			
P-104	4,350			
P-105	3,450			
P-106	4,600	24,600	4,050	54.0
S-101	4,650	2,269. Ft^3	378 Ft^3	5.0 Ft^3
S-102	4,750			
S-103	4,100			
S-104	4,650			
S-105	4,300			
S-106	3,750	26,200	4,366.7	58.2
T-101	2,550	2,447 Ft^3	407.8	5.4 Ft^3
T-102	3,400			
T-103	3,600			
T-104	4,600			
T-105	3,150			
T-106	5,100			
T-107	3,700			
T-108	4,850			
T-109	4,800			
T-110	4,750			
T-111	4,200	4,539 Ft^3	378 Ft^3	5.0 Ft^3
T-112	3,900	48,600	4,050.0	54.0
TOTAL	99,100	99,100	4,155.6	55.4

Assuming grout maintains 80% of its original volume, the quantities pumped into the holes can be translated to final grout volume injected less any grout destroyed by the brine water. A 50 lb. bag of geoseal will occupy approximately 35 gallons of space or approximately 4.67 ft^3. The total volume injected was 9,255 ft^3 of chemical grout.

A pump was conducted after the chemical grout program. The pump test indicated that a flow of 36 gallons per minute could be expected from 30 feet to 105 feet.

Two holes were cored to the salt contact which appears to be at 292 feet. These holes called C-1 and C-2 were cored with the Acker core rig. Hole No. C-1 had a 6 inch core loss just above the salt. Hole No. C-2 had a 1 foot 6 inch loss just above the salt. Hole No. C-1 lost circulation at about 250 feet. Hole No. C-2 lost circulation at 131 feet. These two holes were grouted. C-1 took 75,900 lbs. of grout and C-2 took 105,300 lbs. of grout.

The lower zone, from 105 to 295 feet was next grouted through the original holes on the 32 foot diameter circle. The holes were grouted with a cement grout. The holes were grouted at the following depths: 135 feet, 170 feet, 223 feet, 260 feet and 295 feet. Holes No. P-1, P-2, P-3, P-4, P-5 and P-6 were drilled to 135 feet. As the holes were grouted to 100 psi, they often connected with other holes. At 170 feet they also connected at 100 psi. Again at 223 feet they connected. At 260 feet stage, each hole was drilled and grouted separately. Hole No. P-6 encountered a void at 256 feet to 258 feet and lost circulation. However, the hole was grouted with 13,400 lbs. of grout. The remaining holes had no difficulties at this elevation. The stage from 260 to 295 was grouted with brine water and type I or type II cement grout. The secondary set of six holes were grouted to 260 feet with type V cement and fly ash to a grout pressure of 130 psi. The final set of 12 tertiary holes were surface cased with 5 inch casing and grouted to 260 feet with type V cement and fly ash to a grout pressure of 130 psi.

The final injection stage was made with a NaCl saturated brine and a type I or type II cement was used. No fly ash was used. The final grout pressure was 150 psi. The grout injection in the extended phase took a total of 1,727,985 lbs. of grout. The grout takes per hole were as follows.

No. 5 Shaft Pregrouting (cont'd Page 6)

