ROOM AND PILLAR - SILL MINING METHOD FOR OIL SHALE MINING*

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ABSTRACT

This paper presents a new mining method developed for oil shale mining and is particularly adaptive to gassy mines. The Room and Pillar-Sill mining method is based on mining one room and pillar mine panel section overlying another room and pillar mine panel section leaving a "sill" interval between the two panels. The sill will be recovered on the retreat, thus reducing personnel exposure to the full height mining to a minimum. The method incorporates backfilling of processed shale into the mined-out sections for pillar encapsulation, with smaller pillars left in place, thus increasing resource recovery.

Gassy classification affects mining operations most in ventilation, equipment and explosives. A new ventilation control approach was developed to reduce ventilation problems. Federal regulations for gassy mines were.incorporated into the plan. This included use of schedule 31 equipment. With the limitation on schedule 31 horsepower, mining equipment was selected for the proposed method. Four potentially feasible haulage systems were evaluated. An economic cost analysis was performed.

The results demonstrated that low cost production, good recovery rate (60 to 70%) and high productivity can be achieved by the room and pillar-sill mining method while meeting the gassy mine regulations.

INTRODUCTION

Experience has shown that room and pillar mining is the most promising and feasible underground mining method for oil shale. The development of the room and pillar sill mining method was based on constraints imposed by the thick flat-bedded deposits and by gassy conditions.

Besides being highly flexible, highly mechanized, and productive, the room and pillar-sill method (RPSM) has some other advantages over the standard room and pillar mining methods. Major advantages are shown in Figure 1.

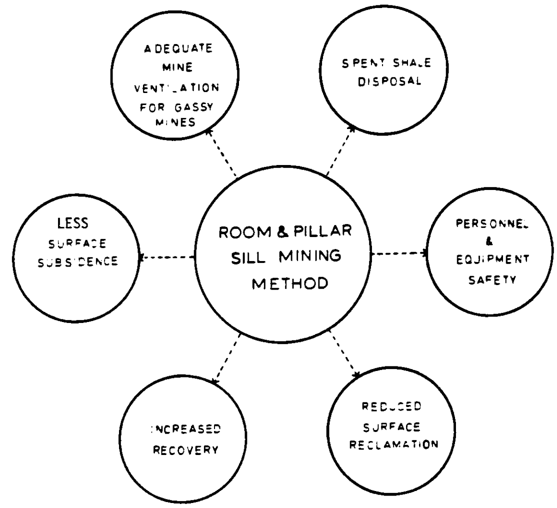

Figure 1. Major Advantages of the Room and pillar-Sill Mining Method.

The following was considered in the development of RPSM:

- Gassy Mine Classification
- Limitation on Schedule 31 Horsepower
- Additional Ventilation for Methane
- Reclamation Requirements
- Surface Subsidence
- Ground Problems
- Manpower
- Increased Safety

DETAILED MINE DESIGN

The RPSM is based on mining one room and pillar mine panel section overlying room and pillar mine panel section leaving a "sill" interval between the two panels. The sill will be recovered on the retreat.

A hypothetical mine is designed to extract, at full production, an average of 55,000 metric tons (60,000 tons) of oil shale per day. The average oil shale grade considered is 104.3 litres/mt (25 gallons/ton). The area of the mine site is estimated to be 2.2 kilometers (1.4 miles) wide and 6.4 km (4 miles) long.

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Access to the mining area is achieved by drifts from the outcrop. Main entries are driven through the center of the mine. Main entries consist of seven parallel entries. The Number One and Number Seven entries are 4 m (12 ft) high and 17 m (55 ft) wide. These two entries are used for ventilation (intake and exhaust airways). The other entries are 8 m (25 ft) high and 17 m (55 ft) wide. Cross-cuts have the same dimensions (Figure 2.).

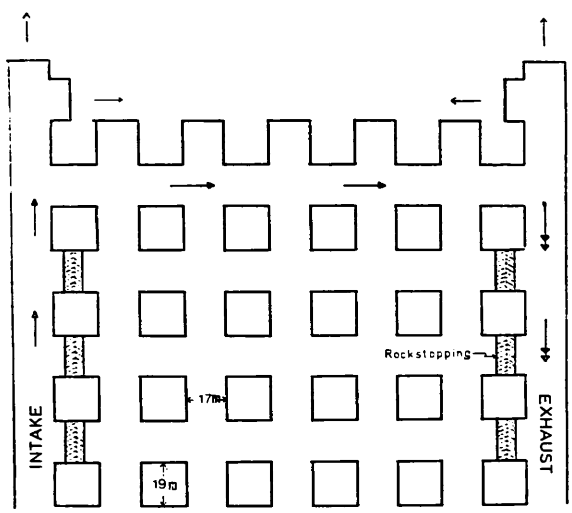


Figure 2. Plan View of Main Entry System

During the initial development of main entries, pillars 19 m (60 ft) wide and 54 m (175 ft) long, are left until panel development work starts. The main entry system has a total width of 227 m (745 ft) and runs the entire length of the mine. Figure 3 shows plan view of the main entry system and panel development.

