NEW MEXICO BUREAU OF MINES

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COST OF URANIUM MINING IN NEW MEXICO

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RELATION OF COSTS AND TAXES

FOR

NEW MEXICO'S URANIUM PRODUCTION

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COSTS OF URANIUM MINING IN NEW MEXICO

At the request of Frank E. Kottlowski, director of the NMBM&MR, acting for the Energy Resources Board, a study was made of the cost of uranium extraction in New Mexico. The writer has no financial interest in uranium companies or properties in New Mexico, nor has he any uranium clients.

This report attempts to present costs in the reasonable foreseeable future, extending to at least 1980, for a presently operating "typical" mine in northwestern New Mexico and the cost of bringing on steam a new uranium mine in that area.

Sources of the cost data are listed in the references; additional cost information was obtained from equipment suppliers, underground miners, contractors, and from my experience as a mine contractor and mine operator.

The operating costs and pre-production costs of a new mine have increased in the past year far above a normal rate. The writer believes the unusual increases in posted prices of yellow cake had an adverse effect on good mining practices which increased the costs and decreased the efficiency of operations.

COST OF PROCURING LEASES

To acquire a land position in the known Grants Mineral Belt, which extends from the Rio Puerco on the east to Church Rock on the west, is presently very difficult. All known fee, railroad, Indian allotment, state and federal lands have been leased and essentially the only way to acquire an area in the past 3 years has been to buy a block of land from another lease holder.

For an exploration target zone to have some potential of success, a block of from 5,000 to 10,000 acres would be needed, although only a small portion may be of value. This acreage in a favorable area would cost from $50 per acre up to $150 per acre for front-end costs, plus a yearly rental. The acreage probably would not be in one block, but would be scattered in section blocks throughout the Belt. To the above front-end costs, the company must add such overhead costs as legal fees, abstracts, and geological research. Uranium land leases acquired during a standard exploration program over a five-year period would cost a mining company in cash bonus, yearly rentals, and in legal and overhead charges approximately:

Low position, a small company	$500,000
High position, a major company	$1,500,000

COST OF EXPLORATION AND DISCOVERY OF THE ORE BODY

The cost of exploration and discovery of an ore body would include the geological staff, contract drilling of the exploration holes, logging of the holes, assay work, surveying, mapping surface location work, clean-up environmental work, and possibly the use of consultants, both geologic and engineering.

The direct contract drilling cost is the major item and depends on the depth drilled, difficulty in penetrating the drilled material, as well as added items as drilling mud and casing. Drill holes near Mt. Taylor may cost $50,000 to $75,000 per hole for depths below 3,000 feet. Standard drill holes about 1,500 feet in depth should average $10,000 to $20,000 per completed hole logged with location and clean up work as follows:

Contract drilling	$5.00/ft.	$7,500
Logging	$1.20/ft.	$1,800
Assaying		$ 200
Geological report		$ 500
Location and clean up		$1,000
		$11,000 per drilled hole

To drill a 10,000-acre block on 500-foot centers and drill-out a mill-size ore body would require a minimum of approximately 500 drill holes. This would require a period of about four years of exploration and development drilling. The mining company's exploration budget during this period would be approximately:

1,000 to 1,500 feet drilling depth, for total exploration	$4,000,000
3,000 feet and below drilling depth; total exploration cost	$10,000,000

FRONT-END COST OF SETTING UP AN UNDERGROUND MINE

The front-end cost of setting a complete mine operation would include dual mine shafts, ventilation shafts/holes, surface plant, underground haulage development drifts and workings, power, haulage equipment, and all mine equipment and supplies needed in the mine operation. The mine costs depend on the depth to the ore body, ground conditions, water pumping, ventilation, size of hoisting equipment, and type of mining methods to be used.

For shallow shafts less than 700 feet, the cost could be as much as $2.5 million and below 3,000 feet as much as $150 million. For a mine operation at about 1,500 feet depth, the costs would be between $25 to $50 million over a 3-year period. This assumes a mill-size ore body, with the mine hoisting capacity of 1,000 to 1,500 tons per day, and with first-class equipment. The listing of costs could be as follows:

1,500 shaft, contracted at $1,500/ft.	$3,000,000
Headframe, surface buildings, shaft steel	$2,000,000
Underground haulage and development workings	$4,000,000
Ventilation drill holes, secondary escapeway	$1,000,000
Power plant, surface plant	$6,000,000
Mine equipment and supplies	$8,000,000
Administration and supervision	$1,000,000
Engineering and consultants	$1,000,000
	$26,000,000

The cost estimates range from a low of $10 million to a high of $50 million, depending on conditions and size of operation.

COST OF MINING

The cost of mining normally is calculated in cost per ton of ore as a direct cost which includes labor, overhead on labor, mine supplies such as explosives and drill steel, mine equipment, ventilation, power, safety and supervision. The cost per ton in a new mine is much higher than the cost per ton in an older mine, since much of the development work in an old mine has been done in the process of extracting ore; and may thus be counted as direct mining cost. In a new mine, however, most development work would be pre-production, and hence would be a capitalized cost to be amortized. Examples are as follows:

Old Mine, developed & operating	$20-30/ton
New Mine, small, at shallow depth	$30-40
New Mine, large, at deep depth	$40-50

In the GMB, costs may be calculated in cost per pound of contained uranium. The cost per pound depends on the ore grade, or the number of pounds of uranium per ton of ore. Representative costs might be:

	per ton of ore	Per Pound U_3O_8 0.15%	0.10%
Labor	$15	$5.00	$7.50
Supplies	7	2.33	3.50
Equipment	4	1.33	2.00
Power & Haulage	2	.67	1.00
Safety - ventillation	1	.33	.50
Supervision - Administration	1	.33	.50
Total	$30/ton	$10.00/lb.	$15.00/lb.