GROUT TAKES EXTENDED PHASE

Hole No.	Takes at 135	Takes at 170	Takes at 223	Takes at 260	Takes at 298	Total for Hole
P-1	18,900	11,600	23,850	20,000	20,200	94,550
P-2	1,800	0	0	19,500	20,500	41,800
P-3	7,800	24,000	14,300	14,200	40,250	110,550
P-4	45,000	0	0	9,400	5,900	60,300
P-5	0	2,000	0	29,500	33,150	64,650
P-6	19,400	21,200	900	13,400	28,000	82,900
S-1	5,500	46,500	6,100	14,700	40,250	113,050
S-2	12,250	44,850	3,100	28,500	28,000	116,700
S-3	1,250	27,900	17,300	20,850	20,400	87,700
S-4	8,200	5,450	31,950	33,400	39,100	118,100
S-5	19,500	45,600	5,200	4,250	30,600	105,150
S-6	9,675	19,510	3,800	900	24,800	58,685
T-1	0	0	7,400	13,800	29,700	50,900
T-2	0	800	27,350	17,800	19,200	65,150
T-3	0	0	1,700	0	5,500	7,200
T-4	27,250	4,700	9,000	2,500	17,300	60,750
T-5	17,100	0	4,000	0	53,500	74,600
T-6	5,200	0	1,900	4,000	8,100	19,200
T-7	3,800	7,800	4,200	0	29,400	45,200
T-8	3,700	2,650	10,400	4,800	43,200	64,750
T-9	0	1,600	25,750	13,000	46,300	86,650
T-10	5,250	1,800	3,700	17,000	7,200	34,950
T-11	2,300	2,700	21,450	9,100	32,100	67,650
T-12	4,200	19,800	17,850	11,800	43,200	96,850
Totals	218,075	290,460	251,200	302,400	665,850	1,727,985

No. 5 Shaft Pregrouting (cont'd Page 7)

Hole No.	Total lbs. Grout	Sub-Total Series	Average Per Hole	Average Per Hole/Per Foot
P-1	94,550			
P-2	41,800			
P-3	110,550			
P-4	60,300			
P-5	64,650			
P-6	82,900	454,750	75,792	382.8
S-1	113,050			
S-2	116,700			
S-3	87,700			
S-4	118,100			
S-5	105,150			
S-6	58,685	599,385	99,897	504.5
T-1	50,900			
T-2	65,150			
T-3	7,200			
T-4	60,750			
T-5	74,600			
T-6	19,200			
T-7	45,200			
T-8	64,750			
T-9	86,650			
T-10	34,950			
T-11	67,650			
T-12	96,850	673,850	56,154	283.6
	1,727,985	1,727,985	77,281	390.3

The extended grout program was completed to the salt at 295 feet. A pump test hole was drilled to 150 feet. There were several difficulties with the pump tests, including difficulties with the probe and pump cables. However, the tests were completed in stages to the salt contact at 295 feet. The first pump test indicated low water inflow rates. A second pump test in a new test well also indicated low water inflow rates. Since the pump did not appear to be effective in the early stages of the first pump tests, the tests were conducted by using an airlift method. A 3 inch pipe and 2 - 1 inch pipes were lowered into the hole. One of the 1 inch pipes was connected to the compressor and air was forced into the three inch pipe. In this fashion all water was forced out by the escaping air flow. The second 1 inch pipe was used to place a probe into and measure the level of the water. The first pump test included measurement of the recharge rate. This recharge rate was used to calculate the permeability of the ground. A graph of the recharge rate of the zone from the top of salt to 235 feet is included. Areas above this zone were grouted prior to the pump test.

Work outside the grout curtain included grouting the ground under the raker leg and hoist foundations. These areas were grouted to a depth of 47 feet. Four holes were required for the raker leg foundations and 29 holes were required for the hoist foundations. Grout takes in these areas were: 81,700 lbs. in the raker leg foundations and 229,700 lbs. in the hoist foundations. Both areas encountered voids at 27 to 28 feet, which were filled with a cement and fly ash grout.

Additional grouting was required to fill various test holes including pump test holes and the IMC holes. Holes which were inside the grout curtain were injected with a total of 243,900 lbs. of cement fly ash grout. The IMC holes which were outside the grout curtain took 427,000 lbs. of grout. To fill one IMC hole located approximately 100 feet from the shaft required perforation since the casing could not be pulled and the hole would not accept water at 200 psi at the collar. The hole was 305 feet deep and cased with 4 inch casing. The hole was perforated from 300 feet to 260 feet on a 1 foot spacing and injected with cement. It was later perforated from 155 to 115 on a 10 foot spacing but would not accept water at 200 psi so it was only filled with cement and not grouted.