Panels are driven perpendicular to the main entries and connected to the main entries with three entries. Barrier pillars, 89 m (290 ft) wide and 52 m (170 ft) long are left between main entries and panels. The middle entry is used for haulage, and the other two are used for ventilation. The dimensions of all entries and breakthroughs in the panels are the same as these of the main entry system. However, 19 m (60 ft) square pillars are left. Panels are 227 m (745 ft) wide and 928 m (3045 ft) deep. A ventilation bleeder entry is established at the final depth. The bleeder entry is protected by adequate pillars for long term openings. This provides ventilation at the back of the panel under gassy mine regulations.

A new ventilation control approach using rockstoppings, was developed. While panels are being developed, the intake and exhaust entries are driven at a lower height, 4 m (12 ft), so that rock stoppings can be constructed by blasting from the higher height, 8 m (25 ft), into the lower height crosscuts. The development of rock stopping is illustrated in Figure 4.

The RPSM is based on mining two levels with a sill interval. Three access drifts are driven to the lower level as the development work continues. These drifts are so designed that they enable belt conveyor haulage. Figure 5 is a cross-section showing access drifts to the lower level. Once again, the middle entry is used for haulage purposes. The other two are used for ventilation. The upper main entry development progresses two or three crosscuts ahead of lower level development due to safety considerations (Figure 6).

Upon the completion of panel development, the sill will be mined on the retreat by drilling down from the top level and blasting the rock to the lower level.

Backfilling of processed shale into the mined-out sections is commenced as soon as retreat mining of the sill begins. Underground disposal of processed shale will reduce the amount of material on the surface requiring reclamation by as much as 85 percent. A study of Earnest, et al., 1981, estimated that up to 16 percent resource recovery may be increased when backfilling provides some supplementary support so that smaller pillars may be left in place.

MINE OPERATION

It is assumed that development of the mine and production are achieved on a two shift, seven day per week basis. It was also assumed that, at least, four panels would be in production. Conventional mining operations such as drilling, blasting, mucking, scaling and roof bolting would be practiced. Equipment and men are assigned to particular faces. The equipment is phased into an operational cycle. At full production, sufficient working faces are available so that all phases of the mining operation run continuously without any cyclic conflict. Cut sequence is shown in Figure 7.

A face is drilled by a two-boom hydraulic drill jumbo which is capable of drilling the entire round from one set up. A total of 39 holes with 64 mm (2 ½ - inch) diameter are required for a 6 m (20 ft) advance. A V-cut round pulls about 1725 mt (1900 tons). Lower height entries require rounds with 19 holes. Two drilling jumbos per panel are necessary to maintain the desired production rate.