Note the increase in the cost per pound of yellowcake which occurs as ore grade drops from .15% (3lb/ton) to .10% (2lb/ton). The grade determined for an ore body is an <u>in-place</u> value, and not the <u>recoverable</u> value. The recoverable pounds/ton is alowas <u>less</u> than the in-place value, and costs per recoverable pound are correspondingly higher. The recovery rate depends on many factors including ground conditions, distribution of uranium in the host rock, and the skill of the individual miners.

Large mines must operate in lower grade ore in order to keep production high and to pay-out the large capital cost. Cut-off grades in stopes may be as low as .07% U_3O_8, and down to .05% in development drifts.

A misnomer has been applied to uranium mining when it has been stated that the uranium mines may "high grade" the ore deposits to ship a higher grade uranium concentrate and to decrease the operating cost. The term "high grading" refers to the practice of miners in gold mines of stealing gold from the company. Later it was applied to the practice, in small mines with vein-type deposits, of stripping off higher values along one wall and leaving lower grade material in the mine. It is not practical to "high grade" uranium ore deposits of the sandstone type because the contained uranium in a ton of ore is unevenly distributed throughout the mining zone with grades from .05% to .20% in the same zone. The higher grade material is not located in such a manner that a concentration of higher percentage of uranium oxide in a ton of ore could be mined differently from the rest of the ore body. The operators mine to the economic cut off, which is the the grade at which all costs are covered (but not profit). During the process, both the higher grade material is taken with the lower grade material, so that the mine-run average is the shipping grade to the mill. If the mine-run cut off U_3 O_8 percentage is raised to meet added cost, then on the retreat system of uranium mining both the high grade and low grade material left will be lost to any future mining. In the retreat system of mining, roofs of the stopes are left to collapse, thus any unmined areas would not be accessible except by costly and dangerous redevelopment of drift tunnels.

FRONT-END COST OF SETTING UP MILLS

The costs of setting up a uranium mill are well known. They are increasing yearly owing to inflation in equipment and engineering costs. A 2,000 ton-per-day uranium mill would cost around $30 million at 1977 prices, including cost of land, power, tailings pond, water, interest on loan, and taxes. Some mills presently are quoted at $15,000 per-ton-day but that figure is low and probably does not include outside cost and overhead.

The mill usually is fed by a company owned supply of uranium from its captive mine, so that the mine-mill complex is normally calculated in an economic feasibility study of inplace value. If the economic feasibility of the ore body is not able to carry a mill, then the ore must be processed in a ore custom- or tolled-mill, a cost which then must be considered as to its total feasibility.

Custom milling costs are about $25 per ton of crude ore, or on 0.20% ore about $6.00 per pound, but excess milling capacity must be available. Direct milling cost by a company mill range from $2.00 to $5.00 per pound of U_3O_8.

COST OF MILLING URANIUM ORE INCLUDING ENVIRONMENTAL COST

Milling cost of uranium ores are the lowest part of the expense of the mining-milling complex but future large increases are expected in fuel to run the mill and in environmental costs.

These costs are between $10 to $20 per ton for a company mill including haulage expenses from the mine. This would be approxmately $2.00 to $5.00 per pound for 0.15% mill heads.

OPEN PIT URANIUM MINES

Costs for an open pit uranium mine are difficult to estimate. It is unlikely that there will be any new open-pit operations in the future near Grants except some very low-grade type of operations with a cut-off of around .04% U_3O_8. With the low-grade material, the cost per pound of U_3O_8 would be near that of underground operation costs with higher grade, although the cost per ton would be much lower. Examples are the open-pit Texas uranium deposits, where shipping-mill heads costs are about $25/lb for .04% U_3O_8 ore.

The cost of operating in other uranium producing states, such as Wyoming, Texas and Colorado, seem by my calculations, to be similar to those in New Mexico; there is very little difference in cost between various states.

SUMMARY OF URANIUM OPERATION COSTS

Costs to mine uranium in New Mexico cover a large range. Presently, operations are at near maximum cost, mainly owing to the higher posted spot price, which affects labor, efficiency, and speed of extraction, all of which add to the operating cost. Old uranium mines have a much lower production cost then new uranium mines. For a new operation in the Grants Mineral Belt, to discover a mill-size ore body of 3 million pounds with an average mill grade of 0.14% U_3O_8 for production in 1980 would require:

\$ 1 million in land lease cost	\$ 0.30/lb.	
\$ 6 million in exploration cost	\$ 2.00/lb.	
\$25 million in front-end mine costs	\$ 8.00/lb.	
\$30 million in front-end mill costs	\$10.00/lb.	
	\$20.30/lb.	capital and interest cost
Mining production cost of	\$13.00/lb.	
Milling extraction cost	\$ 4.00/lb.	
	\$17.00/lb.	

Total for a new undiscovered mine to be put on stream with mine-mill by mid 1980's thus is \$37.30/lb. in 1977 dollars.

REFERENCES

ERDA - Survey of US Uranium Marketing Acitivity, April 1976

ERDA - Statistical Data of the Uranium Industry, January 1, 1976

USBM - Uranium in 1976

NMEI at UNM - Uranium Industry in New Mexico

Sohio L-bar Ranch Mine (name is J. J. No. 1) operations

Ranchers Exploration

Sandia Steel Company

Kerr-McGee Corp.

United Nuclear Corp.

Todilto Exploration and Development Corp.

Reserve Oil and Minerals Inc.

Jones Drilling

Various miners, contractors, and suppliers in Grants area

References from Chemical Engineering, Mining Engineering and Mash & Stevens

BACKGROUND DATA

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7 March 1977

Rautman, Kottlowski, ABT
4p. + 10 figs.

RELATION OF COSTS AND TAXES FOR NEW MEXICO'S URANIUM PRODUCTION

1. Gross value taxes, such as severance taxes, add to direct costs in uranium mining and production. The higher the tax, the higher the cost, and the more uranium that can not be mined profitably -- uranium that will be lost in mining the higher grade ore.