The total grout used in the pregrouting program was 2,986,705 lbs of cement/fly ash grout plus 99,100 lbs. of chemical grout.

The cost of the pregrout program was [redacted] of which, [redacted] was the cost of drilling and grouting equipment and labor. The cost of materials consumed was [redacted] The cost of miscellaneous equipment and materials including fast line, brine, brine tank, pipes and fittings, well perforation and miscellaneous labor was [redacted] The pregrout program was started on August 5, 1982, and completed on December ~~21,~~ 1982. A total of 138 days was consumed. Approximately 10,500 feet of hole was drilled.

The total material injected is equal to 32,800 bags of grout. The approximate cost per bag in place is [redacted]/32,800 bags or [redacted]/bag. Of this cost, equipment and labor represented [redacted], materials represented [redacted], miscellaneous supplies and equipment represented [redacted] per bag.

No. 5 Shaft Pregrouting (cont'd Page 13)

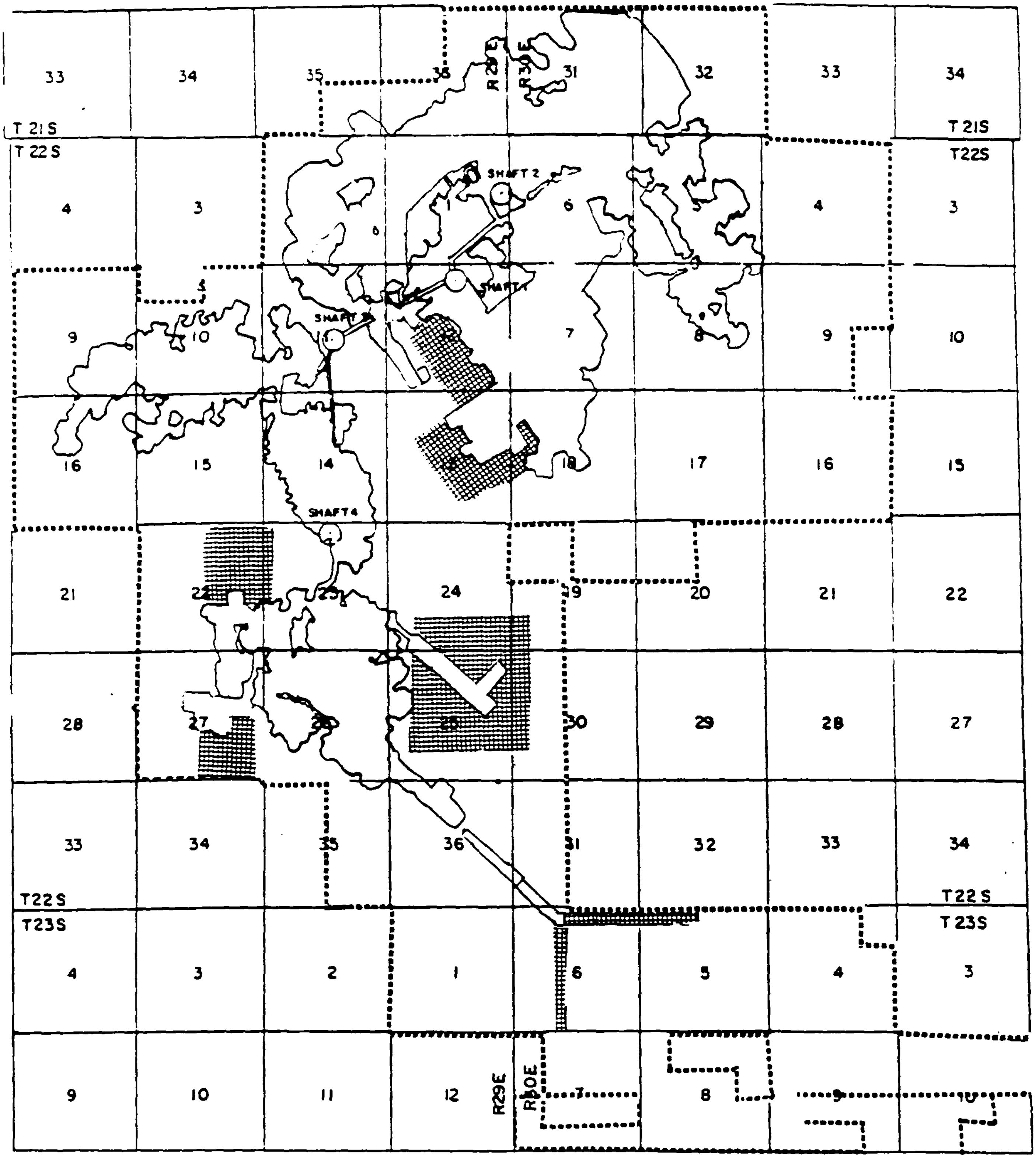
PREGROUT PROGRAM

Amount of Cement

at 298.

P-1	20,200	S-1	40,250	T-1	29,700
P-2	26,500	S-2	28,000	T-2	19,200
