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MINE SYSTEMS ANALYSIS - TERTIARY CHANNEL DEPOSITS
The Badger Hill Pit, San Juan Ridge, Nevada County, Calif.

By Thys B. Johnson, William R. Sharp, and John N. Williams.

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MINE SYSTEMS ANALYSIS - TERTIARY CHANNEL DEPOSITS

The Badger Hill Pit, San Juan Ridge, Nevada County, Calif.

Thys B. Johnson^{1/}, William R. Sharp^{2/}, and John N. Williams^{3/}

ABSTRACT

The mine system analysis and evaluation study presented in this report was part of the U. S. Bureau of Mines' Tertiary channel project conducted under the Heavy Metals program. The Badger Hill pit, located on the west end of the San Juan Ridge area, near Nevada City, California, was the site of the Bureau's field work.

The objectives of this study were: (1) Determine potential alternative mining systems for some of the large tertiary channel gold-bearing gravel deposits, and (2) Identify areas of technology where further investigation would be merited because of their potential inclusion in a mining system for such deposits.

The study involved the development of a mineralized block inventory, an economic block inventory, determination of optimum ultimate mining limits and a preliminary economic mining system evaluation. Computer programs were developed and utilized for each of the study phases stated above.

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The sampling program conducted at Badger Hill by the Bureau Delineation Group together with confidential drill hole data provided by the San Juan Gold Co. formed the basic gold values and distribution information from which a deposit model was developed.

The deposit was divided into minable block units and net economic values were assigned to each block for various configurations of both open-pit and underground mining methods based on cost and performance data provided by the various Bureau of Mines Research Centers.

A number of controllable variables such as: (1) Mining method (open-pit and underground), (2) depth of mining cut, (3) production rate and (4) equipment type and capacity were evaluated. The prime measures of effectiveness on which the mining systems were judged were discounted cash flow rate of return and maximum utilization of natural resources.

The analysis showed that underground mining of the Six-Mile Tertiary channel gold-bearing gravel deposit under consideration was uneconomical and did not permit maximum recovery of the resources within the channel.

It was also apparent that mining the Six-Mile Deposit for gold alone is uneconomical or at best marginal at a gold price less than \$80 per ounce.

The analysis showed that the potential for an economic mining operation within the Six-Mile Deposit exists when the gravel resources of the channel are considered together with the gold. It was determined that the highest rate of return would be realized with a 20-year open-pit mining operation yielding 745,000 ounces of gold and 55 million cubic yards of usable gravel.

INTRODUCTION

The Tertiary Channel Project

With particular emphasis on gold, the Heavy Metals program was devoted to substantially improving upon our domestic capacity to meet more of our domestic demand by seeking ways to affect production from new or presently dormant sources. Conservation of resources and preservation of the other values of the land and environment were also important considerations in this program.

The Bureau of Mines Tertiary Channel project, as an integral part of the Heavy Metals program, was conducted during the period July 1968 - January 1970 to obtain information relative to the Tertiary Channel gold-bearing gravel deposits which would significantly affect the design of a total mining system so that preliminary estimates of cost and performance data could be made on which to base a mine system analysis and evaluation. The Badger Hill pit, located on the west end of the San Juan Ridge area, near Nevada City, California, was selected as the site for the Bureau's field work. (Figures 1 and 2).

Figure 1. - Location of Tertiary River Channels and Present River Systems.

Figure 2. - Location of major deposits of exposed Tertiary Gravels.

This location was chosen because of the ease of access, the availability of private information and the appearance of having reasonably typical deposit characteristics and environment.

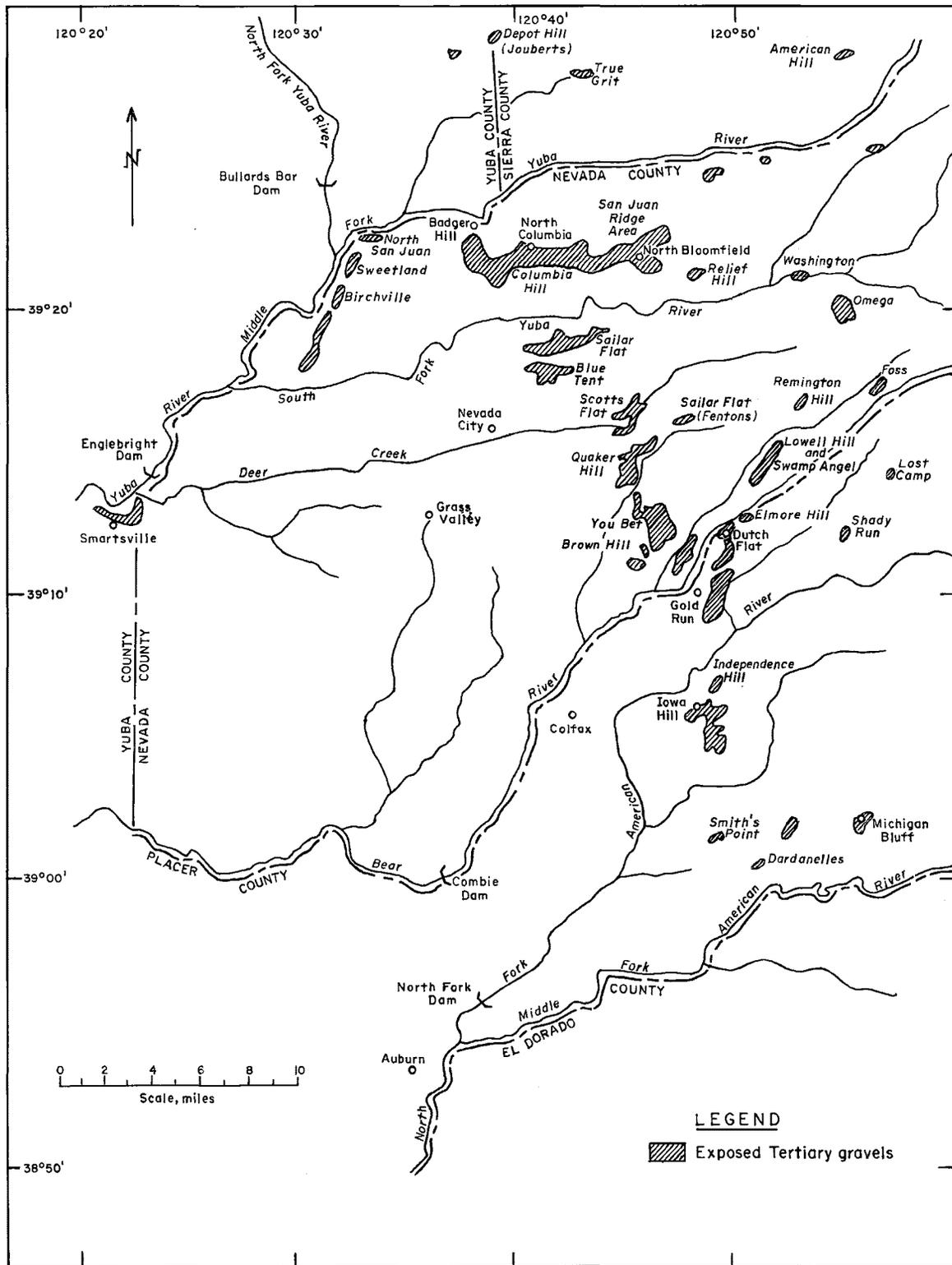


FIGURE 2.- Location of major deposits of exposed Tertiary gravels.

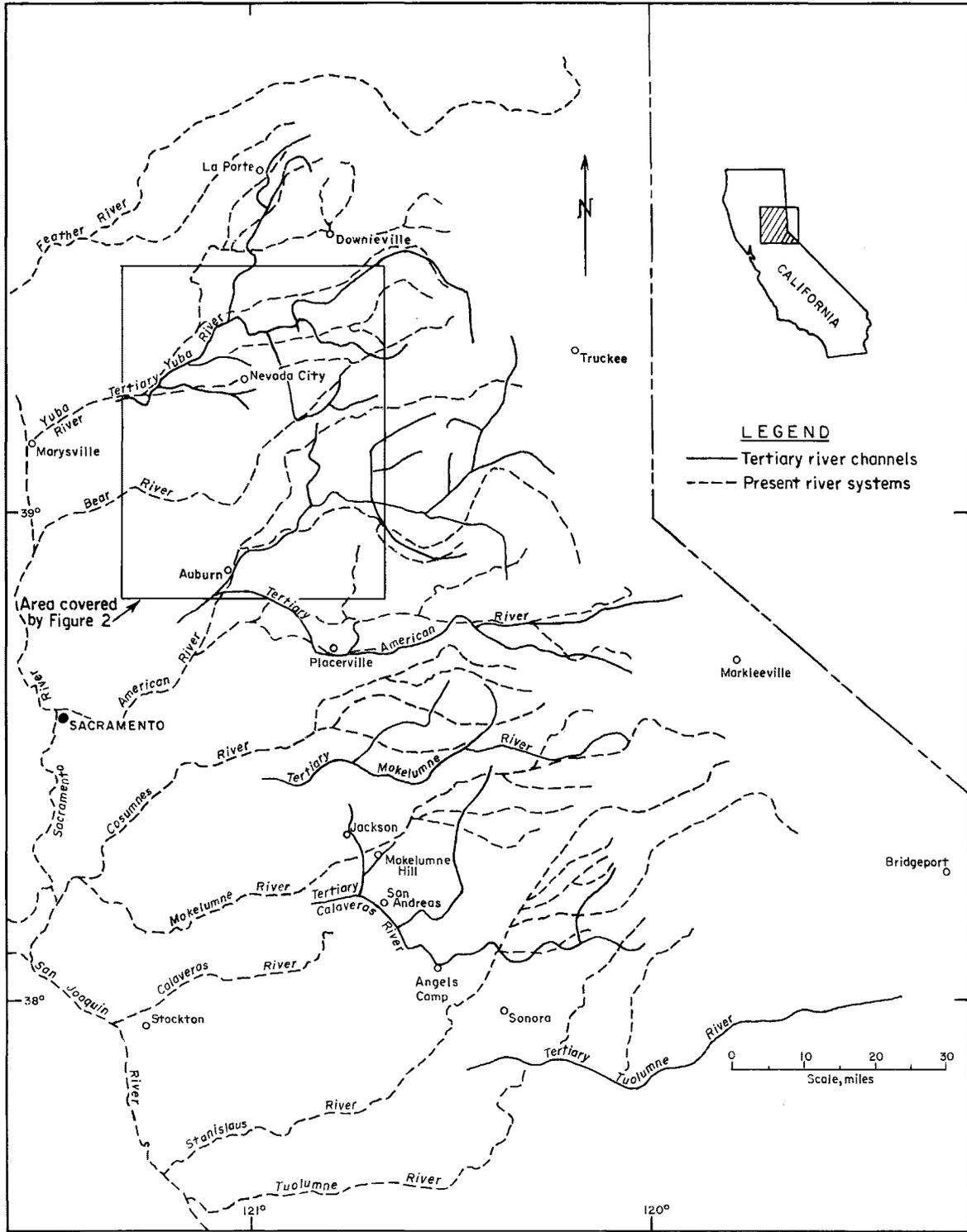


FIGURE 1.— Location of Tertiary river channels and present river systems.

Purpose of the Systems Study

The purpose of the systems analysis described in this report was to: (1) Determine potential optimal mining systems for exploitation of the Tertiary Channel gold-bearing gravel deposits and (2) Identify areas of technology where further investigation would be required or warranted because of their potential inclusion in an optimal total mining system for such deposits.

The basic data on which the analysis was based was primarily limited to that prepared by the subsystem research groups as a result of their field and laboratory work relative to this project. In most cases this data was very restrictive and limited to present-day technology.

The criterion used to select the potential optimum mining system was rate of return on investment. The value of gold is considered to be \$35.00 per ounce throughout this report unless otherwise stated.

THE TERTIARY CHANNEL GOLD-BEARING GRAVEL DEPOSITS

General Geology

Tertiary channel deposits are alluvial placers that were formed by ancient streams during Tertiary age. The work of Lindgren in 1911 (8) is still recognized as the most authoritative publication on the geology of the Tertiary river system. Most subsequent reports are based on Lindgren's work and it is to this report that the reader is referred for a more detailed description than will be given here.

The Tertiary gravels range from a few feet to as much as 600 feet thick with widths up to 8,000 feet. Continuous lengths of channels have been followed for 10 miles with interpolated lengths of 30 miles. It is estimated that the ancient channels extend for a total length of over 400 miles. Few exposed expanses of gravel remain entirely undisturbed by

mining, but most of the deposits still contain large amounts of gravel due to the cessation of hydraulic mining in 1884.

The gravels vary extremely in physical composition both regionally and locally. In size, the gravels range from large boulders several feet in diameter to small pebbles and sand interbedded with volcanic breccia, tuff, and clay. Most of the boulders and pebbles are well rounded and polished.

The lower, oldest channel gravels are generally coarser than the upper gravels and in some areas well cemented with a sand matrix. These gravels are often referred to as "deep" or "blue gravels" due to the presence of a bluish-gray slate and have thicknesses up to 150 feet. The gravel is usually water saturated within 50 feet of bedrock; however, perched water tables are known to exist.

Overlying the deep gravels is a light colored gravel referred to as the upper or bench gravel. In places the upper gravels attain thicknesses of 500 feet.

The bedrock underlying the blue gravels varies regionally in both composition and texture. In some areas it is granitic which is usually soft and decayed. In other areas it is slate or schist and there is also considerable limestone. The gradient of the bedrock varies locally, often due to faulting, but in general it averages about 65 feet per mile.

The Tertiary gravels are considered to contain the largest known reserves of gold-bearing gravel in the United States. From all indications it appears the Tertiary gravels represent a gold potential of between \$750 million and \$1 billion in 3 to 4 billion cubic yards of material (5).

These estimates include the deeper gravels and the virgin deposits capped by lava flows.

Although large nuggets have been found, the bulk of the gold in the gravels is fine, about the size of a mustard seed. Some of the gold occurs as rounded grains, but most of the pieces are flat. The average fineness of the Tertiary channel gold is considered to be about 900 (8).

Generally, the gold is concentrated near bedrock but rich paystreaks may occur within the upper beds of the gravel. Although the distribution of the gold varies extremely both vertically and horizontally it has been reported that from one-fifth to one-half of the total gold in the gravels is contained in the lower 4 to 8 feet (5). A conservative assumption is that 20 percent of the gravels comprising the lower part of the channels contain 80 percent of the gold (5). Based on the previously given volume estimates, this would yield minable target zones of 600-800 million cubic yards of gravel with an average value of \$1.00 per cubic yard.

One of the largest known accumulations of Tertiary gravels occurs in the area known as San Juan Ridge. This area extends from the east end of the North Columbia pit to the Badger Hill diggings, a distance of approximately 6 miles along the channel. This is the area of major concern in this report and will be referred to as the Six-Mile Deposit. (See Figures 2 and 3)

The Six-Mile Deposit

The extensive accumulations of Tertiary gravel in the San Juan Ridge area is primarily due to the confluence of two important streams near North Columbia. Even though this area from North Columbia to Badger Hill has been exploited by early hydraulic mining, a large amount of gravel remains in place. The San Juan Gold Company is the principal owner of the land surface and mineral rights in the channel area between Badger Hill and the

east end of the North Columbia pit. In this area the channel is continuous and the gravel readily accessible until it passes under the lava capping at the east end of the Columbia pit (Figure 3). The field

Figure 3. - Tertiary channel and major hydraulic pits on San Juan Ridge Nevada County, California.

investigations of U. S. Bureau of Mines were concentrated in the Badger Hill pit where the channel is approximately 1,000 feet wide and contains up to 350 feet of gravel fill. The outline of the channel bottom is broadly concave in cross section. It descends generally with a gradient of about 65 feet per mile, however, there are local variations which are contrary to the general gradient.