2. A net income or profit tax would encourage mining of more uranium, and thus entail less loss of resources.

3. Major expenditures in producing uranium (exploration, sinking shafts, building mills, buying mining equipment and part of the interest on loans) are front-end costs, incurred before a single pound of yellowcake is sold. These costs need to be recovered, as well as the actual mining and production costs, as part of the selling price when U_3O_8 is produced.

4. ERDA's uranium reserve calculations, used to suggest the possibility of a high severance tax rate, are based on forward costs (capital required for future development as well as operating costs) and do not include sunk costs such as much of the front-end expenditures.

5. ERDA reports that through 1980 and in 1984 and 1985 more than 50% of yellowcake will be sold at less than $20 per pound, and in the period through 1985, less than 18% of all uranium will be sold at prices more than $30 per pound in any one year. Costs of production range from slightly less than $10 per pound to more than $30 per pound.

The following comments relative to the proposed tax increases on uranium mined and/or processed in New Mexico are to clear up misconceptions of persons not familiar with mining operations.

A simplistic view of ERDA's reserve estimates suggests New Mexico has a large amount of high-grade uranium ore, which supposedly could be mined to yield high profits. Unfortunately, ERDA's cost estimates are only on "forward costs" which are those costs yet to be spent in mining and milling the ore. ERDA's calculations do not include "sunk costs" of exploration and land leases, capital investments to build the mills and to develop the mines, or interest on these front-end costs, yet these sunk costs must be recovered or amortized at some point. The forward costs do not include, for example, the millions of dollars already spent to discover ore bodies, build mills, and sink expensive deep shafts.

On the average, from exploration and discovery of an ore body to mining of the first ore, takes 8 years before the stock holder of a company can be paid a dividend on ore mined, milled, and sold. The selling price of the uranium concentrate, "yellowcake", must not only cover the ERDA forward costs of ore mining and milling, but also the previous 8 years of front-end costs, and interest on that capitalization.

Thus, the ERDA reserves data must be utilized only with full knowledge of exploration, development, mining and processing costs.

The "spot market" price of uranium has been highly publicized. Yet, despite news articles of sales of "yellowcake" at prices greater than $40 per pound, over one-half of the nation's uranium will be sold at prices of $20 per pound or less each year through 1985. Data from the U. S. Energy Research and Development Administration (ERDA) semi-annual marketing survey of July 1, 1976 are summarized as Figure 1. These data show the average price per pound of yellowcake through 1985, as well as the percentage of each year's commitments to be delivered in $5 price increments. Even in 1985, only 10% of the uranium sold in the United States will bring more than $30 per pound.

Estimation of the cost to produce a pound of yellowcake is exceedingly difficult. The data is of a proprietary nature, and the costs vary from company to company, depending on many factors such as depth to ore, grade of mineralization, type of host rock, existing capital facilities, differing geologic facets, and type of mining. Costs are not much lower than $10 per pound for older, shallower mines, and are in excess of $20-30 per pound for newer deeper mines in New Mexico. A recent study for the New Mexico Energy Resources Board by Mining Engineer Donald Buddecke gave an estimated cost of $37 per pound to bring into production by the mid-1980's an orebody that can yield 3 million pounds of U_3O_8.

Uranium orebodies are complex entities, with higher and lower grade material intermixed in a more or less unpredictable fashion, frequently on several levels vertically. Each orebody can only be mined as a whole, under a mining plan developed for that body, under specified engineering and economic conditions. It emphatically cannot be mined for one grade at economic conditions "X", and later reworked for material below the first cut-off grade when economic conditions change to "Y".

The steps involved in the development and mining of an orebody may be helpful in understanding the problem. Essentially all moderately deep uranium ore bodies are found and delineated by surface drilling on roughly 100-150 foot centers (Figure 2). Evaluation of the profitability of the ore mass must be made on the basis of this density of information. If a mine appears feasible, a shaft is sunk in a suitable location, and development drifts are driven into the ore (Figure 3), segmenting the ore into large pillars. As the development drifts extend toward the margins of the mineralized area, a decision is made as to what grade of material will be mined and what will be left as waste. This decision must be made at a point in time under the then existing economic conditions. Once the cut-off grade is determined, and the extent of "ore" ("ore" is only that mineralized material which can be mined at a profit) delineated, the pillars on the margins of the orebody are removed piecemeal, with mining slowly retreating toward the shaft. As the pillars are extracted, the unsupported roof caves-falls in-(Figure 4), rendering it extremely hazardous and essentially impossible to return for lower grade material at a future date. In terms of time, retreat mining of a developed orebody may occupy the bulk of the mine life. However, price increases during the retreat stage can allow only minor changes in the mining plan as determined prior to beginning retreat.

If economic conditions dictate a cut-off grade higher than the grade at which the "ore" is largely continuous, the efficiency of the extraction decreases rapidly, and considerable material is forever lost due to caving. Figure 5 shows the grade distribution of a hypothetical mineralized area. Figures 6, 7, 8, and 9 show the extent of "ore" at various economic conditions which dictate cut-off grades of .05%, .15%, .25%, and .35% U_3O_8. Note the changes which occur in the geometry of the orebody. In Figure 9, the shape of the ore is so irregular and patchy that even if surface drilling indicated economic feasibility and a mine was constructed, underground development will reveal only certain pockets of ore; much uranium will remain undiscovered.

In addition, the lower grade material is largely lost as mining proceeds and the ground caves (Figure 10).