P-3	40,250	S-3	20,400	T-3	5,500
P-4	5,900	S-4	39,100	T-4	17,300
P-5	33,150	S-5	30,600	T-5	53,500
P-6	28,000	S-6	24,800	T-6	8,100
				T-7	29,400
				T-8	43,200
				T-9	46,300
				T-10	7,200
				T-11	32,100
				T-12	43,200

Test Hole No. 2	at	185	4,600
Test Hole No. 2	at	298	6,700
Test Hole No. 1	at	298	6,300
IMC 10	at	155	3,300
Center Hole	at	298	7,500
Test Hole No. 1	at	170	2,850
Test Hole No. 1	at	235	6,900



OPEN MINE WORKINGS

LEASE BOUNDARY

PLANNED MINE DEVELOPMENT

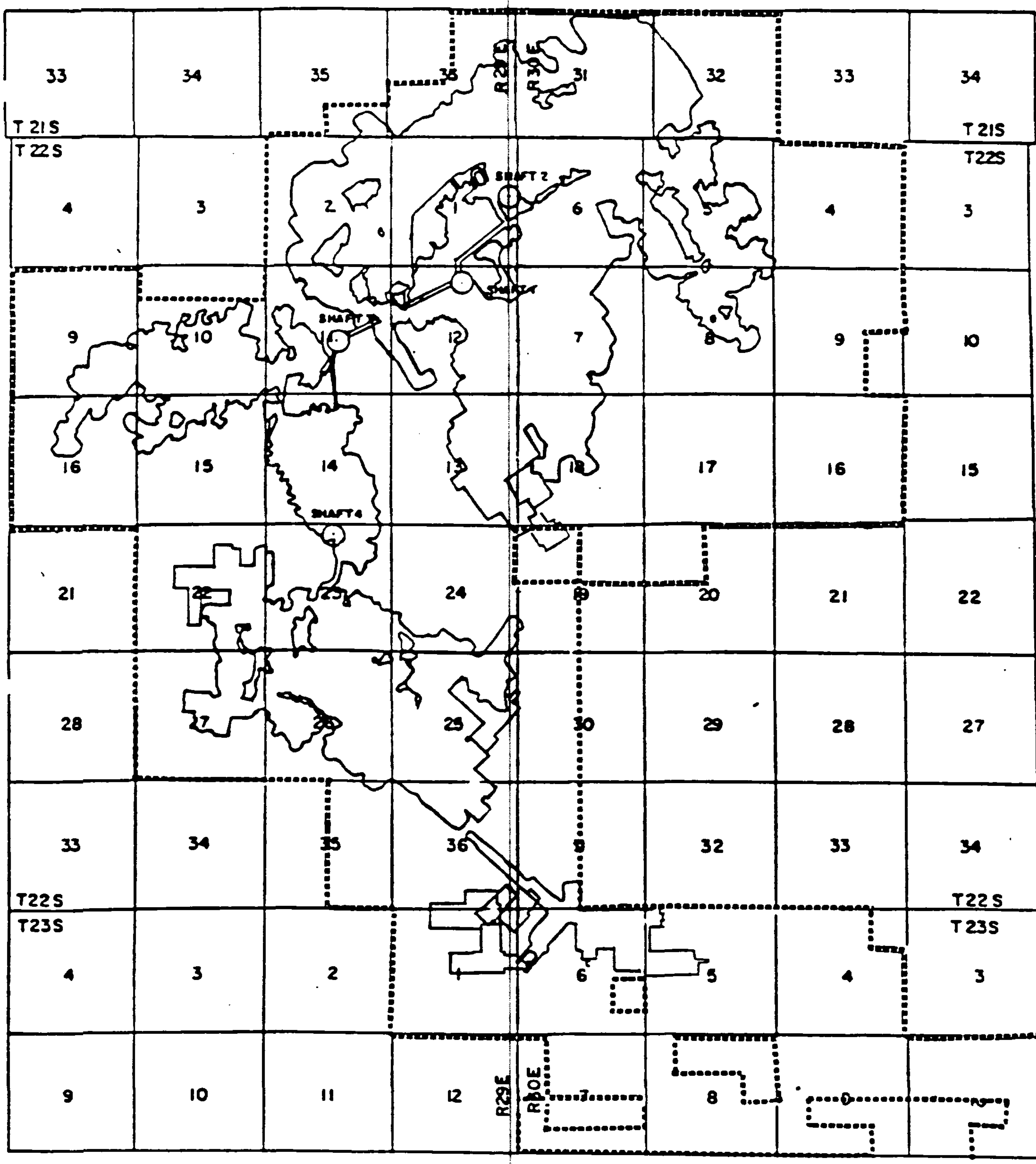
INTERNATIONAL MINERALS & CHEMICAL CORP.