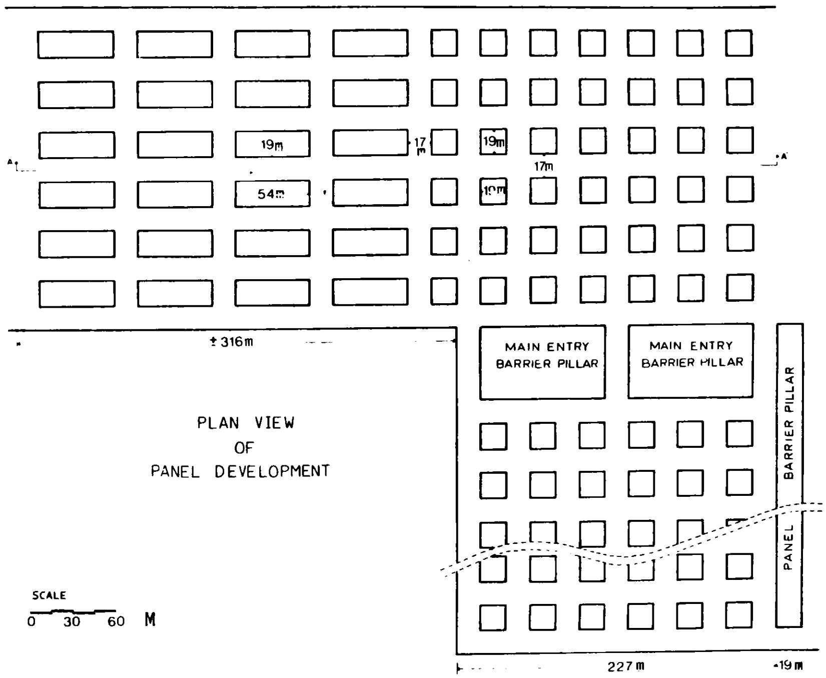


Figure 3. Plan View of Panel Development

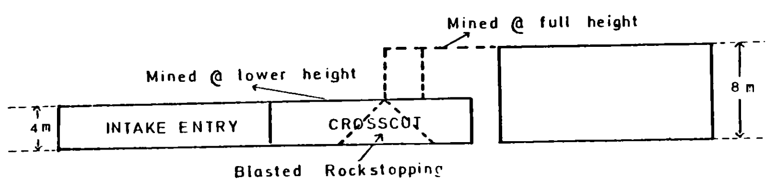


Figure 4. Side View Showing Stopping Development

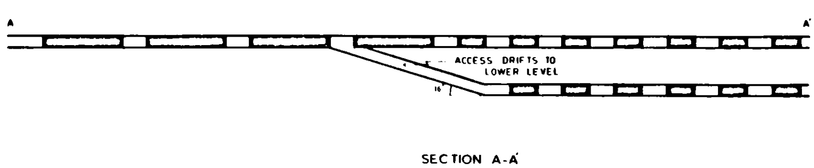


Figure 5. Cross-Section of Mining Levels

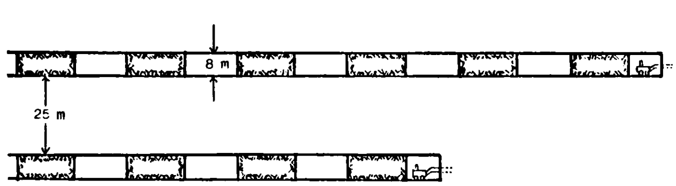
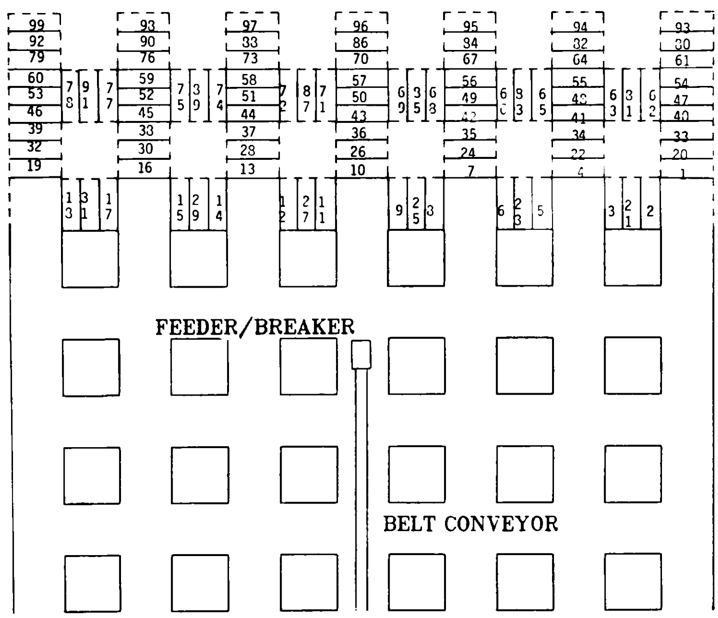


Figure 6. Side View Showing Panel Development

Figure 7.

ROOM & PILLAR SILL MINING METHOD

(PLAN VIEW SHOWING CUT SEQUENCE)



As the round is being drilled, two roof bolting machiens are used to bolt the roof with 2.2 (7 ft) split set bolts on 1.5 m (5 ft) centers. Permissible explosives or other types of explosives (e.g. AN/FO) which must be approved by MSHA are used for blasting. Due to the gassy nature of the mine, onshift blasting may be prohibited. Therefore, oil shale may have to be blasted between shifts or at the end of a shift when no personnel are in the mine.