The Tertiary channel gravel in the Six-Mile Deposit can be divided into two parts; the lower gravel and the upper gravel. (9) The lower gravel is coarse and poorly sorted while the upper is less coarse, better sorted and contains many lenticular beds of clay and sand.

Two stratigraphic zones are visible within the lower gravels; the blue gravels and the red gravels. The blue gravels fill the deepest portion of the channel ranging in thickness from 80 - 140 feet. The material is highly compacted and often is tightly cemented. It is estimated that about 80 percent of the total gold content of the channel deposits is confined to the blue gravels. Bureau of Mines delineation work indicates that approximately 50 percent of the gold is concentrated in the lower 40 feet of the blue gravels but not necessarily resting directly on bedrocks. Distribution of the gold in this zone is erratic both vertically and horizontally. The richest concentrations of gold

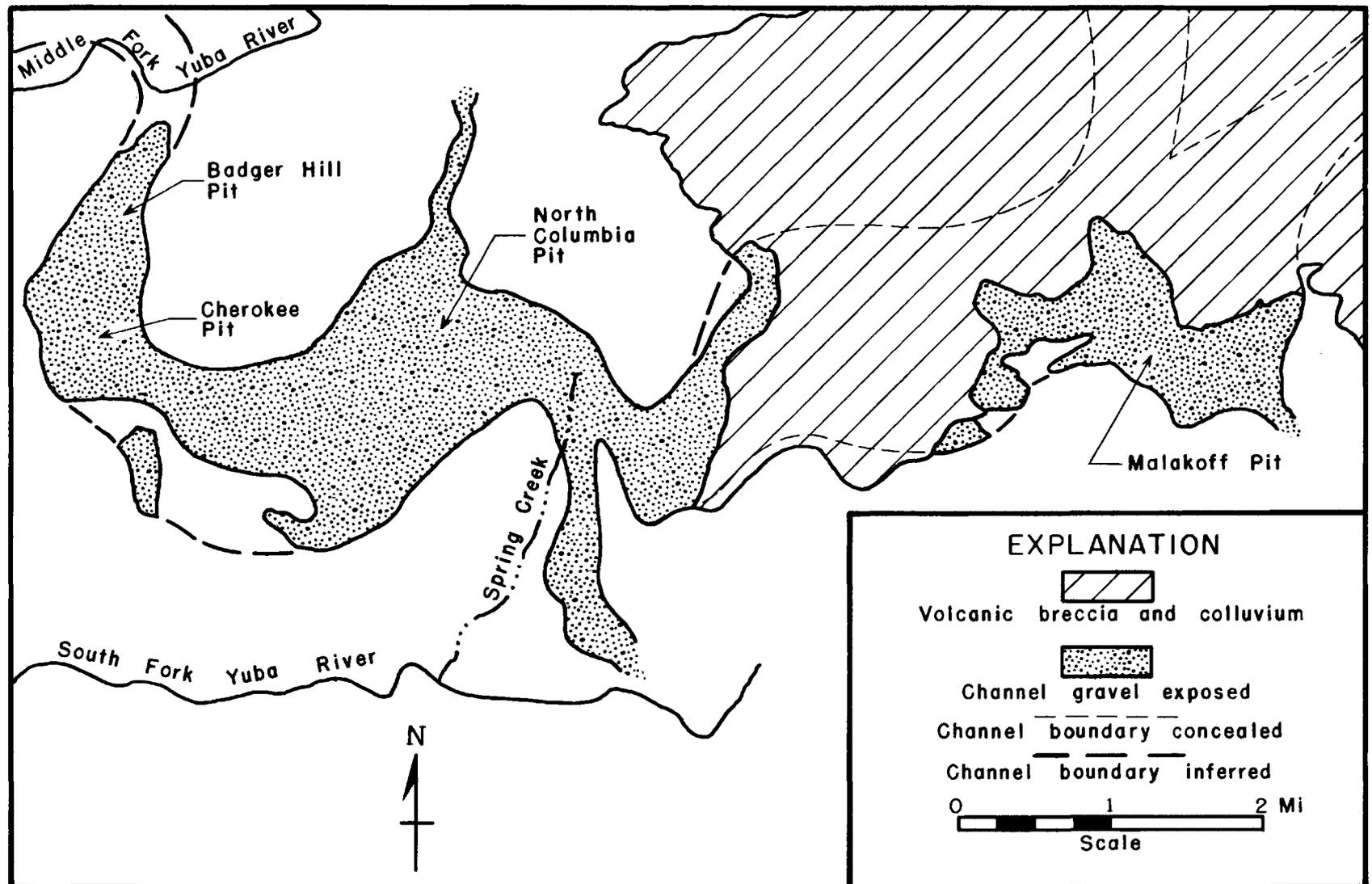


FIGURE 3.- Tertiary channel and major hydraulic pits on San Juan Ridge, Nevada County, California.

within the blue gravels occur in isolated elongated lenses. (9)

The loosely consolidated red gravels rest on the blue gravels and range in thickness from 20 to 80 feet. The gold values in the red gravels are less than the blue gravels but the vertical distribution is not as erratic. The sampling at the Badger Hill site indicated the value of the gold in the red gravels ranged from 0.4 cents to 30 cents per cubic yard with an average of 6 cents per cubic yard. (9) The red gravels also contain clay and sand lenses and these zones were found to be the least favorable for concentrations of gold.

The upper or white gravels are the least coarse of all the channel gravels. Samples from Badger Hill and North Columbia contained only 5.5 percent by weight of plus 1/8-inch material. The average value of gold in the samples was 3 cents per cubic yard. Similarly to the red gravel, the clay and sand lenses within the white gravel zone contain the least amount of gold and in some cases no measurable gold. The white gravels are classified as loose. (9, 12)

The foregoing general geologic description of the Tertiary channel deposits and the Six-Mile Deposit set the stage for the deposit model to be used in the mine system analysis. Because the white and red gravels have similar characteristics relative to mining and milling, that is, they are loosely consolidated, they were combined into one zone which will be referred to as the loose upper gravels in this report.

The recent Bureau of Mines delineation effort and the drilling and sampling data furnished by the San Juan Gold Co. provided the basic information from which the lithology and the gold distribution for the deposit model were developed.

MINE SYSTEMS ANALYSIS

General Approach

The general approach used in the analysis described in this report to achieve the objectives stated in the introduction is based on the block concept and is illustrated by the flow chart in figure 4.

Figure 4. - Flow chart of Tertiary channel mining system evaluation procedures.

The following computer programs were developed and/or used during this study:

1. Block Generation Program - developed specifically for this study to generate mineralized block inventory.
2. Cost Program - developed specifically for this study to generate cost and performance data for each block in the mineralized inventory. The Economic Block inventory is generated by this program.
3. Optimum Open Pit Design Program - developed during this study, but is applicable to general open pit ultimate limit determination. This technique is described in (6).
4. Optimum Underground Mine Design Program - developed for general design of ultimate underground mining limits. Techniques described in (10).
5. Cash Flow Financial Analysis Program - described in detail in (3).

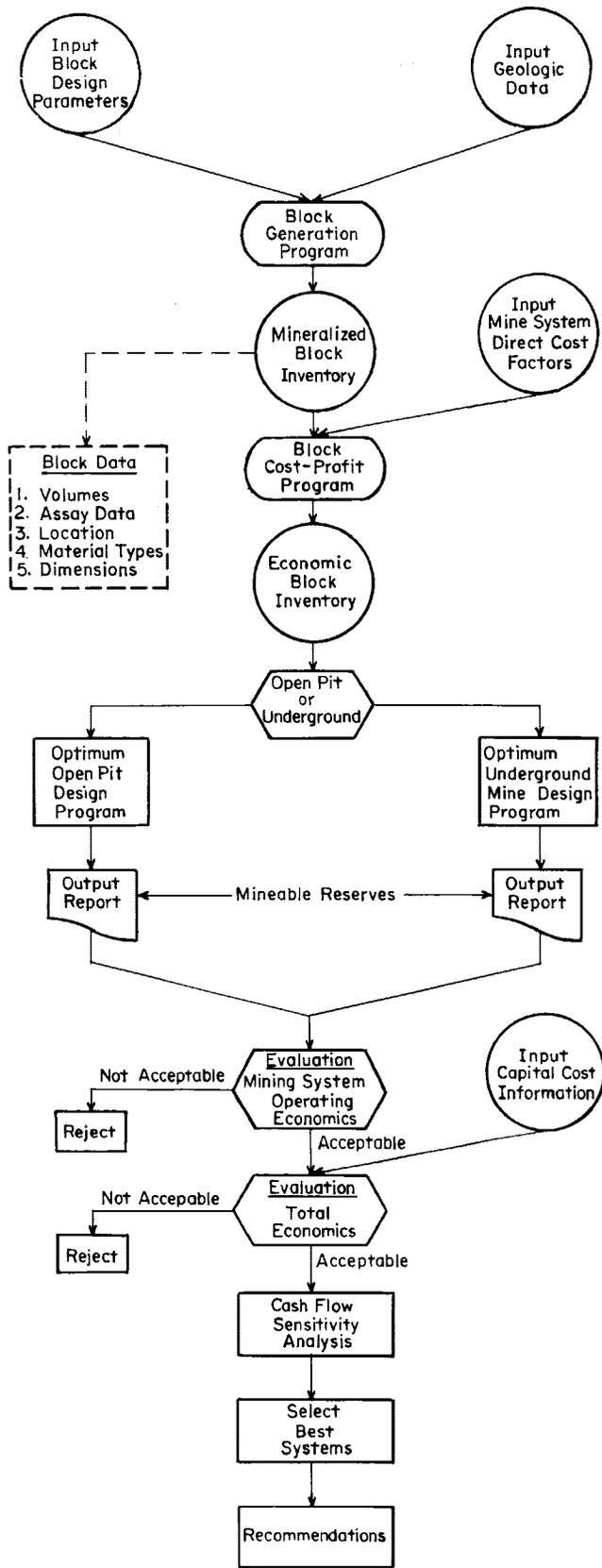


FIGURE 4.-Flow Chart of Tertiary Channel Mining System Evaluation Method.

The controllable variables considered for this study were:

(1) Dimensions of mining cut, (2) mining method, (3) production rate, (4) equipment type and (5) equipment capacity. The noncontrollable parameters considered were: (1) gold value and distribution, (2) material type (gravel, sand and clay), (3) material minability^{1/} and (4) stratigraphy.

The prime measure of effectiveness on which the optimum mining system is to be selected is discounted cash flow rate of return, assuming a uniform annual distribution of the direct operating profit and an initial investment of the total capital cost. Investment payback years was used as a preliminary screening criteria.

The other factors to be considered as measures of effectiveness are conservation of natural resources, health and safety of the miners and environmental considerations such as air and water pollution and surface restoration or improvement.

The major phases of the evaluation method are: (1) Generation of a mineralized block inventory, (2) Generation of an economic block inventory, (3) optimum mine design and (4) evaluation.

^{1/} Material minability is a parameter value which is defined in this report to be that which represents the effect of a group of material properties on the cost and performance of elements of a mining system.

Mineralized Block Model

Generation of a mineralized block inventory which represents the deposit under consideration, in this case the Six-Mile Deposit, is the key to the system analysis. The input to the block generation computer program are as follows:

1. Block dimensions
 - a. mining height
 - b. block width (width on cross-section)
 - c. block length
2. Geologic stratigraphic data
 - a. shape and locations of lenses
 - b. lens composition (clay, sand or gravel)
 - c. bedrock configuration
 - d. elevation of loose-cemented material contact
 - e. surface topography
3. Channel configuration and location
4. Block values and distributions

The block dimensions, although all controllable within the program, are not all truly controllable design variables in the sense of the optimal design method used for this study. Only the mining height may be controlled in this sense.

Once the mining height is selected, the block length and width are determined because the particular procedures used to determine optimum ultimate mining limits in this study assumes equal dimensional blocks (cubes).

Mining height is the bench height in open pit mining and the height of an operating face in underground mining. A particular value selected for the mining height affects the cost and performance of mining equipment

and also the metallurgical processing through inclusion of varying proportions of different material and hence affects the economics of the total mining system. Determination of the optimal value of such a design variable as mining height will be one of the results of determining the optimal total mining system. The block heights evaluated in this study are given in table 1.

TABLE 1. - Mining heights considered in analysis of mining systems for Six-Mile Tertiary Channel Deposit

<u>Mining Method</u>	<u>Mining Height</u>
open-pit	50
open-pit	40
open-pit	30
underground	15

The stratigraphic data furnished by the Delineation Group of MSEG was based on their recent field work at Badger Hill and an analysis of the confidential drill logs from a drilling program conducted in the North Comrade Pit Area furnished by the San Juan Gold Co. This was the best information available by which to characterize the stratigraphy of the Six-Mile Deposit and determined the material characteristic of each block.

Cross-sections were prepared for the Six-Mile Deposit on intervals ranging from 700 to 3,000 feet with the most common interval being approximately 1,000 feet--a typical cross-section through the Six-Mile Deposit is shown in figure 5. These cross-sections were the source

Figure 5. - Typical cross-section through Six-Mile Tertiary Channel Deposit

of the stratigraphical computer input.

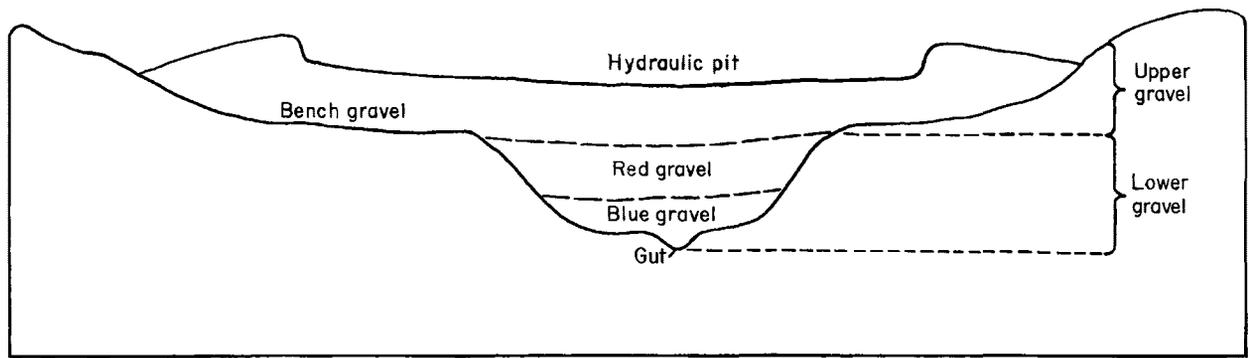


FIGURE 5.-Typical cross-section through Six-Mile Tertiary Channel Deposit.