Possible windfall profits have been predicted because of the uranium price escalation since 1973. However, the formula for cut-off grade determination argues for a tax based on income or profit, rather than a severance and/or processing tax.

$$\text{cut-off grade (\%)} = \frac{\text{sum of costs (mining, hauling, milling, royalties, interest, gross value taxes)}}{\text{selling price x mill recovery x scale factor}}$$

If any cost item increases, the cut-off grade must increase as well, unless compensated by an increase in the selling price. If the gross value taxes are increased by an order of magnitude, then the cut-off grade must be increased by a like amount, since many sales contracts contain little or no provision for tax pass-through. Such a large increase in the cut-off grade would inevitably lead to the situation shown in Figures 6 through 10. This would result in highly inefficient extraction of uranium ore, and a corresponding loss of uranium reserves from the national energy bank. This country can ill afford such losses at this time.

Conversely, a tax based on net income or profit guarantees that, with care, a company may make a profit, and would thus encourage the efficient extraction of mineralized material. As more ore would be mined over a greater time period, gross payroll income and equipment and supply purchases in New Mexico will be increased, as well as more workers employed and more income, property, and sales taxes paid.

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This brief report is a summary of material requested by the New Mexico Energy Resources Board to evaluate costs of uranium mining and milling in New Mexico. Costs are based in large part on a review by Donald Buddecke, Mining Engineer at New Mexico Tech.

21 February 1977

FIGURE 1. Range of reported U_3O_8 prices as of 7-1-76. Source ERDA, 1976

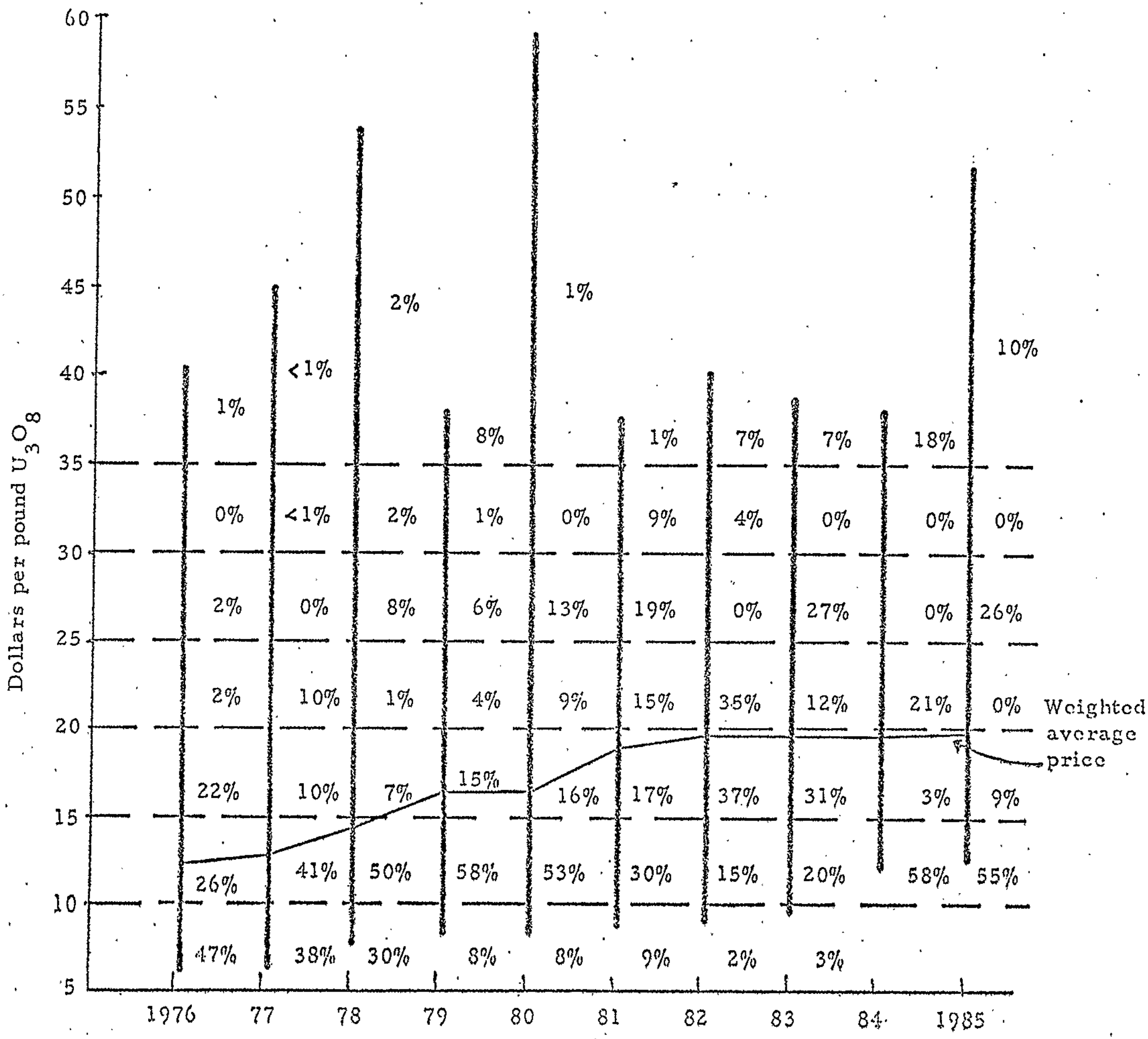


FIGURE 2. Uranium ore body as delineated by surface drilling. Maps such as this provide database for economic evaluation.