900', 850', & 800' LEVEL PERIMETERS

SCALE 1" = 6000'   JANUARY 1, 1981

THIS MAP IS PREPARED FOR THE
NEW MEXICO OIL CONSERVATION
COMMISSION FOR USE UNDER

CONFIDENTIAL



OPEN MINE WORKINGS

LEASE BOUNDARY

PLANNED DEVELOPMENT

INTERNATIONAL MINERALS & CHEMICAL CORP.

900', 850', 800', 700' LEVEL PERIMETER

SCALE 1" = 6000' JANUARY 1, 1986

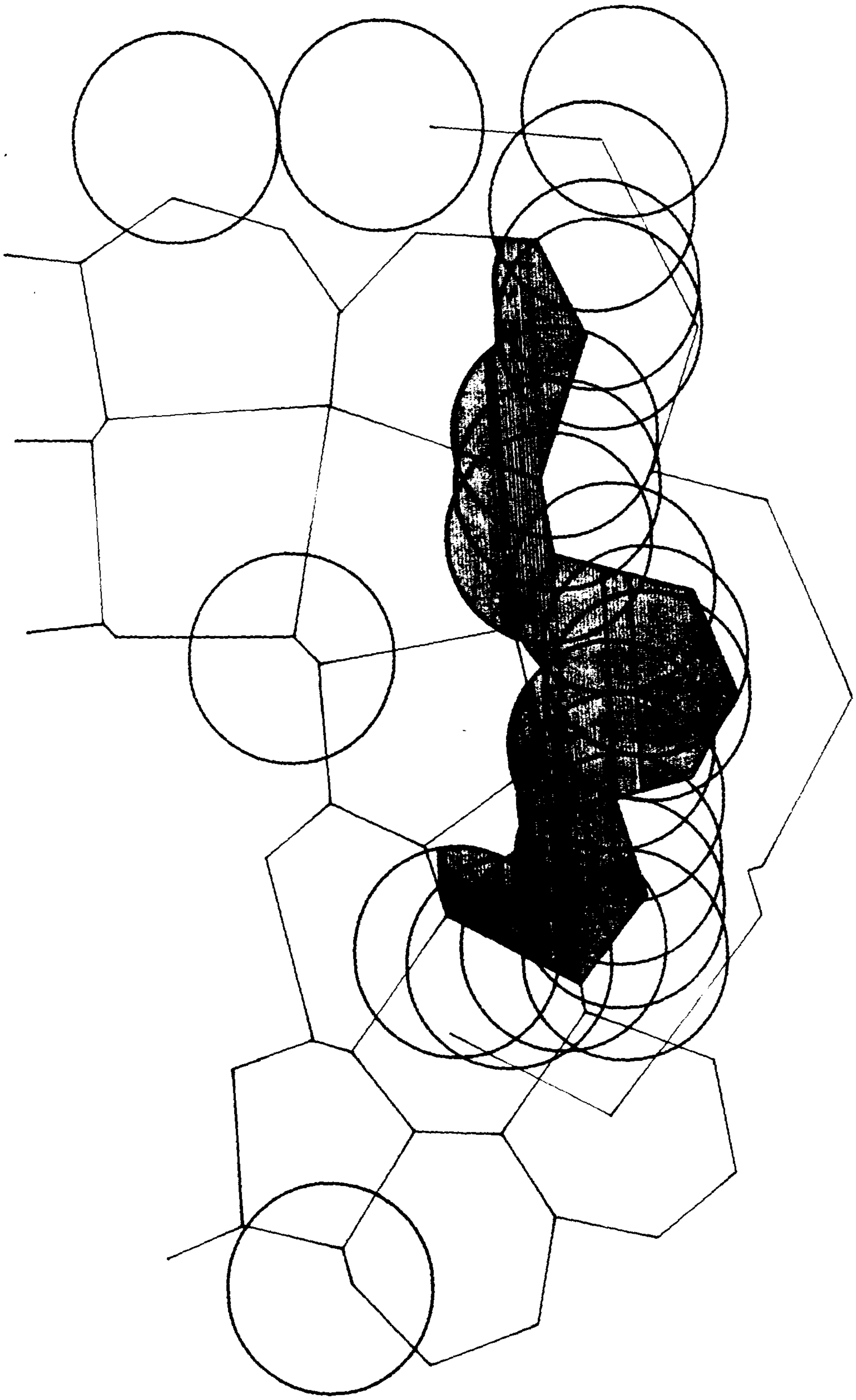
Waste of Potash Immediately East of WIPP