Estimating gold for small volumes within the Tertiary Channel was one of the more difficult--yet essential--jobs for a meaningful evaluation of the Six-Mile property. Relationships for estimating that part of the channel which was not covered by previous sampling programs were developed from available data. The approach taken was to relate gold values and distribution to physical parameters suspected to control the deposition and which could be readily measured. The most significant parameters were assumed to be: (1) Radius of curvature of the stream channel, (2) slope of stream channel, and (3) width of stream channel. It has been reported by Lindgren and observed many times over that the gold was generally concentrated near bedrock. This fact is readily observed from drill-hole samples. However, a significant, statistical, difference was observed to occur along the axis of the ancient stream channel. By trial and error, it was found that the following relationship would give a statistically valid estimate of the average gold content for the lower, gold-rich gravels (within 25 feet of bedrock):

$$(1) \quad \bar{Y} = b_1 \frac{1}{R^{1/2}} \left(\frac{W}{S} \right) + b_0 + e$$

where

- \bar{Y} = predicted gold content, mg/cubic yard
- R = radius of curvature of stream channel, ft
- S = slope of stream channel, ft/ft
- W = width of stream channel, ft
- b_0 = 313.3
- b_1 = 1.24
- e = random error

Testing the hypothesis that $b_1 = 0$ using an F test, we may reject the hypothesis with only a 5 percent chance of error. Therefore, the relationship was assumed to be statistically valid. Also, it appears intuitively sound, that is, reasonable when the parameters, R, S, and W, are permitted to reach their upper and lower limits. Using this model for that portion of the channel not covered by previous sampling programs, the estimate varies from 250 to 2000 mg/yd³ which are within the bounds of those determined from the Bureau of Mines sampling program at Badger Hill. For the upper white gravels sampling indicated an average gold content of about 40 mg/yd³ with no statistical evidence of longitudinal trend.

All drill-hole sample data exhibited a vertical trend, (figure 6)

Figure 6. - Vertical trend exhibited by gold values in drill holes for Six-Mile Deposit.

with the gold content increasing with depth from an average 40 mg per cubic yard for the upper white gravels to the average predicted by equation (1).

It was also observed from the drill hole data that the contact between the cemented lower blue gravels and the upper loose gravels generally occurred at the same elevation as the 100 mg gold per cubic yard isogram.

Based on the location of the 100 mg gold per cubic yard cut-off line (loose-cemented gravel contact) and the calculated gold content (\bar{Y}), the following equation was derived to predict the average gold content at any location within the cemented gravel horizon.

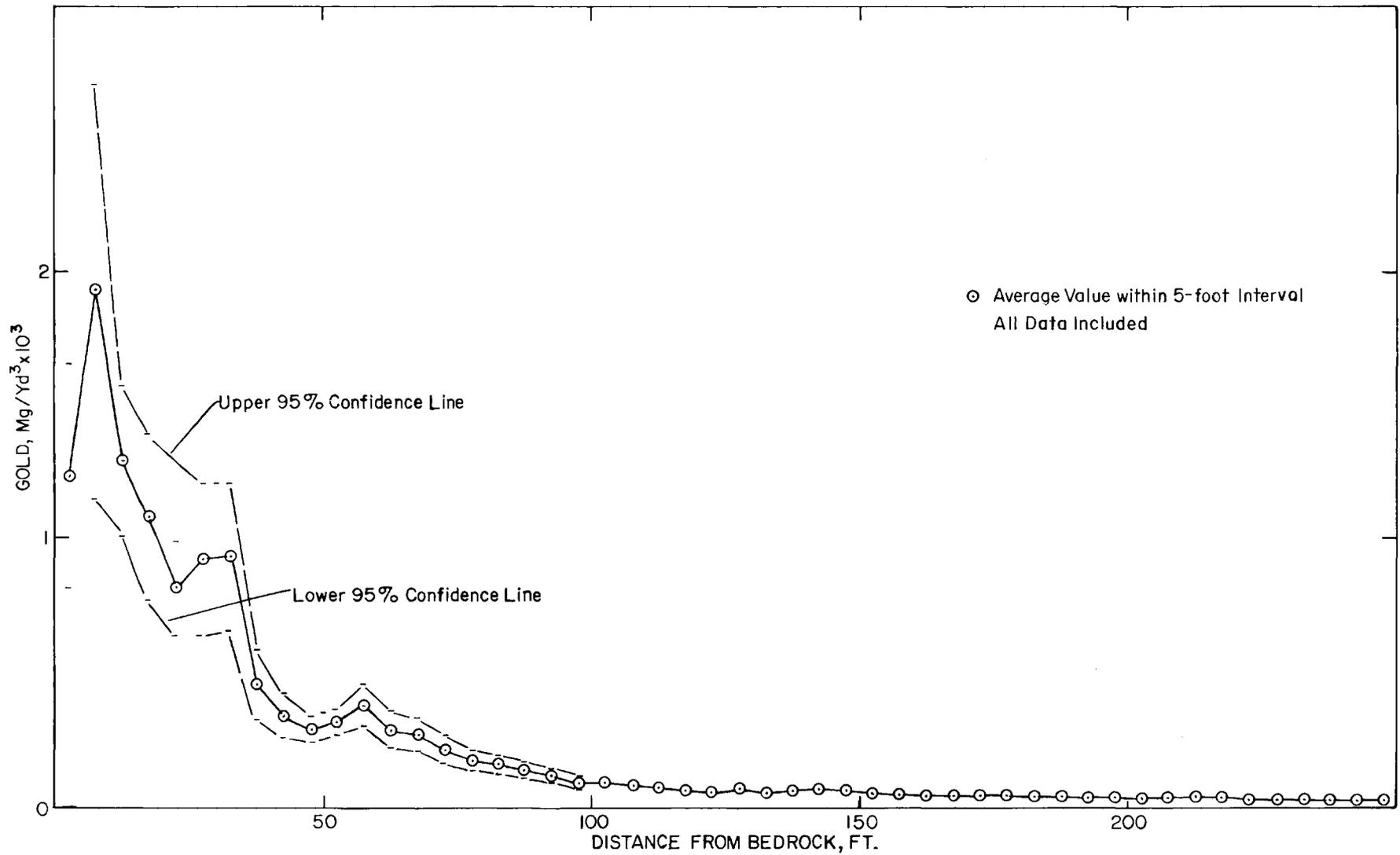


FIGURE 6.-Vertical Trend Exhibited by Gold in Drill Holes for Six Mile Deposit.

$$(2) \quad A_A = \frac{(y - 12.5)}{(D - 12.5)} 100 + \frac{(D - y)}{(D - 12.5)} 12.5 \frac{\bar{y}}{y}$$

where

A_A = average gold content mg/yd³

y = distance above bedrock, ft

D = distance from bedrock to hardpan, ft

\bar{y} = gold estimate for lower 25 ft, mg/yd³

Results of the Bureau of Mines sampling program indicated that material type (clay, sand or gravel) greatly influenced the value and gold distribution (9). In general it was found that the gold content increased with the coarseness of the host material. Analysis of the San Juan Gold Co. confidential data substantiated this conclusion (figure 7).

Figure 7. - Typical Drill Hole Analysis from Six-Mile Deposit Illustrating Dependence of Gold Values on Material Type.

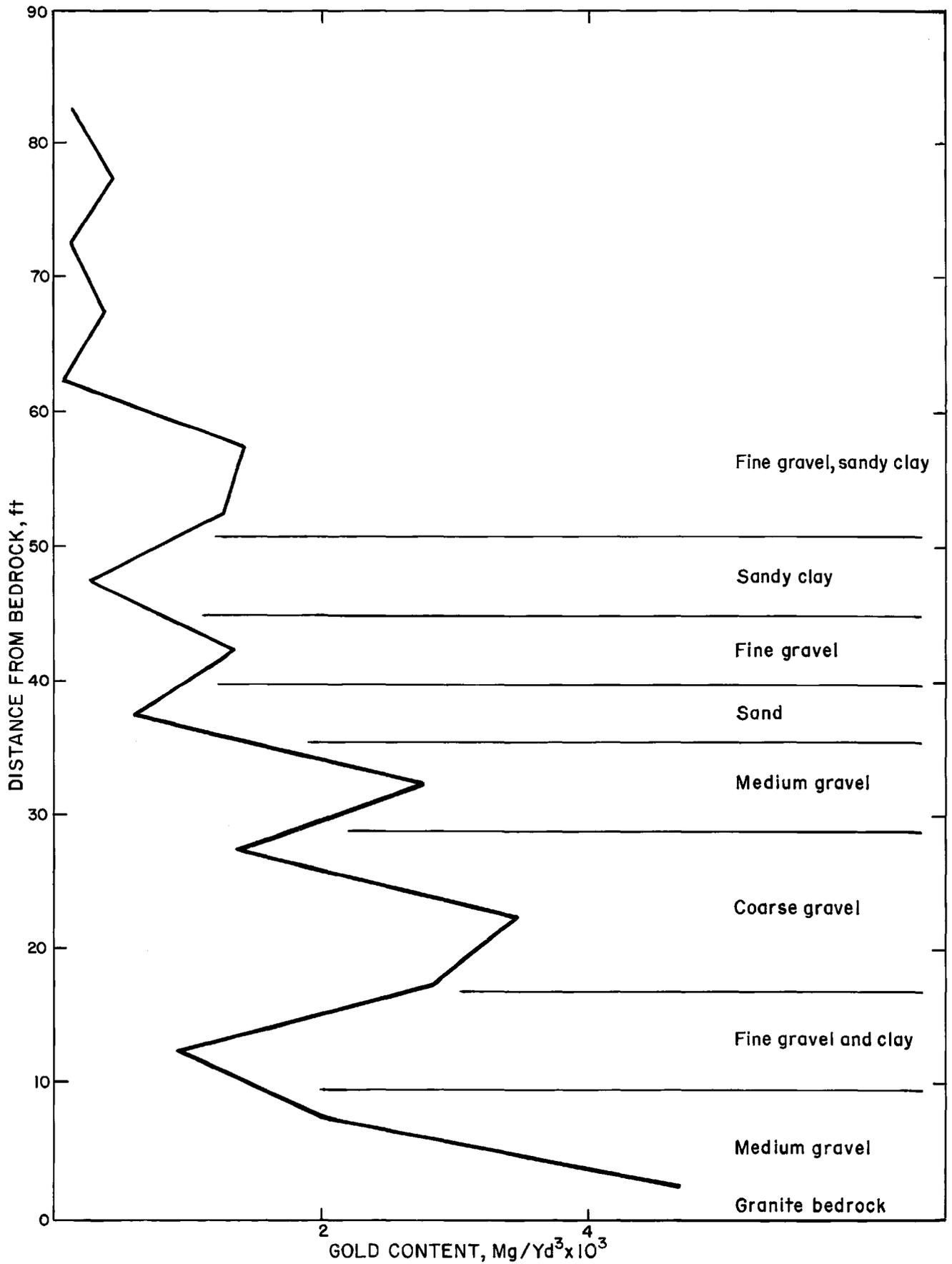


FIGURE 7.-Typical Drill Hole Analysis from Six-Mile Deposit Illustrating Dependence of Gold Values on Material Type.

The following equation was derived to modify the average gold content (A_A) calculated by equation (1):

$$3) \quad A_V = (1.5 P_1 + 0.5 P_2 + 0.3 P_3) (A_A)$$

where P_1 = percent gravel

P_2 = percent sand

P_3 = percent clay

This equation was used to generate gold content for each block in the inventory below the loose-cemented gravel contact.

Above the contact, the gold content of the gravel averaged 40 mg per cubic yard. This was assumed to be a good estimate of the mean but required an adjustment for the influence of host material type. The following expression was derived to compensate for the host material in the case of the loose gravels.

$$4) \quad A_V = 90 P_1 + 20 P_2 + 10 P_3$$

where A_V = gold content, mg/yd³

P_1 = ratio of gravel to total volume.

P_2 = ratio sand to total volume.

P_3 = ratio clay to total volume.

In total volume the loose gravels are generally considered to be 1/3 gravel, 1/3 sand and 1/3 clay and thus the above expression yields the assumed average of 40 mg per cubic yard. The above expression was used to generate gold content for the blocks in the upper gravels.

Further verification is needed to fully demonstrate the usefulness and accuracy of this approach to model this type gravel deposit. However,

it is felt this model can be used to estimate gold content outside the area from which the samples were taken with some degree of confidence. This is possible due to the fact that this model is based on many of the parameters suspected to control deposition of the gold. Variation within a given locality is suspected to be a result of the host material together with a random error introduced by sampling. Variation between one locality and another was assumed to be a function of these physical variables suspected to control deposition (see equation 1) and the host material.

Gold concentration, mg/cubic yard, for analytical purposes was calculated based upon the actual weight of gold and the theoretical volume for a 5-foot length of vertical drill hole. The 5-foot samples were made from drill hole logs provided by The San Juan Gold Co. which consisted of samples taken at 6-inch to 5-foot intervals.

Two different sampling procedures were used in the past on the Six-Mile Deposit: One, in the upper loose gravels the drill casing was driven ahead and the material within the casing removed by churn drilling, and two, in the lower cemented gravels the sample was taken by drilling ahead of the casing and then the hole reamed and the casing driven down. This procedure resulted in two sample volumes for a 5-foot interval: One, for the upper loose gravels (0.057 cu. yd.) and another for the lower, cemented gravels (0.040 cu. yd.). Figures 8 and 9 give the actual sample volumes for the two volumes considered. Of interest is that in both the lower and upper gravels the actual volume was significantly less than the theoretical volume of the sample and for both sample horizons the variation

Figure 8. - Frequency distribution of sample volumes within upper gravels in Six-Mile Deposit.

Figure 9. - Frequency distribution of sample volumes within lower gravels in Six-Mile Deposit.

is extremely large in relation to the mean. This implies, assuming no sampling bias, that the actual gold content is greater than that which is given in this report.

A plot of the gold particle distribution for the upper and lower gravels is given in figures 10 and 11. It is seen that for the respective

Figure 10. - Frequency distribution of gold particles within lower cemented gravels in Six-Mile Deposit.

Figure 11. - Frequency distribution of gold particles within upper loose gravels in Six-Mile Deposit.

volumes of the lower and upper gravels the probability of occurrence of a particle is much greater for the lower gravels than the upper. Sampling of rare particles does give rise to highly skewed distributions which become even more skewed as the sample volume decreases. For a further description and analysis of how the skewness of a sample distribution may be affected by the volume of the sample, the reader is referred to Report of Investigations 5669 by R. M. Becker and Scott W. Hazen, Jr. (2).