Mine fans located on the surface supply ventilation. The rock stoppings are constructed to control air flow. The estimated ventilation requirement of the mine is about 71,000 m^3/min. (2,500,00 ft^3/min.). The calculatins are based on providing 3.5 m^3/min. (125 ft^3/min) of fresh air per diesel horsepower and 2.8 m^3/min. (100 ft^3/min.) per man. A 50 percent leakage loss of intake air is assumed. A 15 percent contingency factor is also used.

To initiate sill mining, a large hole is drilled in the middle of the next to last breakthrough (Figure 8.). This hole provides a second free face for blasting. The sill is drilled using mobile down-hole drilling jumbos.

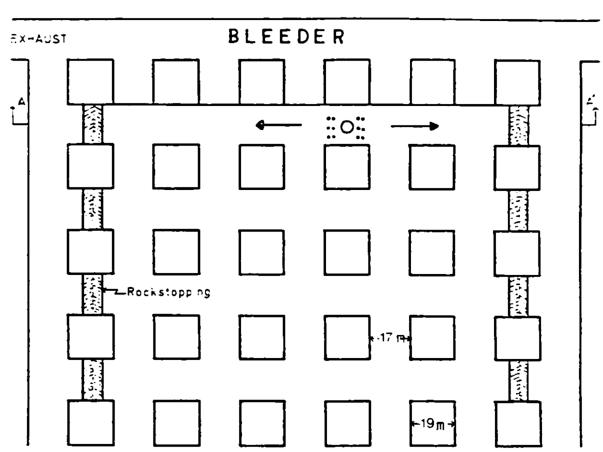


Figure 8. Plan View of the Room and Pillar-Sill Method

Drilling is then expanded as shown in Figure 9. Sill drilling operation is not restricted by any other mining operations, therefore, vertical holes can be drilled continually. The sill is mined on the retreat as shown in Figures 10. and 11. While the sill is being mined out, no roof bolting is required. Mucking is done from the lower level (Figure 12.).

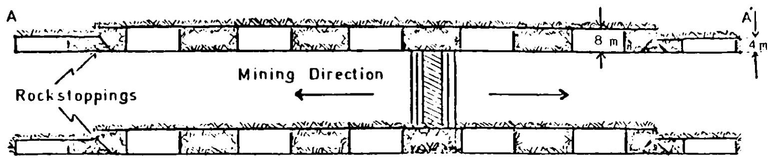


Figure 9. Section A-A' Sill Mining Development

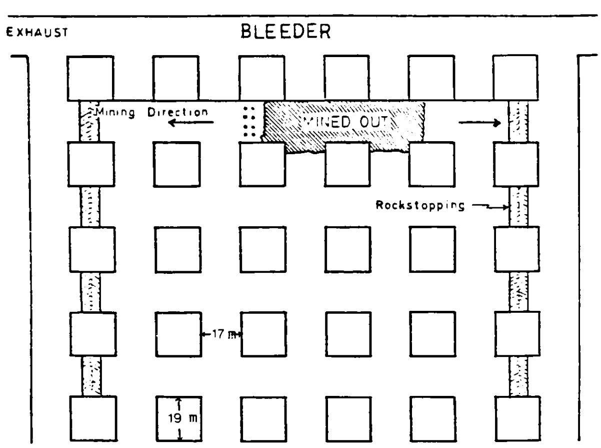


Figure 10. Plan View Showing Sill Mining Sequence

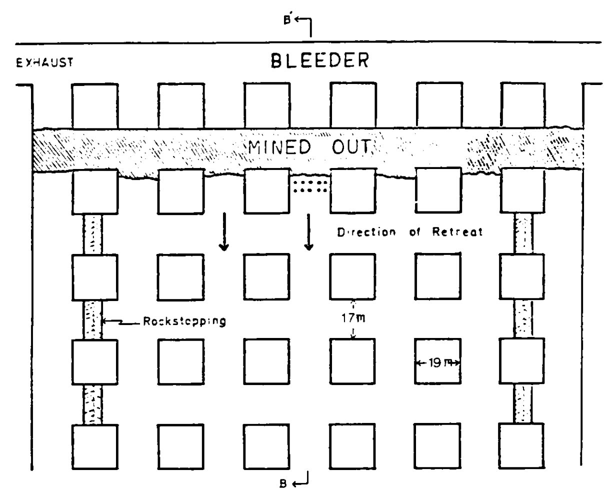


Figure 11. Plan View of Retreat Sill Mining

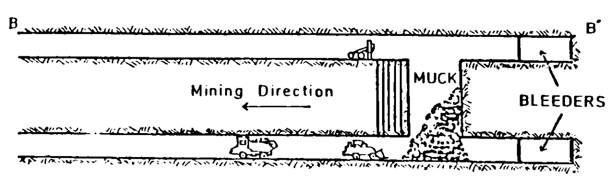


Figure 12. Section B-B' Side View Showing Sill Mining Operations

This reduces personnel exposure to full height of the sill to a minimum. Figure 13 shows an isometric view of retreat mining operations. This type of mining provides enough working spaces so that no cyclic conflict can occur. Water drainage is achieved through the lower bleeders.