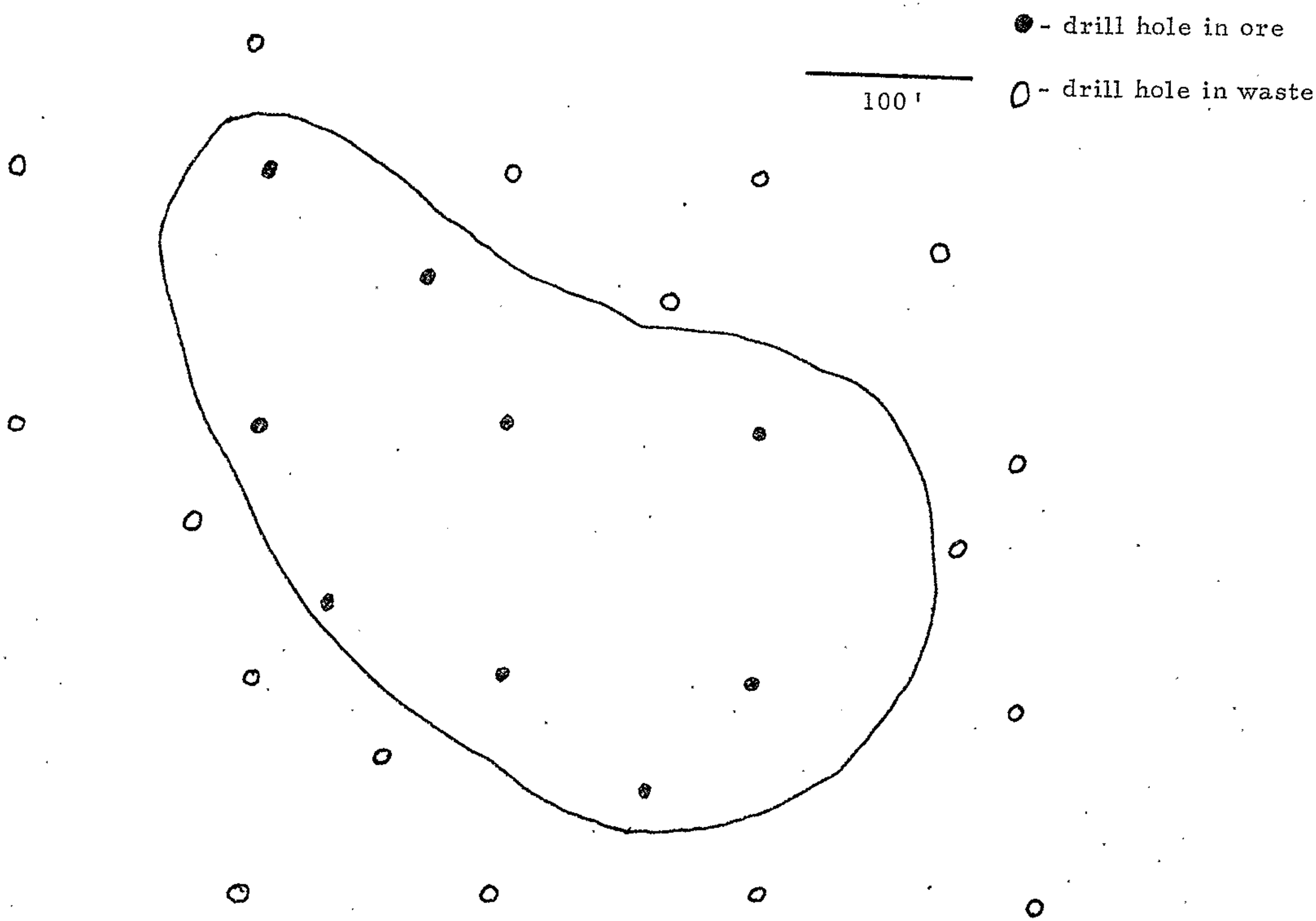


FIGURE 4. Retreat mining of orebody; pillars are extracted as indicated by pattern and roof caves (collapses).