Knowing that little can be done to study the effects induced by

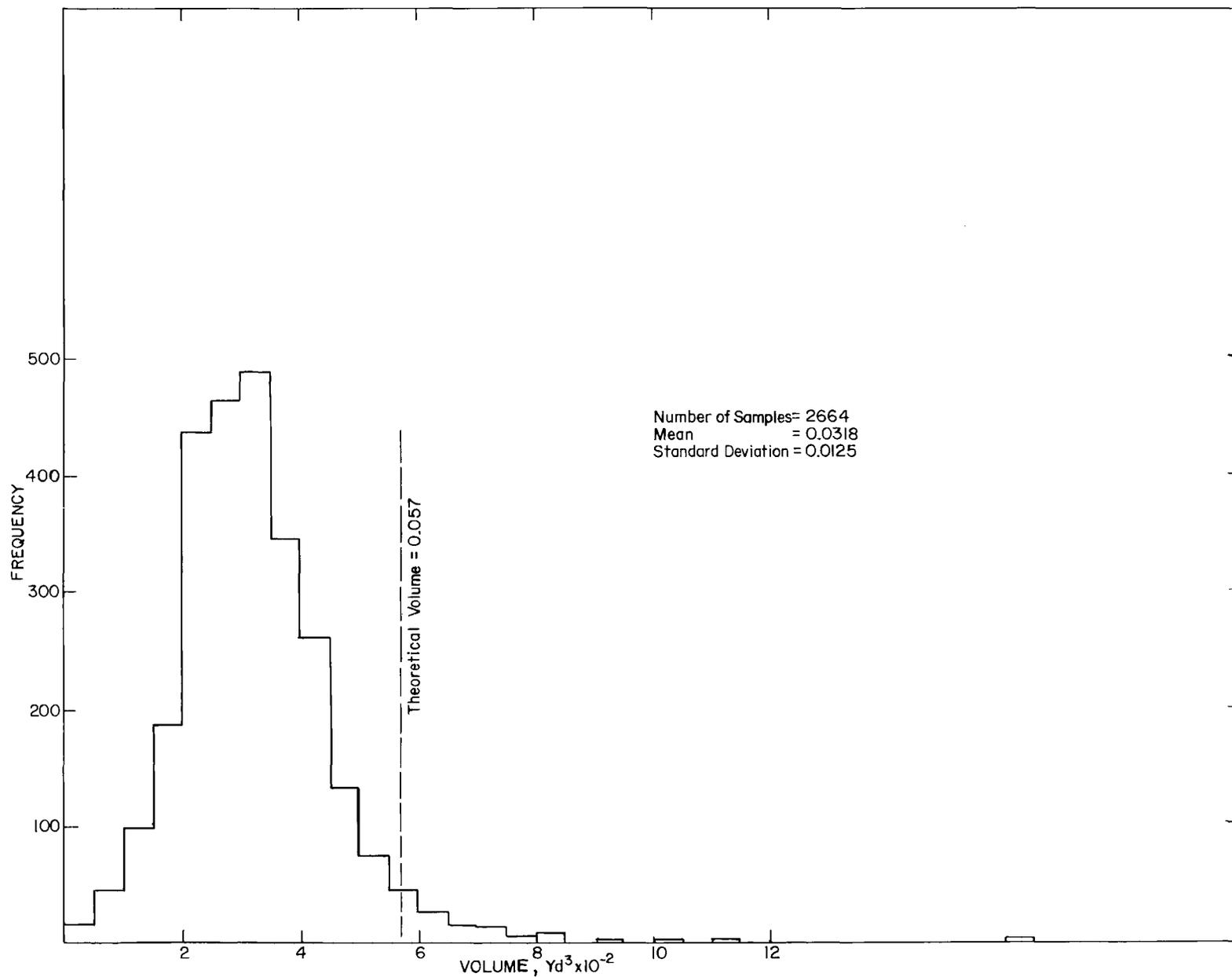


FIGURE 8.—Frequency Distribution of Sample Volumes within the Upper Gravel in Six Mile Deposit.

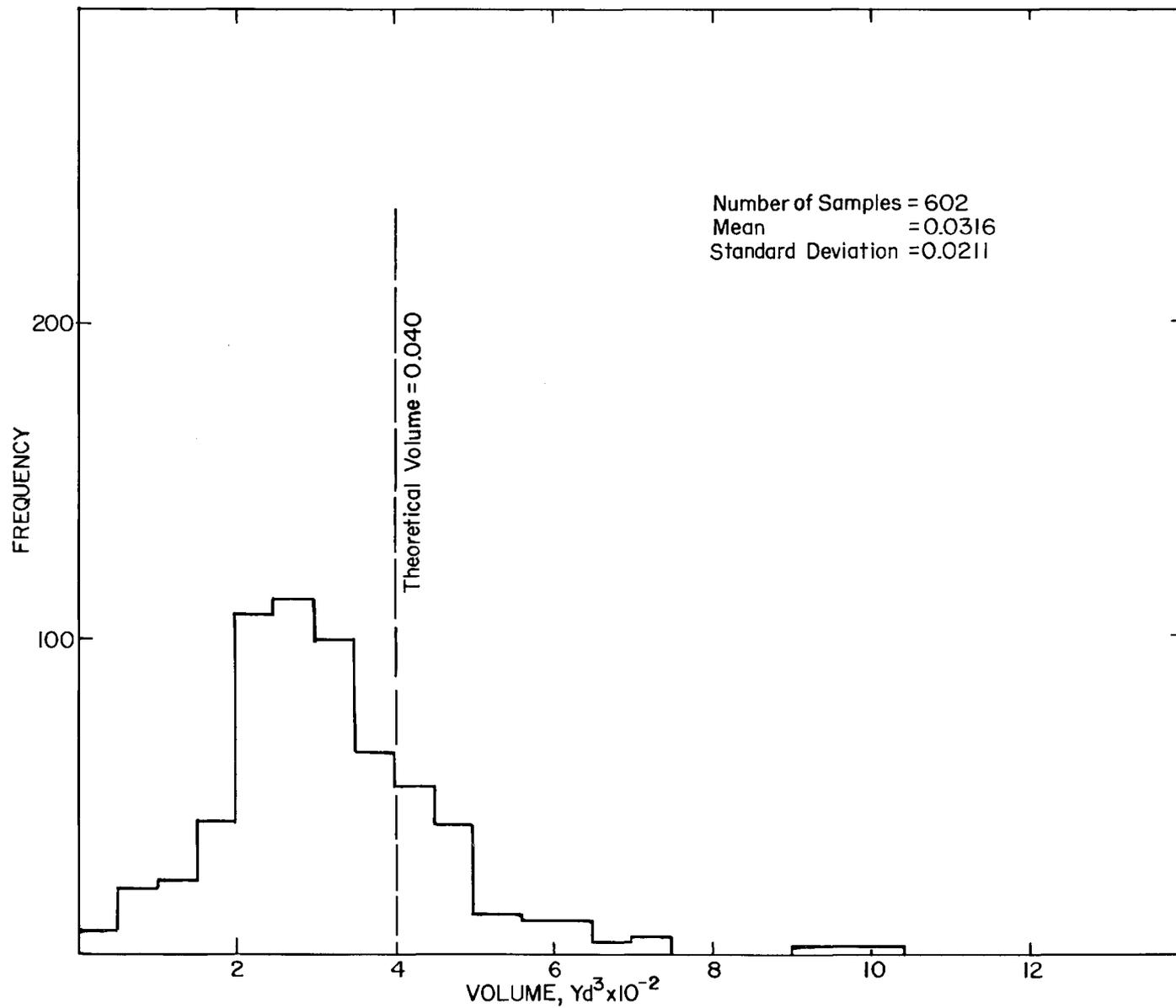


FIGURE 9.- Frequency Distribution of Sample Volumes within the Lower Gravels in Six Mile Deposit.

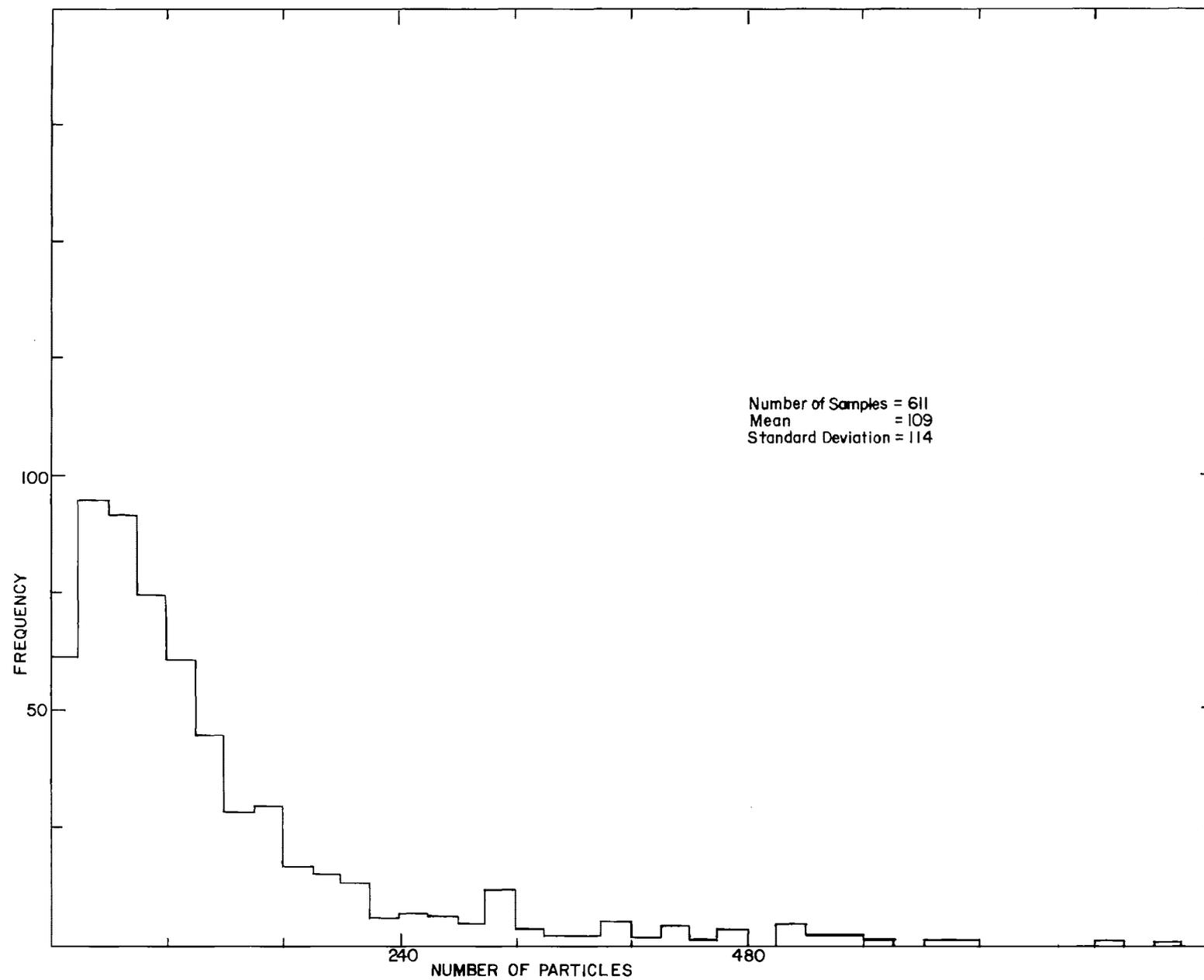


FIGURE 10.- Frequency Distribution of Gold Particle within the Lower Cemented Gravels in Six Mile Deposit.

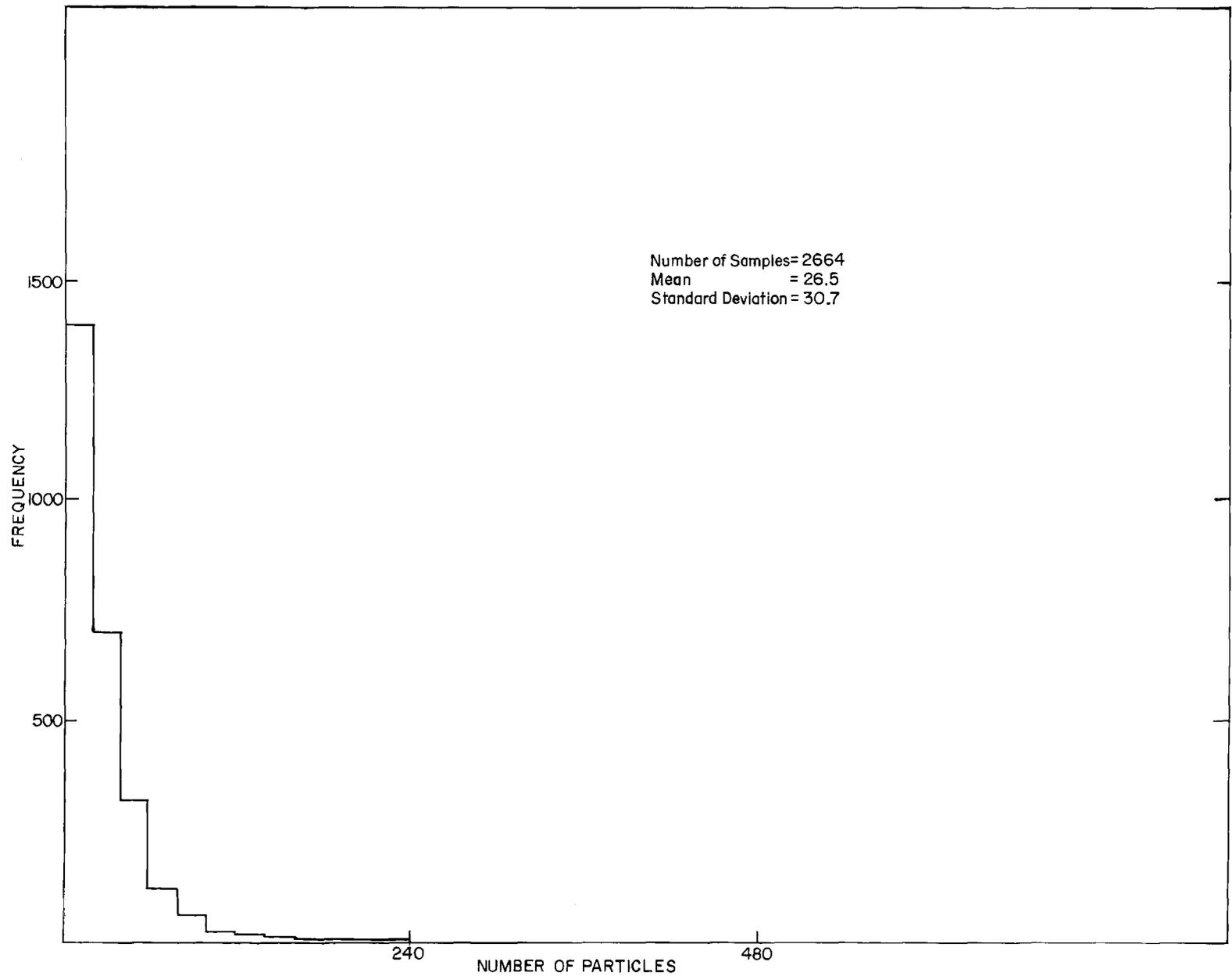


FIGURE 11.- Frequency Distribution of Gold Particles within the Upper Loose Gravels in Six Mile Deposit.

sampling, the following tables and figures are given to illustrate the distribution of gold bearing upon the sampling work in the Six-Mile Deposit. Taken as a whole (all composited 5-foot samples inclusive) the gold is so badly skewed that illustration is very difficult; therefore, the frequency distribution is given in table 2. If the samples are stratified relative to geologic constraints, significant reduction can be made in the magnitude of standard deviation relative to the mean. Stratifying the deposit into upper loose white gravels results in a gold concentration distribution shown in figure 12. With regard to this figure the mean for the upper gravels was found to be 33 mg/yd³ with a

Figure 12. - Frequency distribution of gold content for upper loose gravels in Six-Mile Deposit.

standard deviation of 53 mg/yd³. For the lower gravels the gold concentration was distributed as illustrated in figure 13. Of particular

Figure 13. - Frequency distribution of gold content for lower cemented gravels in Six-Mile Deposit.

interest is the distribution of the total gold content relative to the bedrock. Figure 14 illustrates the percent gold content against distance

Figure 14. - Cumulative gold percent versus distance from bedrock in Six-Mile Deposit.