Mined out sections are backfilled simultaneously with retreat mining of the sill (Figure 14.). Processed shale as the backfill material is introduced from the upper level bleeders in slurry form. As retreat mining progresses, pipelines are used to distribute processed shale into the mined-out areas. Figure 15 illustrates two panels. In the first panel, backfilling is completed. Retreat sill mining continues in the second panel.

HAULAGE COMPARISON

A comparison of four potentially feasible haulage systems was performed to select the best haulage system for the room and pillar-sill mining method (Senocak, 1982). The haulage systems evaluated in this research are:

	Loading	Secondary Haulage	Primary Haulage
1.	FEL	Truck	Truck
2.	FEL	Truck	Conveyor Belt
3.	LHD	LHD	Conveyor Belt
4.	FEL	Conveyor Belt	Conveyor Belt

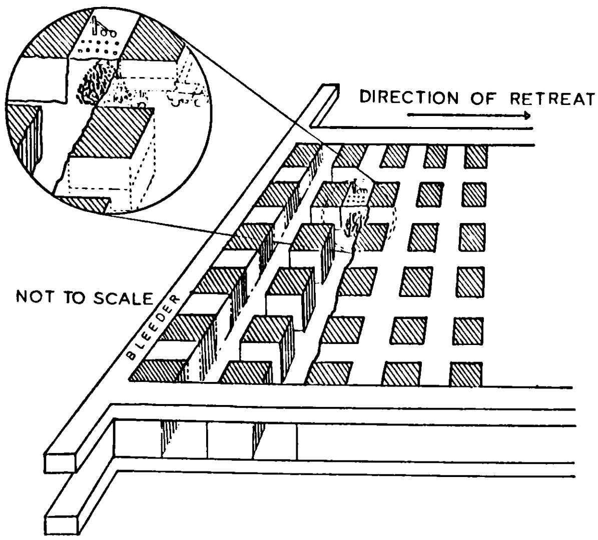


Figure 13. Isometric View of Retreat Sill Mining

Major consideration was given to the limitation on Schedule 31 horsepower. According to the regulations, every diesel-powered equipment to be used in gassy mines must have MSHA's approval. Presently, the MSHA diesel testing facility is capable of testing diesel engines up to 400 hp. However, MSHA is expanding its testing facility. In the near future, it will be capable of testing diesel engines up to 650 hp. Based on this information, diesel equipment having engines up to 650 hp is considered to be permissible in this study.

An interactive computer program was written to simulate the four haulage systems. The program consists of a main program and seven subprograms. The simulation model is event-oriented. After each mining operation, related reports are printed. The model permits some degree of flexibility in specifying parameters associated with mine operations. Sensitivity analyses can be conducted.

The selection of the best haulage system for the RPSM was based on comparisons of haulage cost, productivity, labor and ventilation requirements. For the proposed method, a combination of Load-Haul-Dump units and belt conveyors was found to be the best haulage system. This system offers distinct advantages over the other systems. It provides the lowest haulage cost. High productivity rates can be obtained. Ventilation required is less than those for the other haulage systems. LHDs with Schedule 31 approval are currently available. All of these reasons make this system the best choice among the others.

CONCLUSIONS

It is the authors' opinion that low cost production, good recovery (60 to 70%) and high productivity can be achieved by the RPSM while meeting the gassy mine regulations. Economic analysis of the mining method and backfilling is recommended for further research.