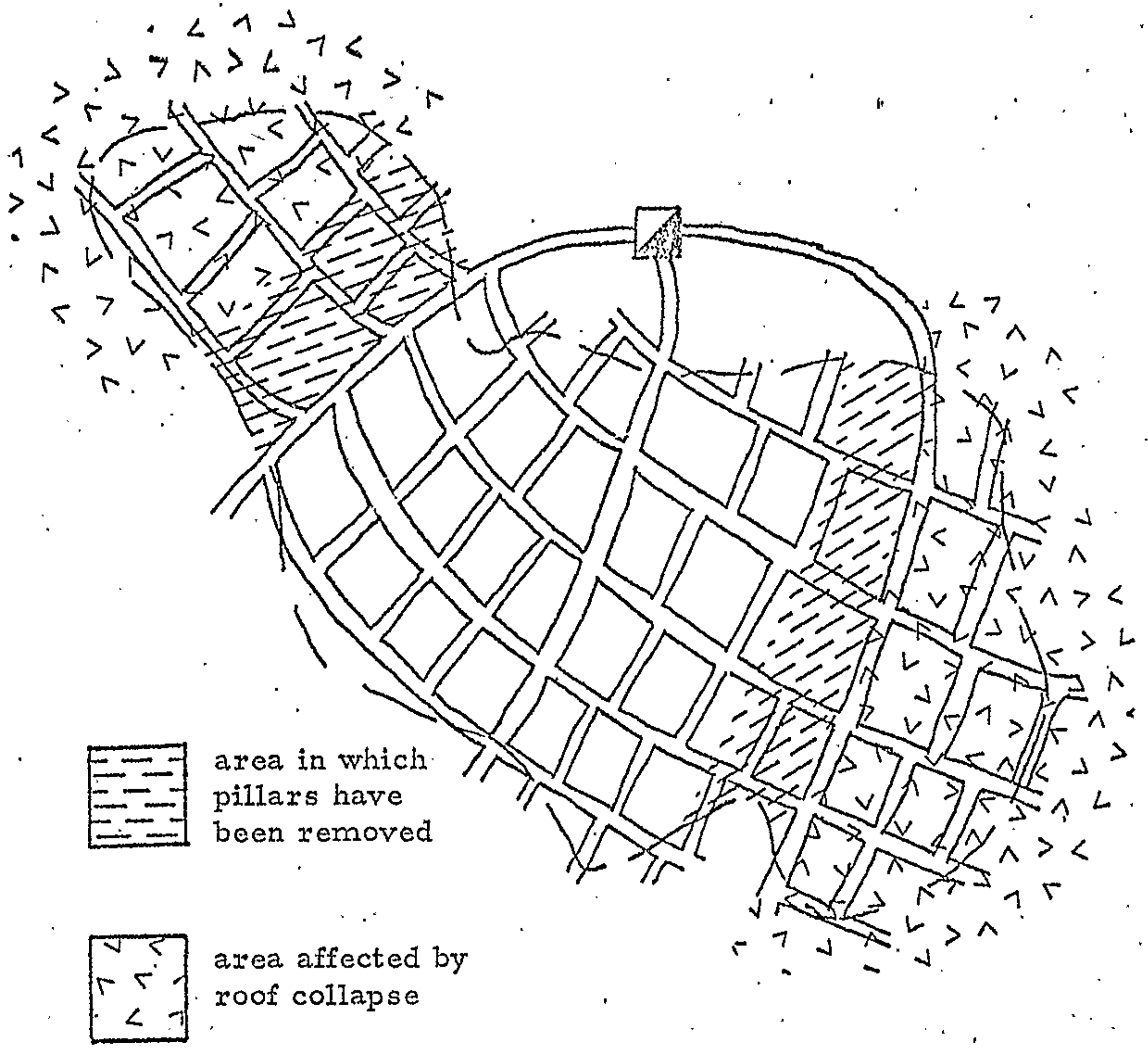


FIGURE 3. Fully developed orebody, showing shaft, haulage and development drifts. Cut-off grade as determined by development work indicated.

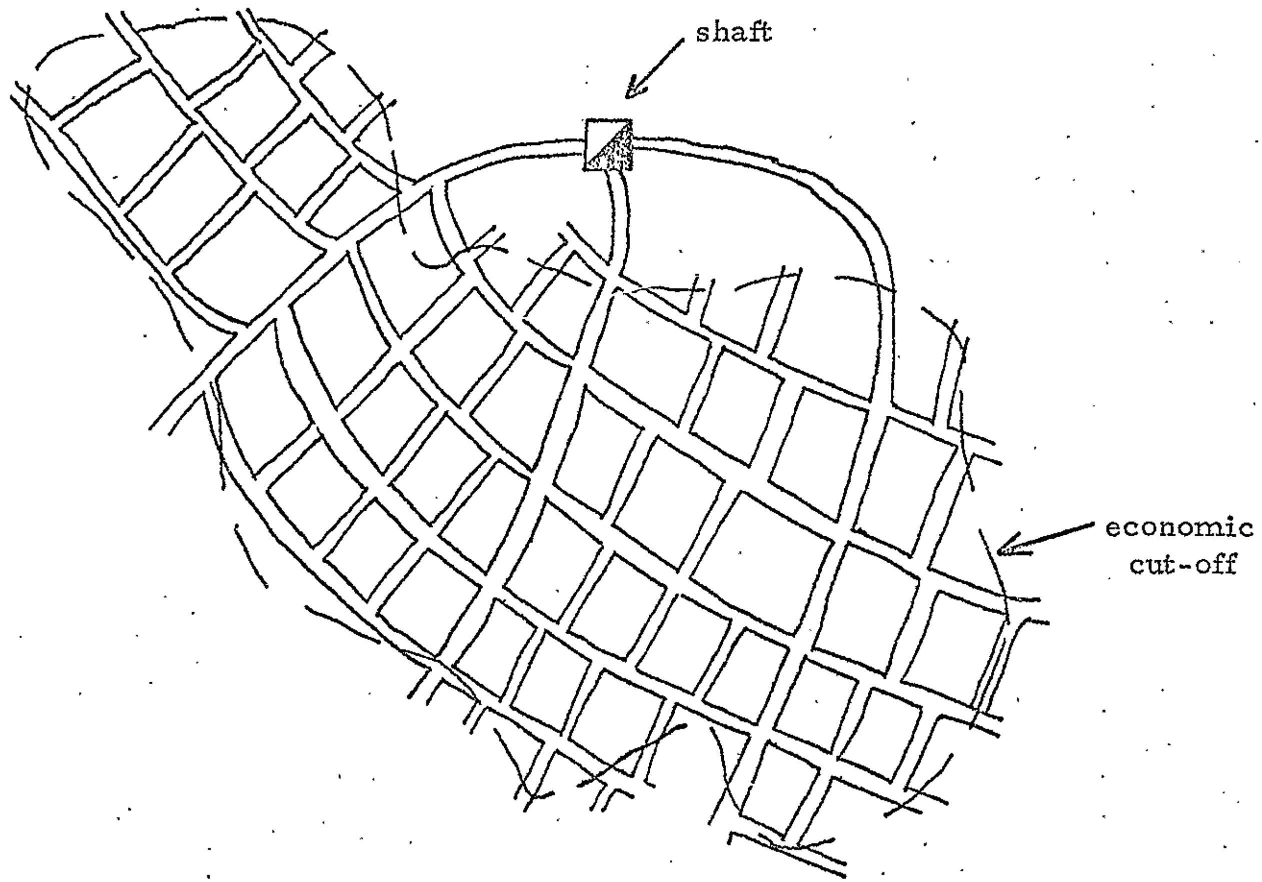


FIGURE 6. Possible development of hypothetical ore body under 0.05% cut-off grade.