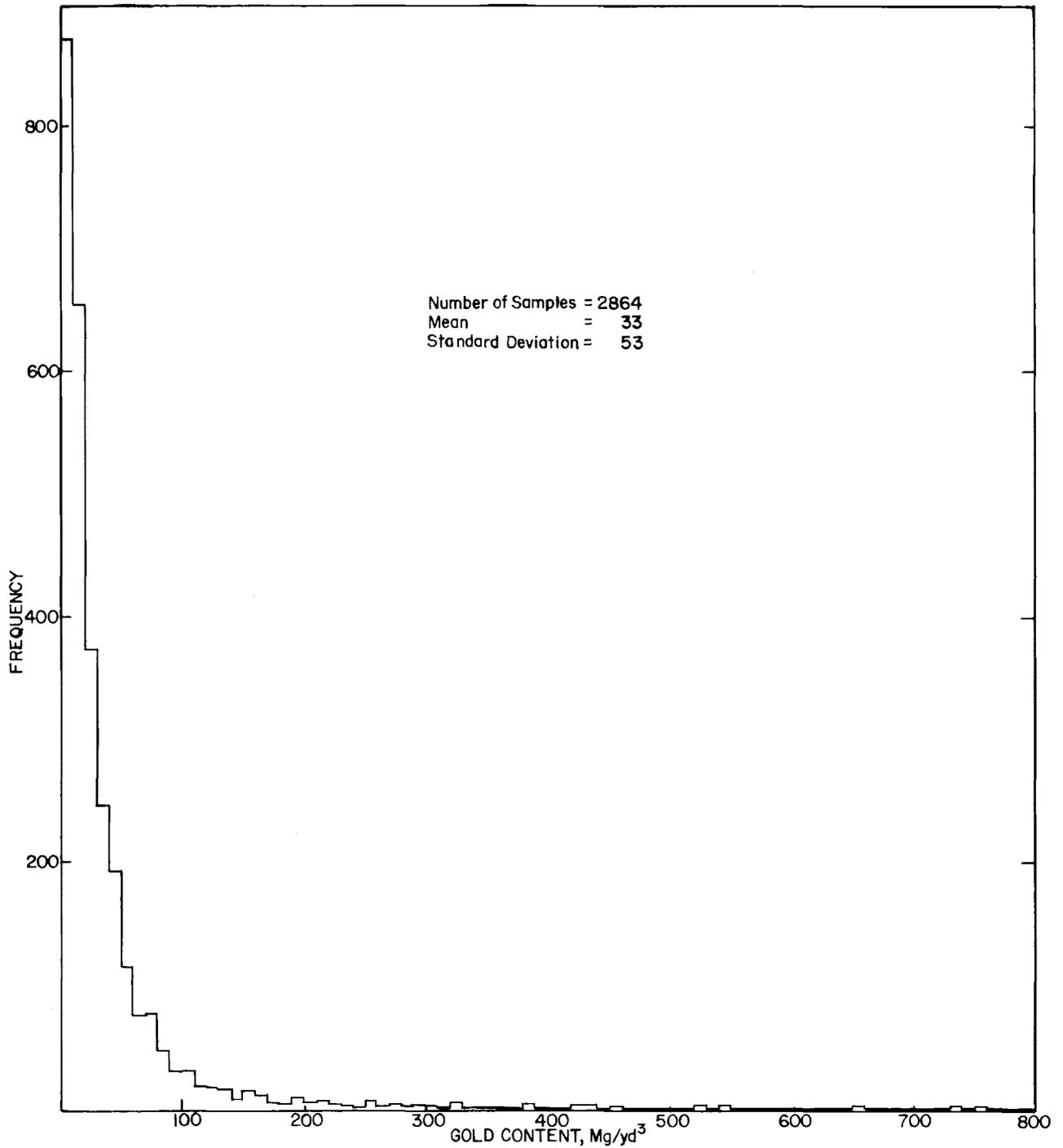


FIGURE 12.- Frequency Distribution of Gold Content for Upper Loose Gravels in Six Mile Deposit.

CUMULATIVE PERCENT GOLD

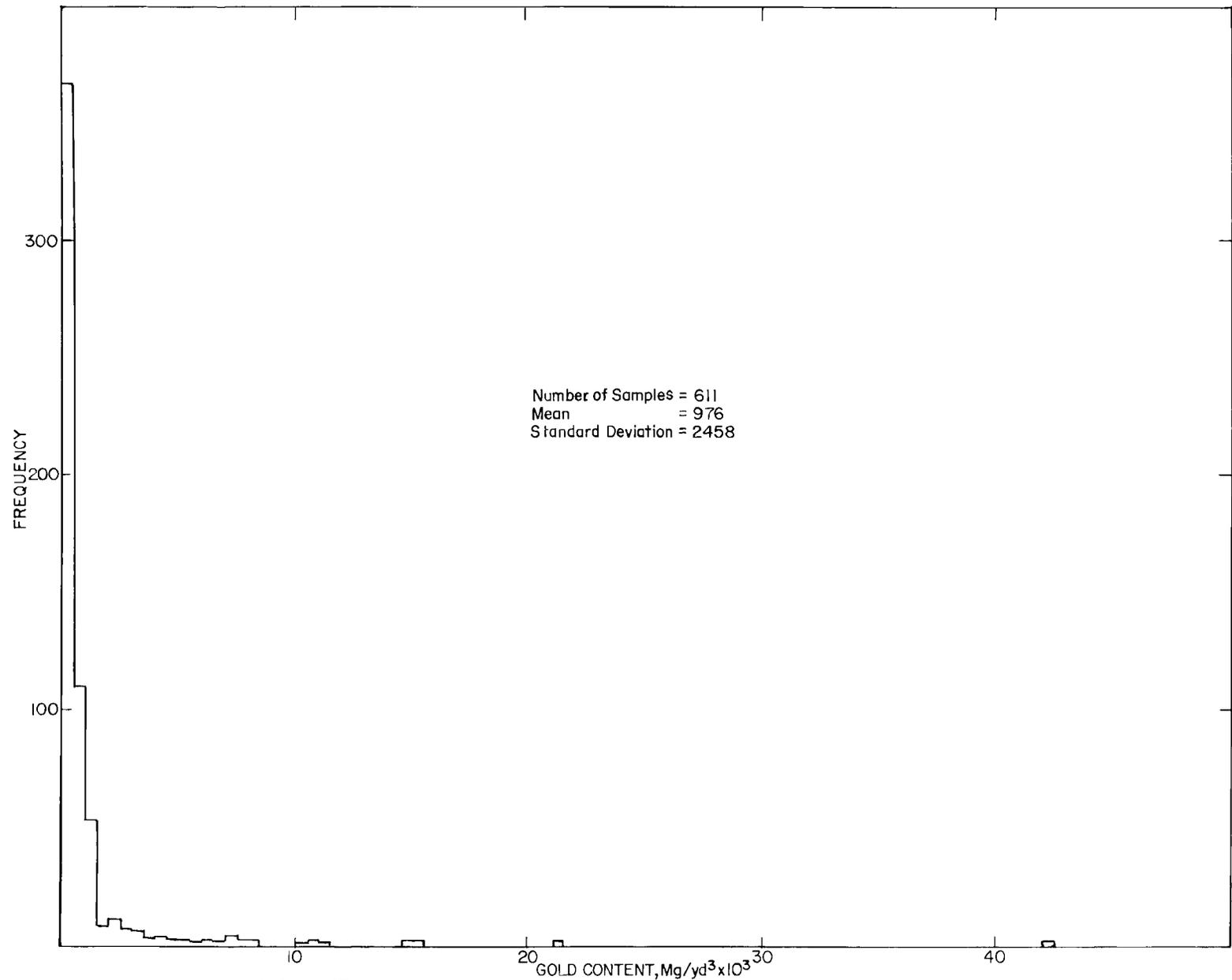


FIGURE 13.- Frequency Distribution of Gold Content for Lower Cemented Gravels in Six Mile Deposit.

from bedrock. For these particular drill hole samples sixty percent of the gold content is concentrated within 35 feet of bedrock. However, contrary to expectations, the highest grade zones are not at the lowest place in the channel. (figure 15)

Figure 15. - Cumulative gold content versus distance from bedrock in Six-Mile Deposit.

For the reader wishing a little more insight into the detailed sampling information, refer to Appendixes A and B.

Economic Block Model

The data on which this analysis was based was supplied by Pittsburgh, Spokane and Twin Cities Mining Research Centers, together with the Salt Lake Metallurgy Research Center. All engineering estimates of cost were made relative to the Six-Mile Tertiary gravel deposit. Within the limited manpower and budgetary constraints of this project, it must be realized that it was not possible for the Centers involved to exhaust all possible subsystem alternatives of mining this type deposit; however, sufficient detail information was available to evaluate several surface and underground operations based upon present-day mining technology. Input to the cost-program which was used to develop economic and performance data for each block in the mineralized block inventory is outlined in the following paragraphs. External environment and milling will be treated separately.

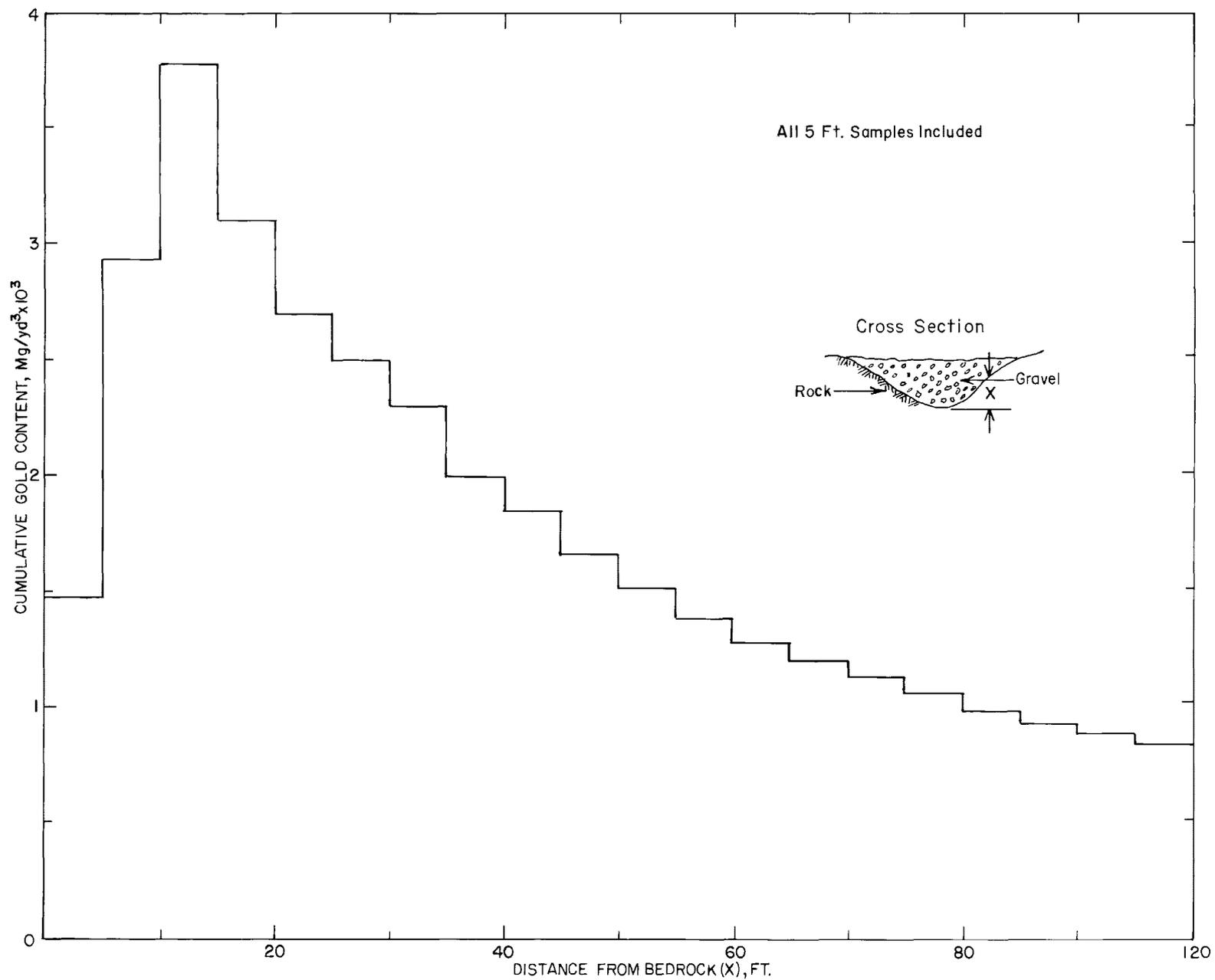


FIGURE 15.-Cumulative Gold Content Versus Distance from Bedrock in Six Mile Deposit.

Surface Mining

The guidelines for an open-pit mining operation were based on a preliminary estimate of the final pit configuration which yielded 260,464,000 cubic yards of total material mined, of which 37,000,000 cubic yards was tightly cemented blue gravels and included 20,000,000 cubic yards of ore. A mine plant layout as shown in figure 16, was assumed to simplify the flow of ore and waste material from the pit to

Figure 16. - Preliminary mine and facility layout for Six-Mile Deposit.

mill or waste dump areas and also to fix the flow of tailings disposal. In addition, the potential ore deposit was subdivided into seven areas to simplify estimating haulage costs. Information based upon a mining life of 5, 10, and 20 years is summarized in the following sections.

Materials Handling

Preliminary operating cost and performance data for the truck and shovel combinations used in this study are given in table 2. The truck-shovel combinations used were the least cost combinations provided by the Material Handling Sub-Systems Design Group.