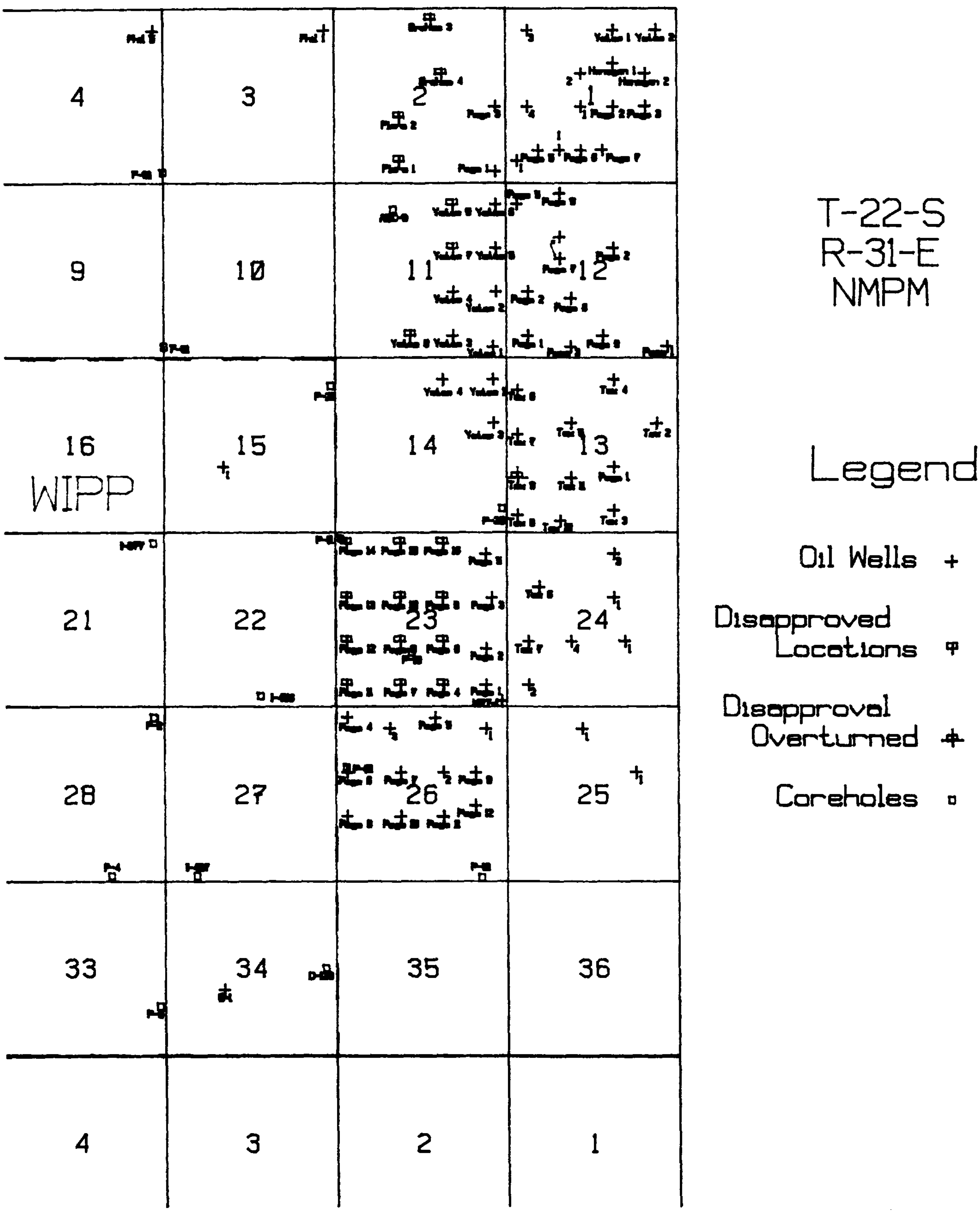
Approximately 29 million tons of potash ore have been wasted in an area immediately east of the WIPP lands in T-22-S, R-31-E, NMPM, Eddy County, New Mexico. Following is a map of the area and an overlay delineating the waste. The scale of the map is 1 inch equals 4,000 feet. It shows clearly the extent to which oil drilling in the area has affected known potash reserves.

The extent of ore around each core hole was determined using the polygon method (the red lines on the overlay). This method has been used extensively in the basin and provides a good estimate of the area of influence of each core hole. The potash grade assigned to each core hole was taken from information gathered for the Department of Energy concerning the WIPP site. Ore was present on the 2nd, 4th and 10th orezones in differing quantities. The value of the ore was determined using actual operating extraction and recovery rates.

Due to the hazard presented, both the "Industry Agreement" and the OCD's R-111-P use one half mile as the distance an oil well over 5,000 feet deep should stay away from commercial potash reserves. The green circles on the overlay have a one half mile radius. The blue line on the overlay is drawn one half mile away from the edge of the ore bodies. No wells should have been drilled any closer to the ore bodies than this line.

The yellow portion of the overlay is the area containing potash that has been wasted by oil well drilling. It can be easily seen that over two square miles of potash reserves have been wasted. The value of these ores is approximately $450,000,000.




T-22-S
R-31-E
NMPM
Legend
Oil Wells
Disapproved Locations
Disapproval Overturned
Coreholes
WIPP
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