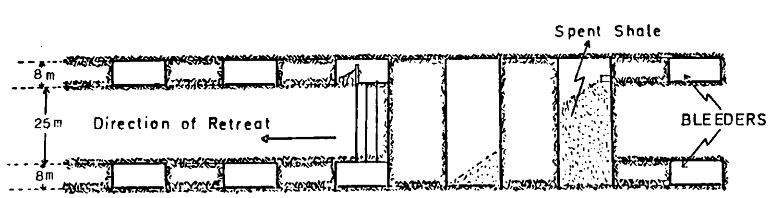


Figure 14. Side View Showing Sill Mining and Backfilling

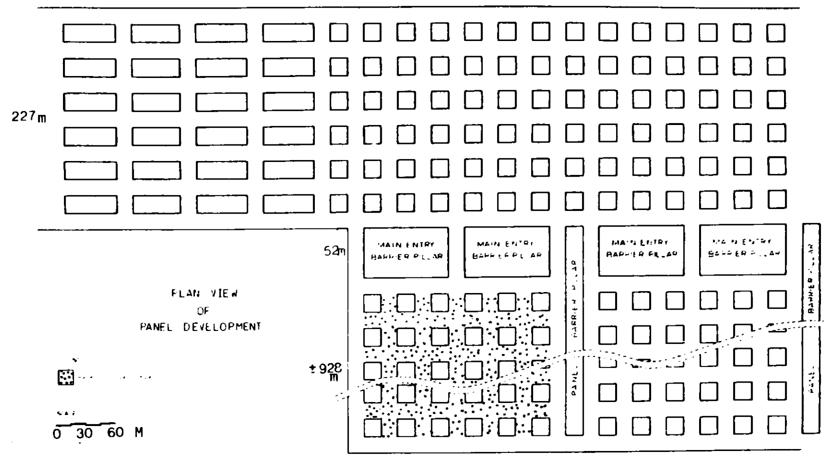


Figure 15. Plan View of Panel Development

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INDUCED HORIZONTAL STRESS METHOD OF PILLAR DESIGN IN OIL SHALE

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ABSTRACT

Pillar design in oil shale by the induced horizontal stress method is based on in-situ stress determinations of pillars before and during failure, on computer analysis incorporating site specific rock properties, and on the pre-mining stress field. An empirical strength equation which relates vertical and horizontal stresses at failure was developed from stress determinations through the center of 60-ft cube pillars. Induced horizontal stresses within the pillars are then evaluated for different width-to-height ratios by simple finite element analysis. Design curves are developed relating pillar stresses and strength with pillar widths and extraction ratios.

The induced horizontal stress method, which is based on the in-situ strength of large pillars, has been used for planning and resource recovery evaluations throughout the Piceance Creek Basin.

INTRODUCTION

Design of mine pillars is performed by empirical methods because of difficulties in assessing and quantifying the in-situ rock strength of large pillars. Pillar design methods have been developed mostly from coal mining experience where many years of room and pillar mining provide a good background for linking experience and theory, and field and laboratory work.

Pillar strengths can be determined essentially by two methods: the width-to-height (W/H) ratio, and the confined core methods. In the first method, described extensively in the literature (1, 2, 3, 4, 5), the strength is related to the pillar width, height, and the laboratory unconfined strength. In the confined core method, the strength is obtained by using a Mohr-Coulomb formulation based on laboratory triaxial strength values and an assumption of a failed outer zone confining an unfailed core (6). Applications of both methods to oil shale have been proposed and are described in the literature (7, 8).

This paper describes another empirical design technique, the induced horizontal stress method, developed for oil shale. This method is based (1) on strength criteria obtained by stress determinations in 60-ft cube pillars performed before and during failure; and (2) on field calibrated computer analysis to project the induced horizontal stresses and strength to locations with different material properties and stress fields. Basic pillar strength criteria was developed at the Colony Pilot Mine and has been described in previous publications (9, 10, 11). This experimental mine is located in the Colony property owned by Exxon Company, the operator, and Tosco Corporation.

GEOLOGIC STRUCTURE OF THE PICEANCE CREEK BASIN

The Piceance Creek Basin contains about 80 percent of the oil shale resources of the Green River Formation; this amounts to about 1200 billion barrels of petroleum equivalent with 600 billion barrels occurring in material with a grade of 25 gal/ton or more. Oil shale is an economic term used for marlstones with a recoverable kerogen content of more than 5 to 10 gal/ton.

Most of the oil shales of economic interest occur in the Parachute Creek Member of the Green River Formation. In this member, the oil shale is divided into rich zones designated R2 through R6, Mahogany and upper oil shale separated by leaner zones designated L2 through L5, A- and B-grooves. Most of the experimental mining operations have been conducted in the Mahogany zone because it is shallower and contains nearly 30 percent of the basin's resource.

Wet sediment deformation features resulting from lake bottom sediment slumping are common through most of the oil shale intervals,