	Unit Cost (\$)
Shovel, 12 cu yd	660,000
Shovel, 8 cu yd	420,000
Truck, 200 ton (1,650 hp)	412,000
Truck, 120 ton (1,125 hp)	196,000
Truck, 62 ton (672 hp)	120,000

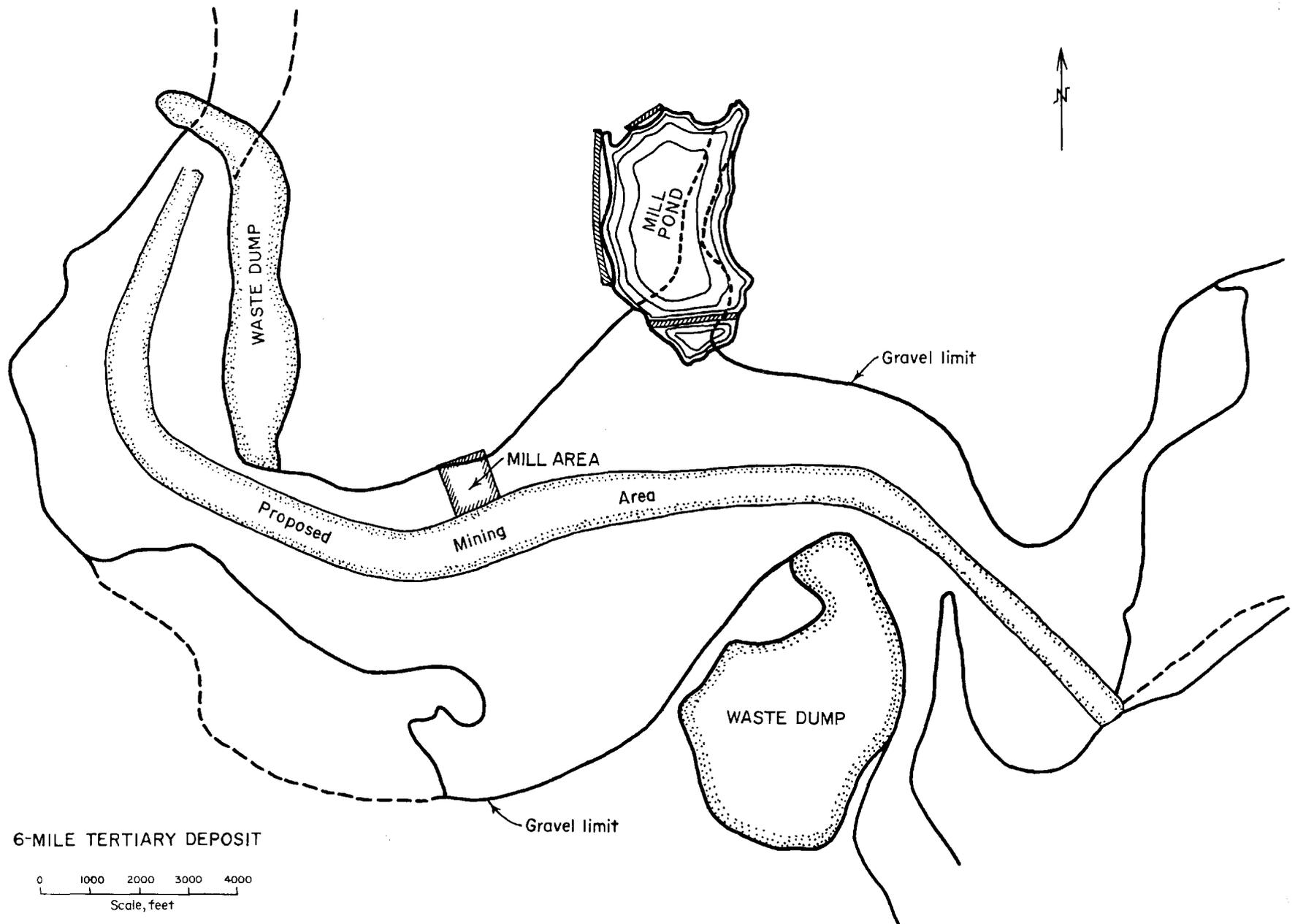


FIGURE 16.- Preliminary Mine and Facility Layout for Six Mile Deposit.

TABLE 2. - Summary of preliminary truck - shovel operating data for Six-Mile Deposit

	Mine Life								
	5			10			20		
	Bench Ht			Bench Ht			Bench Ht		
	30	40	50	30	40	50	30	40	50
Hours per year	8000	8000	8000	3000	3000	3000	2000	2000	2000
Shovel - Size	8	12	12	8	12	12	8	12	12
- Prod (cu.yds/hr)	865	1037	734	865	1037	734	865	1037	734
- Operating Cost (\$/hr)	17.06	23.76	23.68	17.06	23.76	23.68	17.06	23.76	23.68
- Operating Cost (\$/cu.yd)	.02	.02	.03	.02	.02	.03	.02	.02	.03
Trucks - Size	62	120	200	62	120	200	62	120	200
- Prod (cu.yds/cycle)	36	72	116	36	72	116	36	72	116
- Operating Cost (\$/cu.yd)									
- Route 1 - ore	.26	.17	.17	.26	.18	.17	.27	.19	.18
- waste	.25	.16	.16	.24	.17	.16	.26	.18	.17
- Route 2 - ore	.34	.22	.21	.34	.22	.21	.36	.24	.22
- waste	.32	.21	.20	.32	.21	.20	.34	.23	.21
- Route 3 - ore	.38	.24	.22	.37	.24	.22	.39	.26	.22
- waste	.36	.25	.22	.36	.25	.22	.38	.27	.22
- Route 4 - ore	.31	.20	.19	.31	.21	.19	.32	.22	.20
- waste	.22	.14	.14	.22	.15	.14	.23	.16	.14
- Route 5 - ore	.22	.15	.15	.22	.15	.15	.24	.17	.15
- waste	.13	.09	.10	.13	.10	.10	.14	.11	.10
- Route 6 - ore	.22	.15	.15	.22	.16	.15	.23	.17	.16
- waste	.13	.09	.10	.13	.10	.10	.14	.11	.11
- Route 7 - ore	.27	.17	.16	.27	.18	.16	.28	.19	.17
- waste	.16	.11	.11	.17	.12	.11	.18	.13	.12

	Unit Cost (\$)
Dozer, Track (360 hp)	71,000
Dozer, Wheel (360 hp)	72,000
Grader (360 hp)	73,000
Conveyor Belt 1,000 ft (400 hp)	358,000
Truck, Fuel	25,000
Fuel Storage Tank	15,000
Truck, Pickup	2,500

Fragmentation

Operating cost and performance data are listed below:

Blasting

Powder factor = 0.4 lb/cu yd

Caps No. 6 Lead 30' = \$66.00/1000

Caps No. 6 Lead 40' = 78.15/1000

Caps No. 6 Lead 50' = 90.30/1000

ANFO, Cartridge (30,000 lb. lots)

Drilling

9 in. Blast Holes

Burden = 25 ft

Spacing = 35 ft

Volume Broken Per Blast Hole

30 ft Bench - 972.2 cu yd

40 ft Bench - 1296.3 cu yd

50 ft Bench - 1620.4 cu yd

Hole Per Shift Drill

30 ft Bench - 3.730

40 ft Bench - 3.045

50 ft Bench - 2.562

Drilling Cost

30 ft Bench - \$0.0772/cu yd

40 ft Bench - 0.0709/cu yd

50 ft Bench - 0.0674/cu yd

Capital cost for a drill capable of drilling 9-inch holes to a depth of 60 ft at rates as given above are estimated at \$150,000.

Pit Slopes

A bank slope of 65 degrees in the loose gravels and a bank slope of up to 80 degrees in the tightly cemented gravel is assumed to stand well. However, if a bench of sufficient width to allow for passage of equipment is accounted for an overall pit slope of 45 degrees from toe of the bottom bench to the crest of the top bench would be required. Although it is recognized some pit wall robbing may be possible as a final stage of mining, it was not considered in this evaluation.

Safety & Environmental Control

One of the major environmental problems to be confronted by a surface operation would be dust, because of the considerable amount of minus 200-mesh silicious material which would propose a health problem as well as excessive wear on machinery. Dust formation would be most severe during the dry, warm summer months and would be alleviated by a light service sprinkling 4-ton truck. The cost of such a truck would be \$7,500 including an operating cost of \$5.00 per

operating hour. Fume and smoke control costs are estimated to be approximately 2 percent of the equipment costs. All diesel equipment to be used in the open pit area must meet Bureau of Mines specification as to emission of gases. It is assumed that the control of gas and dust emission in the pit will be continually monitored by the engineering staff. It is also mandatory that all equipment has installed noise suppression devices which comply with the Walsh-Healy Public Contracts Act and would add approximately 1 percent to the equipment costs. Noise suppression costs are contained in the equipment costs.

Perhaps the most significant environmental factor encountered at the Tertiary gravel deposit will be that of controlling flow of subsurface water. Many of the problems of ground water can be effectively met by proper pit production scheduling. Drainage should be used to its fullest to avoid costly drilling and pumping costs.

Underground Mining

Similar to the approach used in estimating costs for the open pit, the underground operation assumed that the gold content was concentrated near bedrock and involved a total of 4,720,000 cubic yards of material to be mined, of which 720,000 cubic yards was waste and 4,000,000 cubic yards was ore. Three mine-lives were considered: 5, 10 and 20 years.

Ground Control

Both room and pillar and modified longwall methods of mining were considered. The modified longwall method was developed by a single entry partially in bedrock along the axis of the channel with three foot

ventilation and escape shafts drilled in advance of the longwall panels. The method considered two advancing open stopes on each side of the main entry to the extent of ore, support being maintained by backfilling. The room and pillar method considered three main entries with rooms developed in the ore on the advance and pillar robbing on the retreat. The major concerns in applying either of these two basic mining methods to the Tertiary gravel is the extreme uncertainty to which the gold-bearing stratas may be forecasted, particularly for small volumes needed to design an underground system and extreme local variations in bedrock or mining floor. Another area of concern is the effect that increasing overburden pressures will have on multiple entries needed in an operating mining system to be used within the Six-Mile Deposit.

Materials Handling

Similar to the open-pit, the subsurface plan was broken up into 29 areas from which travel times and costs were found to two different points of portal entry dependent upon the area location. Transportation costs varied as function of distance as illustrated by the operating costs and performance information for telescopic trucks given in table 3.

TABLE 3: Underground Haulage Cost and Performance Data for Six-Mile Deposit

Area No.	Minutes per cycle	Cost per cu yd			Area No.	Minutes per cycle	Cost per cu yd		
		5-yr level	10-yr level	20-yr level			5-yr level	10-yr level	20-yr level
1	8.27	\$0.173	\$0.179	\$0.176	16	17.35	\$0.362	\$0.375	\$0.369
2	10.54	.220	.228	.224	17	19.62	.410	.425	.417
3	12.81	.268	.277	.272	18	21.89	.457	.474	.465

Area No.	Minutes per cycle	Cost per cu yd			Area No.	Minutes per cycle	Cost per cu yd		
		5-yr level	10-yr level	20-yr level			5-yr level	10-yr level	20-yr level
4	15.08	.315	.326	.320	19	24.16	.505	.533	.514
5	17.35	.362	.375	.369	20	26.43	.552	.572	.562
6	19.62	.410	.425	.417	21	28.70	.600	.621	.610
7	21.89	.457	.474	.465	22	30.97	.647	.670	.658
8	24.16	.505	.533	.514	23	8.27	.173	.179	.176
9	26.43	.552	.572	.562	24	10.54	.220	.228	.224
10	28.70	.600	.621	.610	25	12.81	.268	.277	.272
11	30.97	.647	.670	.658	26	15.08	.315	.326	.320
12	8.27	.173	.179	.176	27	17.35	.362	.375	.369
13	10.54	.220	.228	.224	28	19.62	.410	.425	.417
14	12.81	.268	.277	.272	29	21.89	.457	.474	.465
15	15.08	.315	.326	.320					

From the two external points the ore and waste material was transported by larger trucks to the mill location. The information given in table 4 is typical of the truck performance and costs used in the study for the portal to mill haulage.

TABLE 4: Portal to Mill Haulage Data for Underground Operations of Six-Mile Deposit

Portal	Truck size, ton	Ore			Waste		
		Number of trucks	Minutes per cycle	Cost per cu yd	Number of trucks	Minutes per cycle	Cost per cu yd
1	200	1	35.04	\$0.179			
1	62				1	10.88	.109
2	200	1	35.04	.179			
2	62				1	10.88	.109

Capital costs are as indicated below:

8-ton Scooptrain	\$58,370
20-ton Telescopic Truck	65,380
Battery Powered Tractor	16,000
Supply Trailer	1,810
Loading Pocket & Transfer Station	50,000

Fragmentation

Drilling and blasting costs were based upon the following engineering input for both room and pillar, and modified longwall mining methods.

Drilling costs for a cubic yard of gravel in place for three tunnel geometries are given as follows:

	<u>Mining Ht</u>	<u>Cost/(\$/curyd)</u>
Jackleg	6	1.20
Single-Boom Jumbo	6	1.05
Double-Boom Jumbo	12	0.69

Powder Factors varied from 1.5 lbs. explosive/cubic yd material in place, for small 10' x 10' headings to 0.8 for larger 15' x 15' headings. The powder factors decreased to 0.5 for an open face.

Safety and Operation Environmental Control

Similar to the surface, the major health problem would be the fine silicious material inherent in the working environment which is magnified by the confinement of the underground network of development and production workings. Instrumentation to properly control and monitor the mine environment was added to the cost of mining.

A major contribution to environmental costs to an underground operation would be the cost of ventilation which is estimated to have an initial capital investment of \$15,000 and a maximum operating cost of \$1.12/hour.

Small submersible pumps would be required to control ground water in and around the working faces. By properly designing the access entries to allow gravity drainage considerable pumping costs would be avoided. This could lead to considerable development in the bedrock itself.

Related Subsystem

Two factors which would be common to either a surface or subsurface mining technique would be the effects on the external environment and the on-site beneficiation. Both of these subsystems may be treated independently of the actual mining subsystems; they only depend on the total quantity mined or the flow of material per unit time.

External Environment

Many of the problems considered with regard to the external environmental are concerned with intangible subjective evaluations at this point in time; therefore, an additional 5 percent of total capital was added as an additional cost to cover any unforeseen costs relative to the potential environmental problems. It would be mandatory for any mining effort that the land must be restored to a state equal to or better than its premining state. Tailings Disposal costs are considered to be part of beneficiation costs.

Beneficiation

Salt Lake Metallurgy Research Center was responsible for evaluating various treatment methods and their associated costs to recover gold from the tightly cemented gravels of the Badger Hill deposit. Table 5 gives the operating and capital costs used in this study for the various size operations.

TABLE 5. - Estimated capital and operating costs for gravel treatment plant for Six-Mile Deposit

<u>Length of Operation</u> <u>Years</u>	<u>Capital Investment</u> <u>\$ x 10⁶</u>	<u>Operating Cost</u> <u>per cubic yd</u>	
		loose	cemented
5	18.20	\$.17	\$.27
10	9.20	.21	.31
20	4.85	.23	.33

Systems Evaluation

Evaluation Techniques

The selection of mining systems with the greatest potential for economically exploiting the Tertiary channel gold-bearing gravel deposits within the next ten years was based on:

1. 1970 Economics plus a gold price condition of (\$35-70/oz).
2. Present mining technology.
3. Maximum utilization of resources.

Both open pit and underground mining systems were considered. Based on the economic parameters developed and assigned to each block during the development of the economic block inventory, optimum ultimate mining limits were determined for the Six-Mile Deposit (figure 4). The techniques used to determine optimum mining limits for open pit and underground operations are discussed in detail in (6) and (11) respectively.

The first rejection stage in the system evaluation phase was based on the total operating economics of the optimum ultimate limit mining plan. If operating costs exceeded the expected revenue a system was rejected on the premise that no economically feasible operation could exist with the particular mining system under consideration.

If, based on operating economics only, a potential economically feasible mining operation existed, a determination of the requirements such as equipment, physical plant and other elements requiring capitalization was made. Estimates of the required initial capital costs together with net operating revenue provided the data for the second criteria of acceptance or rejection of mining systems. Payback period was used as a

selection tool for this second rejection stage. A third stage evaluation employed the Discounted Cash Flow - Rate of Return criteria. The annual cash flows were determined by dividing the total net operating revenue by the assumed life of the operation.