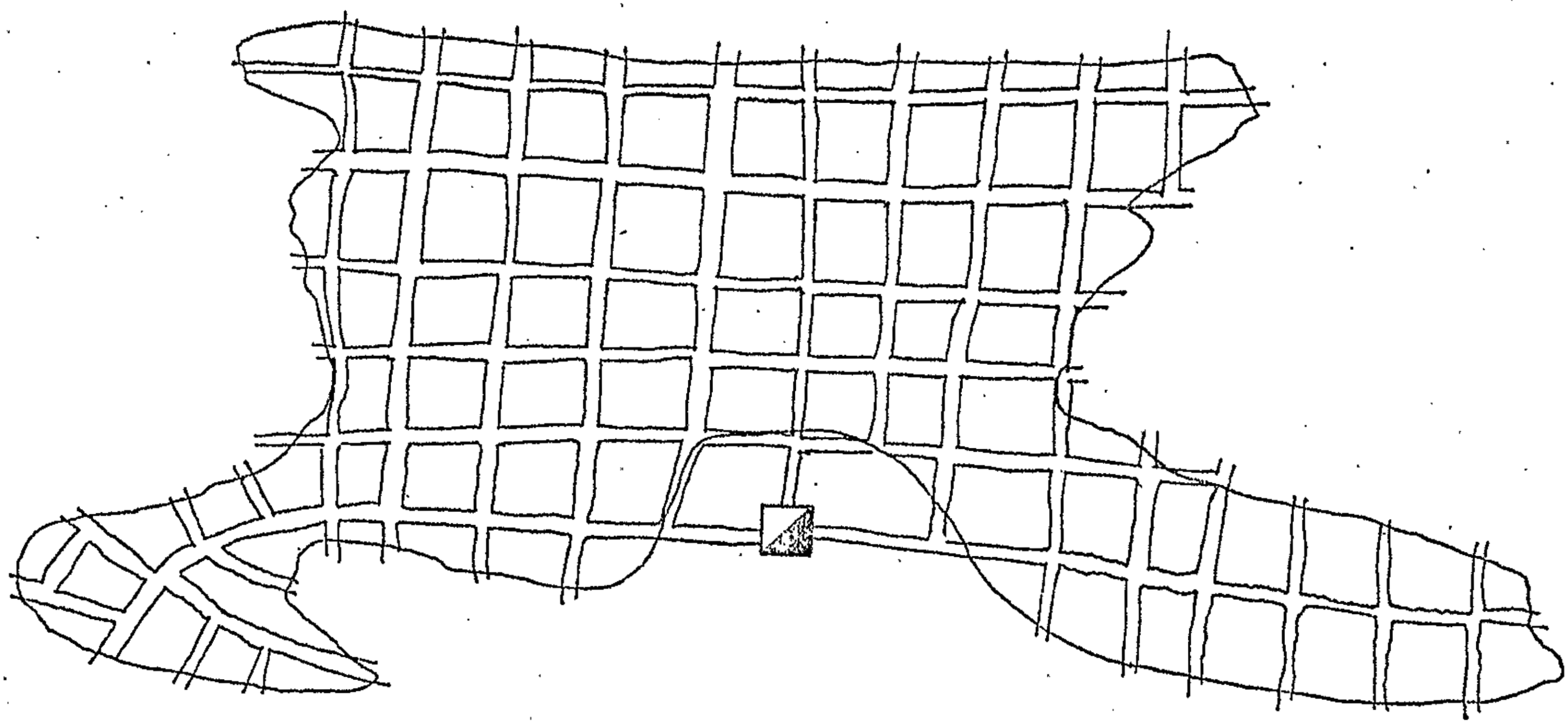


FIGURE 7. Possible development of hypothetical orebody under 0.15% cut-off grade.

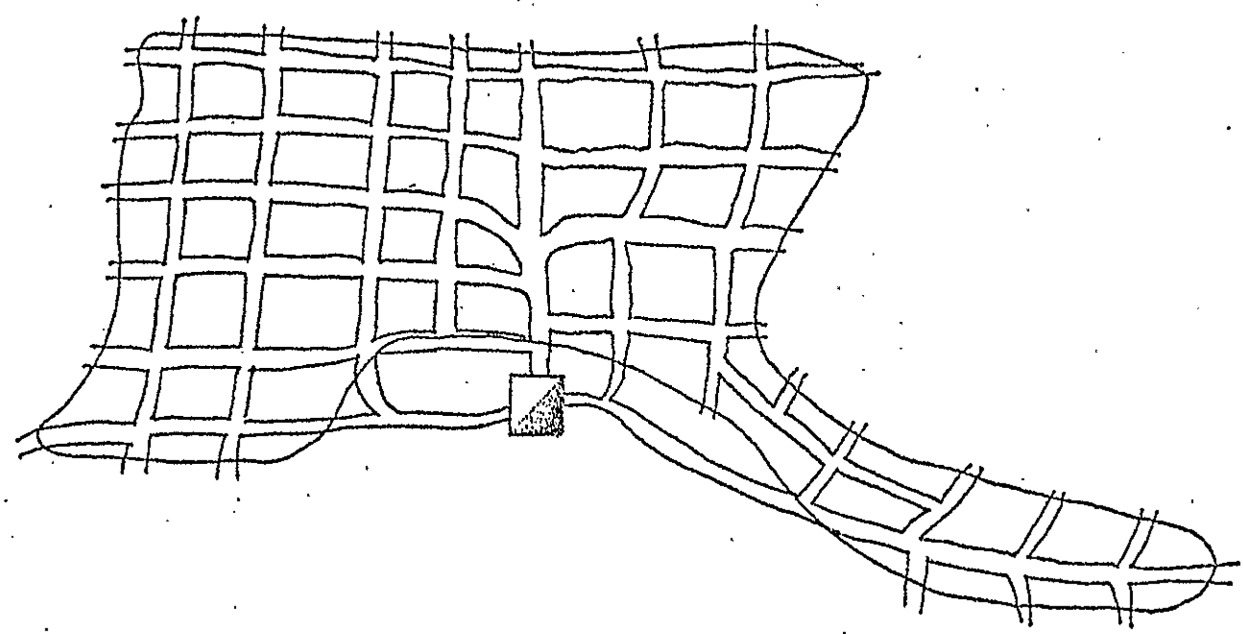
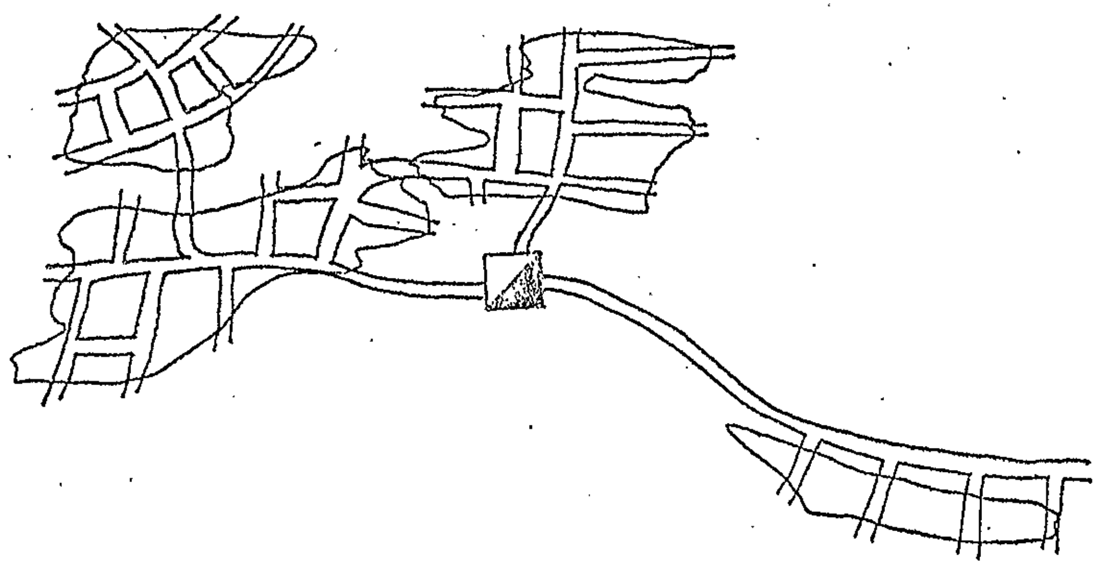