The mining systems which were judged acceptable through the third rejection stage were considered to have the potential for economically exploiting the Tertiary channel gold-bearing gravel deposits. Such systems are considered to have significant potential and merit further investigation.

Analysis and Results

Nine open pit mining configurations were considered along with two underground systems. The primary parameters considered for variation in evaluation of the open-pit operations were bench height and mine life. Mine life determined the production rate which in turn together with the mining bench height influenced the selection of the mine equipment such as drills, shovels, trucks, etc. The selection of equipment, size and number, was made on the basis of that which would provide a required production rate at the least cost under the specified mining conditions.

Similar procedures were followed in the analysis of the two underground systems.

A summary of the evaluation results of the systems is given in table 6. The first column, Mining Method, gives a brief description of the mining method and operating configuration. The second column gives the net return from mining, excluding capital costs (total revenue - total operating costs). The last four columns provide total capital costs and

total cubic yards ore, waste and total material included in the minable reserve. This evaluation was based on the 1970 gold price of \$35 per ounce with corrections for 900 fineness and a 90 percent mill recovery.

As seen from table 6, the open-pit mining system utilizing a 30 ft. bench height does not result in an economical operation for any of the production rates considered.

The remaining eight (methods 4-11) mining configurations considered show a net operating return but none have net operating return which exceeds the estimated initial capital expenditures. Thus none of the systems considered are economically feasible. This does not imply that no such systems exist nor under slightly different conditions an economically feasible operation would not exist. In fact, open-pit mining using a bucket-wheel excavator should be given prime consideration in further studies of the Tertiary channel deposits but was not considered in this evaluation because of time constraints and lack of data.

The further analysis to be reported will attempt to show the effect of variations in mining costs, gold price and full utilization of valuable resources within the deposits on the minable reserves and the economic feasibility of mining the Tertiary channel gravel deposits.

Underground mining will not receive further consideration in this report as it is the authors' opinions that open-pit mining is more favorable for this deposit and also that open-pit mining is more consistent with the objective of total and wise utilization of our natural resources in this particular case.

TABLE 6. - Summary economic - production data for evaluation
of Tertiary Channel Six-Mile Deposit

Mining Method	(\$ x 10 ³) Net Oper Return	(\$ x 10 ³) Total Revenue	Total Cost (\$ x 10 ³)		Cubic Yards Mined (x10 ³)		
			Operating	Capital	Ore	Waste	Total
1. 5 yr, O. P. - 30' Bench	-0-	-	No	Economical			Operation
2. 10 yr, O. P. - 30' Bench	-0-	-	No	Economical			Operation
3. 20 yr, O. P. - 30' Bench	-0-	-	No	Economical			Operation
4. 5 yr, O. P. - 40' Bench	2,246	7,882	5,636	10,528	4,607	23,503	28,111
5. 10 yr, O. P. - 40' Bench	2,140	7,783	5,643	4,088	4,443	23,250	27,693
6. 20 yr, O. P. - 40' Bench	1,858	4,507	2,649	1,895	2,187	8,191	10,378
7. 5 yr, O. P. - 50' Bench	1,813	7,422	5,609	11,058	5,155	21,571	26,726
8. 10 yr, O. P. - 50' Bench	1,603	7,235	5,632	4,511	4,702	21,829	26,531
9. 20 yr, O. P. - 50' Bench	1,444	3,715	2,271	1,880	2,335	6,057	8,392
10. Room and Pillar 50' Mining Ht.	835	5,867	5,032	1,500	824	334	1,158
11. Modified Longwall 15' Mining Ht.	1,745	7,244	5,499	2,000	1,310	262	1,572

Also, all further analysis will consider only open-pit mining with 40 ft. benches as it appears this is the most favorable situation of those considered in this report. (See Table 6)

A graph of the ratio of possible operating costs to the cost estimates used in this study versus operating return shows that operating costs would have to be reduced by more than 75 percent in order for an operation to be economically feasible, within a 5-year mining life (Figure 17).

Figure 17. - Effect of Lowering Mining Costs on Economic Feasibility of Six-Mile Deposit.

It also appears that operating costs would have to be reduced by more than 57 percent if a 10-year mining life is to be considered. The rationale behind this conclusion is based on the assumption of a 5-year payback period cutoff and a rough calculation of the actual payback period as:

$$(1) \quad \text{Payback years} = \frac{\bar{L} \times \bar{C}}{\bar{R}}$$

where \bar{C} = Initial Capital Costs

\bar{R} = Net Operating Return = Total Revenue - Total Operating Cost

\bar{L} = Years Mine Life

In the case where operating costs are reduced, the volume of the minable reserve is always greater than or equal to the minable reserve given with the initial estimate of operating costs. For example, the reserve at a cost ratio of 1.0 is less than or equal to the reserve at a cost ratio of 0.5. For any particular mine life this would imply a monotonically increasing capital expenditure as the operating costs are reduced. Therefore, if \underline{C} represents the required capital costs at a

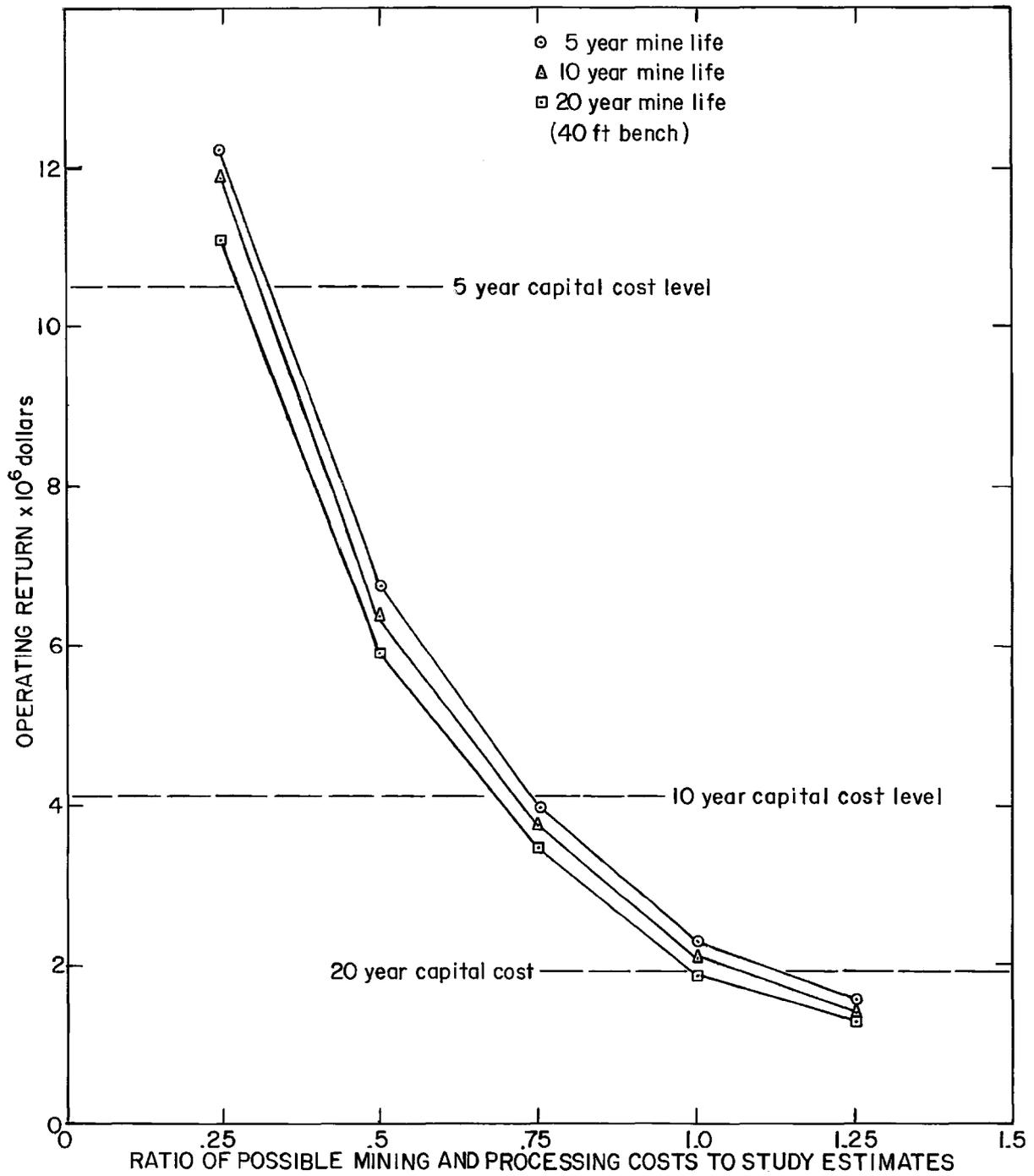


FIGURE 17.-Effect of Lowering Mining Costs on Economic Feasibility of Six Mile Deposit.

reduced operating cost level we know that; $\underline{C} \geq \bar{C}$. Also, the actual total operating return, R_a , from an operation resulting from a reducing costs, will be less than or equal to the total operating return resulting from the total minable reserve at a lower operating cost, \bar{R} . For example, if the production rate remained the same reducing operating costs would result in a return, R_a , from the original volume of ore thus, $\bar{R} \leq R_a \leq \underline{R}$. Thus for the 10-year life with a cost ratio of 0.5:

$$\begin{aligned} \text{Payback years} &= \frac{L \times \underline{C}}{R_a} \\ &= \frac{10 \times \underline{C}}{R_a} \geq \frac{10 \times \bar{C}}{\underline{R}} \\ &\geq \frac{10 \times 4.1 \times 10^6}{6.4 \times 10^6} \\ \text{Payback years} &\geq 6.4 \text{ years.} \end{aligned}$$

Calculation of the cost ratio at which the lower bound of the payback period for a proposed 10-year mine life is 5-years proceeds as follows:

$$\begin{aligned} \text{Payback Years} &= 5 \geq \frac{10 \times 4.1 \times 10^6}{\underline{R}} \\ \underline{R} &\geq \frac{10 \times 4.1 \times 10^6}{5} = \$8.2 \times 10^6 \end{aligned}$$

with $\underline{R} = \$8.2 \times 10^6$ and from figure 17 the cost ratio is found to be .425. This indicates that the lower bound of the payback period is 5 years at a cost ratio of .425 or a 57.5% operating cost reduction. Similarly, for a 20-year mine life operating costs would have to be reduced by 57% before the lower bound of the payback period is 5 years (see figure 17 at $4 \times \$1895 \times 10^3 = \7580×10^3). A reduction of operating costs of this magnitude does not appear readily attainable under present economic conditions hence this avenue of obtaining an

economically feasible operation for Tertiary channel deposits does not merit further consideration by itself.

The next parameter to receive consideration is the price of gold. Operating return and minable reserve volumes are plotted against gold price in figure 18. Also shown are the initial capital cost requirements for a 20-year mine life operation at various gold prices.

Figure 18. - Operating Return, Capital Costs and Minable Yards as a Function of Gold Value for Six-Mile Deposit.

At gold prices of \$40 per ounce or less the net operating return is approximately equal to the initial capital costs thus making mining operations uneconomical at these gold prices (figure 18). The data plotted in figure 18 also show that at \$50 per ounce gold estimated capital costs are $3,600 \times 10^3$ and operating returns are $5,400 \times 10^3$. Using the previously given approximation for payback years gives an estimated time for payback of 13.33 years with \$50 per ounce gold.

$$(\text{Payback years} = \frac{20 \times 3,600 \times 10^3}{5,400 \times 10^3} = 13.33 \text{ years}).$$

$$5,4000 \times 10^3$$

The payback period of 13.33 years implies an economic mining operation for the Six-Mile Tertiary channel is not feasible under the conditions assumed in this report.

Assuming a capital cost of \$4 million and using the payback formula it was determined that a total net return of $\$16 \times 10^6$ is required if a 20-year operation is to provide for payback within 5 years.

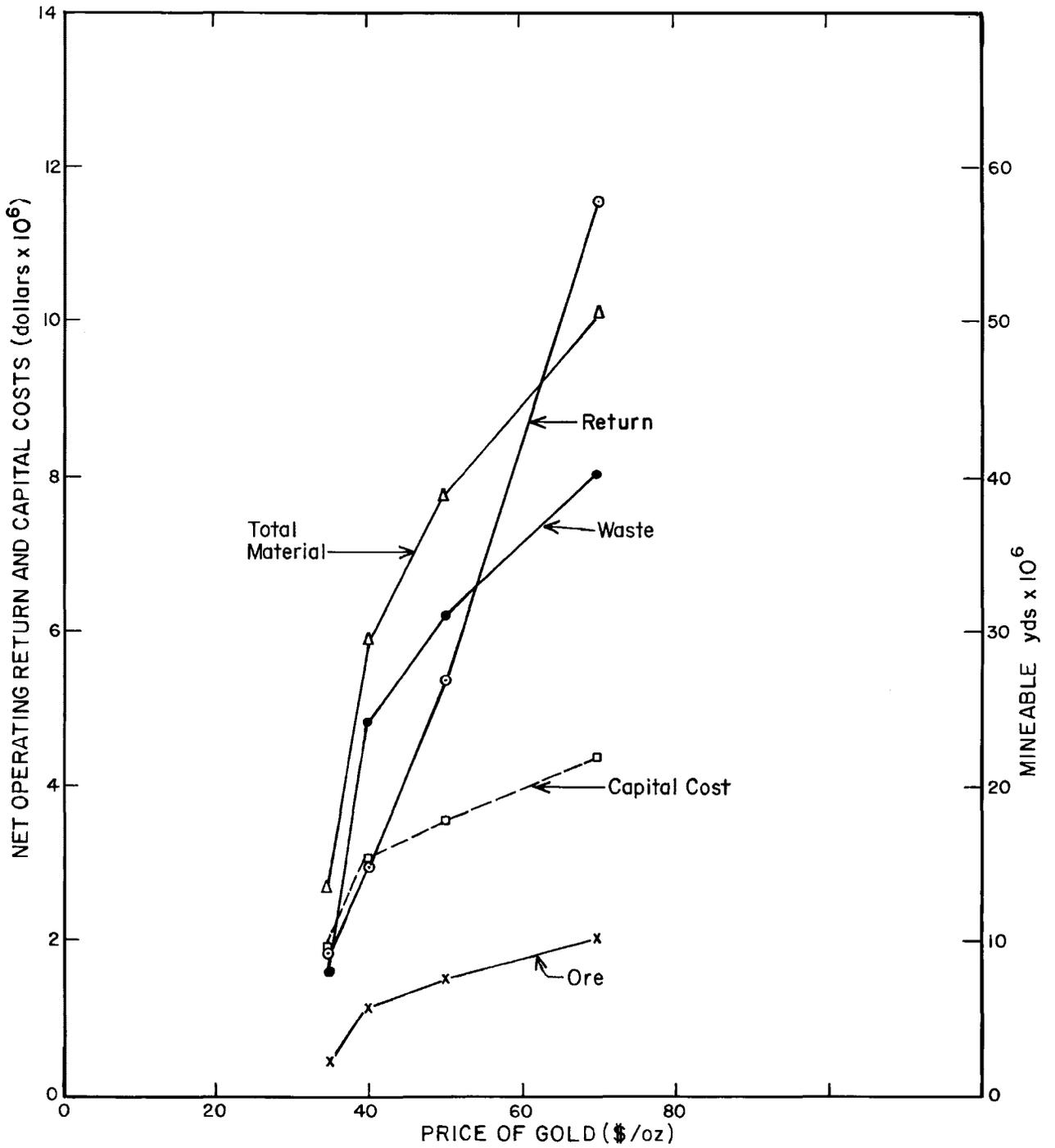


FIGURE 18.-Operating Return, Capital Costs and Mineable Yards as a Function of Gold Value for Six Mile Deposit.