FIGURE 8. Possible development of hypothetical orebody under 0.25% cut-off grade. Compare with Figure 5 and note pockets of "ore-grade" material which remain undiscovered; efficiency of extraction declines.



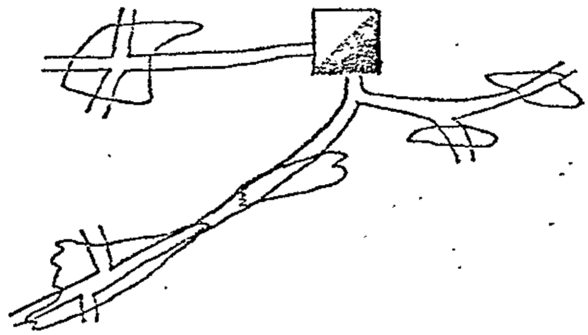


FIGURE 9. Possible development of hypothetical orebody under 0.35% cut-off grade. Compare with Figure 5 and note pockets of undiscovered ore-grade material. Efficiency of extraction is poor.

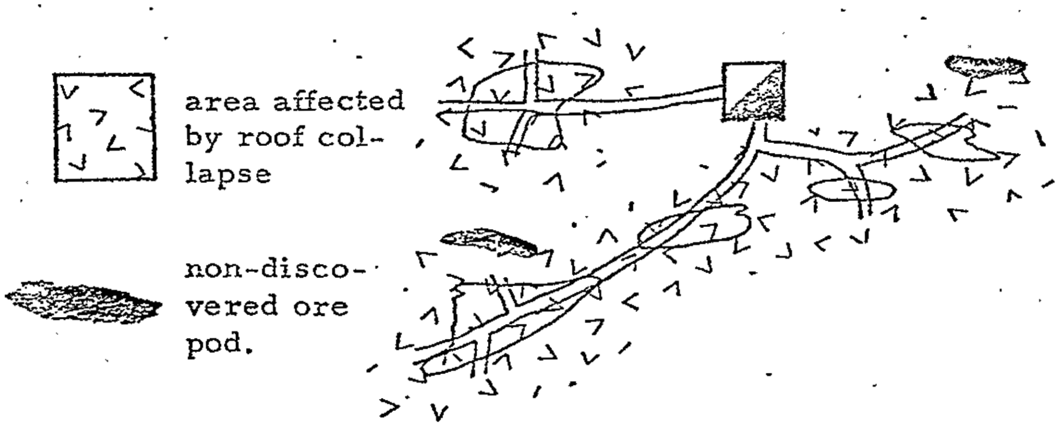


FIGURE 10. Mine shown in Figure 9 following extraction of pillars and roof collapse. Note ore-grade material lost because of caving and non-discovery.

Telegraph mining district, Grant County, New Mexico. The deposit now being worked is 5 miles north and west of the Red Rock post office. From Red Rock post office it is reached over a rather poor road for autos and trucks. Red Rock, New Mexico, post office is reached over good improved gravel roads from Silver City, New Mexico, a distance of 53 miles, and from Lordsburg, New Mexico, a distance of 23 miles. Silver City is shipping point on Santa Fe railroad and Lordsburg is shipping point on Southern Pacific railroad. Actual distance of truck haul from deposit to Silver City is 58 miles and from Lordsburg 28 miles. The deposit and nearby camp are on what is known as Alder Creek, a tributary of the Gila River.

ELEVATION

The elevation of the deposit is between 5,000 and 5,500 feet above sea level.

TOPOGRAPHY

The topography of the area is mountainous, and is very rugged. Erosion has cut a deep narrow crooked canyon gorge across the deposit and eventually the drainage reaches the Gila River.

WATER - TIMBER - POWER

Water for domestic purposes only is available at a spring just below the deposit of ricolite. It is not thought that enough water is continuously available that would furnish a processing plant on the ground.

Timber is absent in the area, except in the bottom of the canyon, and this is not of quantity or quality that can be used for any purpose whatever except minor fuel requirements for camp.

There is no available electric power in the area. All provisions for power must be planned for.