As seen from figure 18, such a return is not obtainable for gold prices within the range considered (less than \$70 per ounce).

Assuming a capital cost of \$3 million would require a net return of \$12 million for a 5-year payback. A total gold amount of 230,600 ounces was mined in the \$40 gold operation so that a gold price of \$81 per ounce would be required for a 5-year payback period.

Assuming capital costs as given for each operation at the different gold prices, thus limiting the minable reserves correspondingly, and working with a gold price of \$70 per ounce the payback would be as follows:

	<u>Years Payback</u>
1. \$35 gold reserve	7.65
2. \$40 gold reserve	6.28
3. \$50 gold reserve	6.44
4. \$60 gold reserve	6.91
5. \$70 gold reserve	7.71

The pit limits for the \$35, \$50, and \$70 gold reserves are shown in figure 19.

Figure 19. - Ultimate Pit Limits for \$35, \$50, and \$70 Gold Reserves.

This preliminary analysis indicates that considering only gold up to a price of \$80 per ounce is not sufficient to provide for an economically feasible operation within the deposit under consideration. At a gold price greater than \$80 per ounce a gold-mining operation appears feasible.

Even with the potential for an economically feasible mining operation at \$80 per ounce of gold such an operation could not satisfy one of the

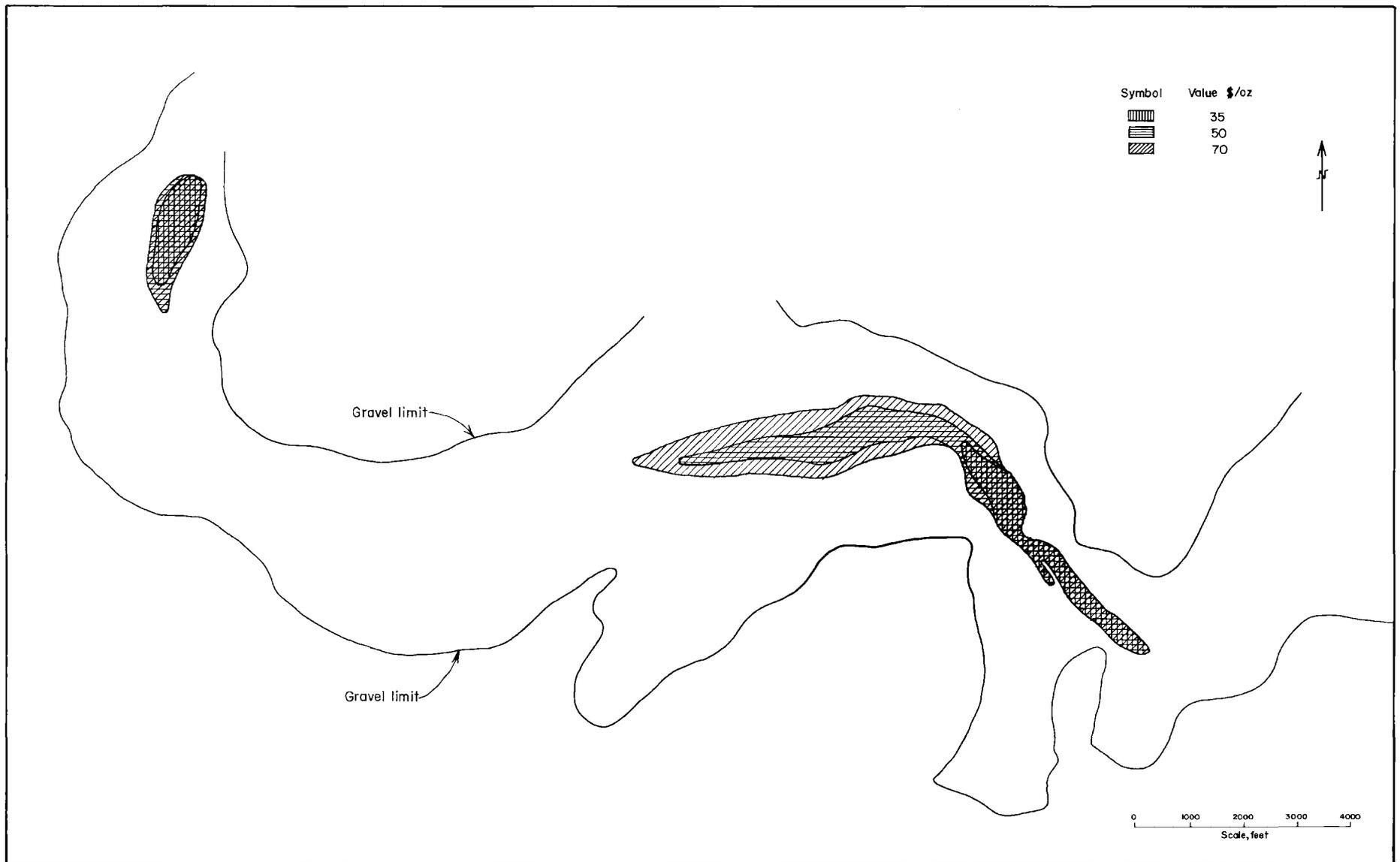


FIGURE 19.-Ultimate Pit Limits for \$35, \$50, and \$70 Per Ounce Gold Reserves.

important objectives of this study which is to maximize utilization of our natural resources.

The Tertiary channel deposits have been reported to contain large reserves of potentially useful sand and gravel (9). In all previous evaluations discussed in this report such material has been considered to be strictly waste. Mining waste contributes directly to the cost of the operation but not to the profits.

A graph of gravel value vs. operating return shows that capital costs are approximately equal to total operation returns up to a gravel value of \$0.60 per cubic yard (figure 20). At a gravel value of

Figure 20. - Operating Return, Capital Cost and Movable Yards as a Function of Gravel Value for Six-Mile Deposit.

\$0.90 per cubic yard and gold at \$35 per ounce, it is estimated that the total net operating return would be \$43.138 million with required capital expenditures of \$19.366 million. Using the payback criteria with a 20-year mine life, it was determined the payback period would be 9.0 years. Such a payback period again implies the operation would be uneconomical.

The conclusion reached here is that it would be uneconomical to mine the Tertiary channel gold-bearing gravel deposits under the conditions assumed in this study with a gold value of \$35 per ounce and a mine value of \$0.90 or less per cubic yard of gravel.

The question still remains, however, is there a combination of

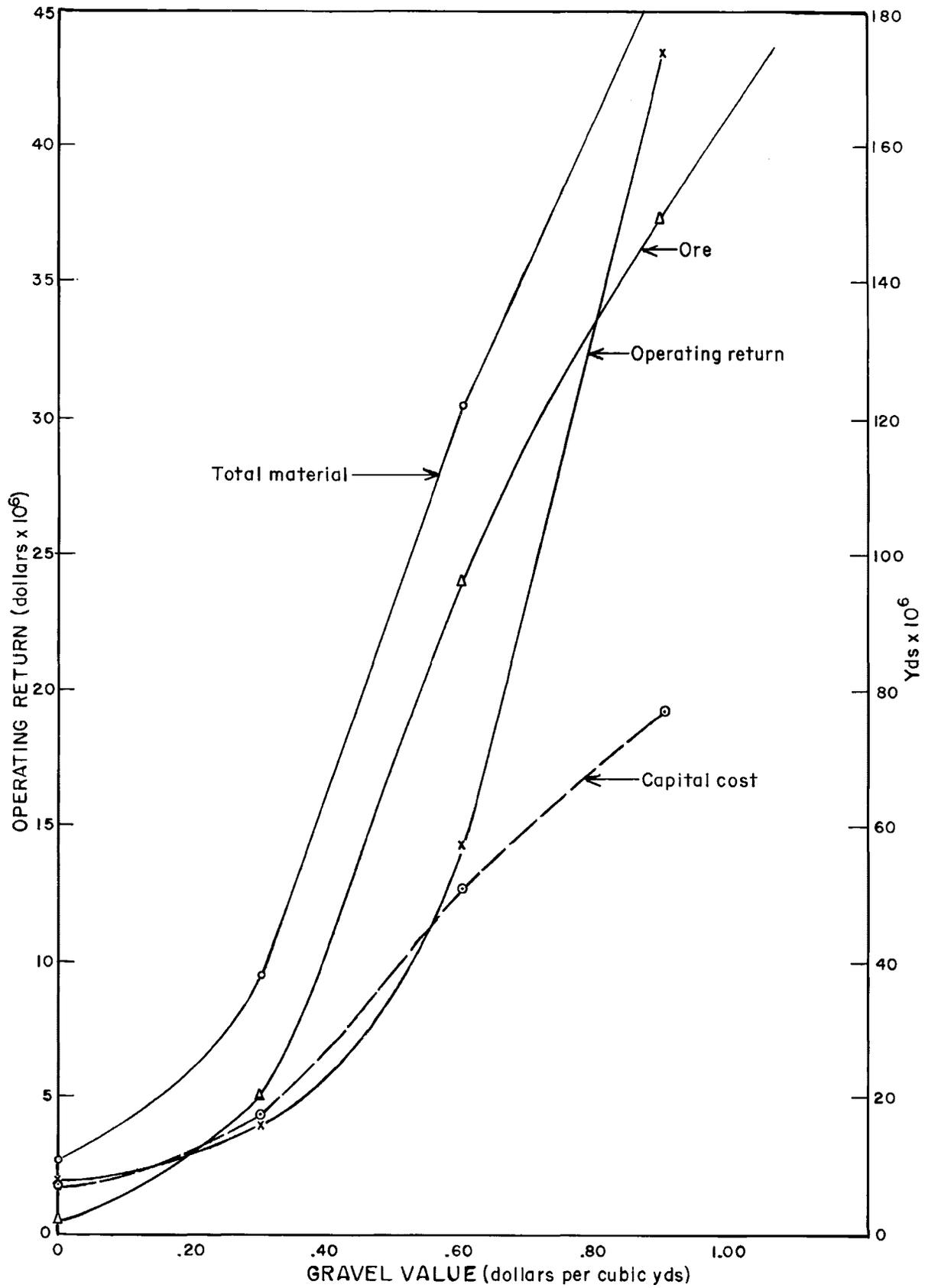


FIGURE 20.—Operating Return, Capital Cost and Mineable Yards as a Function of Gravel Value for Six Mile Deposit.

increased gold and gravel values where mining of the Tertiary channel gold-bearing gravel deposits would be potentially profitable.

In order to gain insight into the answer to the foregoing question and to provide a check on the conclusions drawn concerning the profitability of mining the Six-Mile Deposit with the payback criteria, discounted cash flow rates of return were calculated for operations resulting from various combinations of gold price and gravel values. The discounted cash flow routine and computer program used are described in I. C. 8495 (3). Results of the discounted cash flow analysis are shown in table 7. The maximum rate of return shown in table 7 is 6.69 indicating the conclusions based on the payback criteria are supported by the rate of return criteria using profitable exploitation of the Six-Mile Deposit at gold prices less the \$70 per ounce for gold in combination with gravel returns of \$0.90 per yard or less does not appear favorable for the operations considered under the assumptions of this investigation.

The basic data used for the cash flow analysis is listed in table 8. The minable reserves used in each operation were determined on a net operating return before depreciation, depletion or taxes. Considering this, the minable reserves may have been larger than they should have been, thus, the capital expenditures higher than actually required. Reiterating through the minable reserves program accounting for capital expenditures and taxes would of course provide a more accurate analysis. However, it was felt an indication of the results of such a study could be obtained more quickly by a discounted cash flow evaluation of each operation using a gold price of \$70 per ounce and a

		<u>Gravel Value c/yd³</u>			
		0	30	60	90
<u>Gold Value \$/oz</u>	35	—	—	—	3.37
	40	—	—	—	3.17
	50	—	—	—	4.83
	60	3.08	4.25	4.35	5.23
	70	6.40	6.49	6.59	6.69

TABLE 7. - Discounted cash flow rates of return for operations at various combinations of gravel values and gold prices.

TABLE 8 . - Economic and reserve data for various mining operations within Six-Mile Deposit.

	Gravel Value (c/yd ³)																			
	0					30					60					90				
	Gold Price (\$/oz)					Gold Price (\$/oz)					Gold Price (\$/oz)					Gold Price (\$/oz)				
	35	40	50	60	70	35	40	50	60	70	35	40	50	60	70	35	40	50	60	70
Ore (yds ³ x 10 ⁶)	2	6	8	9	10	20	40	50	62	70	96	115	124	130	145	150	169	184	195	210
Gravel (yds ³ x 10 ⁶)	2	5	6	8	9	18	36	45	55	60	74	87	92	102	113	108	115	123	129	135
Gold (oz x 10 ³ recovered)	106.1	2306	2854	312.4	339.4	307.8	560	650	745	840	598.4	690	744	780	870	800.8	865.1	929.4	967.1	1004
Waste (yd ³ x 10 ⁶)	6	24	31	35	40	18	33	45	48	63	26	35	39	40	55	39	47	57	64	74
Oper.* Return (\$ x 10 ⁶)	2.0	3.0	5.4	8.4	11.4	3.7	5.6	7.3	23.8	31.6	14.0	16.1	22.3	40.0	48.7	43.1	47.1	55.8	60.9	70.
Capital Cost (\$ x 10 ⁶)	2.0	3.0	3.6	4.0	4.4	4.5	8.3	9.5	10.7	11.9	12.8	15.0	16.2	10.7	18.0	19.4	21.0	22.8	24.1	25.
Oper. Cost (\$ x 10 ⁶)	2.2	6.6	8.8	10.3	12.4	12.5	25.1	32.3	37.4	45.2	51.7	59.3	65.2	68	80	82.1	91.0	101.4	113.2	121.
Oper. Cost/yd ³ Total Material	.27	.22	.24	.24	.25	.33	.33	.34	.34	.34	.42	.40	.40	.40	.40	.43	.43	.42	.44	.43
Oz/yd ³ ore	.053	.038	.036	.035	.034	.015	.014	.013	.012	.012	.006	.006	.006	.006	.006	.005	.005	.005	.005	.00
Oper. Return/Capital \$	1.0	1.0	1.5	2.1	2.6	.8	.8	.85	2.25	2.65	1.1	1.2	1.5	2.35	2.7	2.2	2.2	2.4	2.5	2.8
Capital \$/yd Total Material	.25	.10	.09	.09	.09	.12	.11	.10	.10	.09	.10	.10	.10	.10	.09	.10	.10	.10	.09	.09

* Return before depreciation, depletion and taxes

\$0.90 per yard gravel value. In each operation minable tonnages, operating costs and capital costs were held as indicated in table 8.

The results of the discounted cash flow analysis are given in table 9.

As indicated by the results of the discounted cash flow analysis, the greatest return on investment would be obtained from an operation as defined by the pit generated by using \$60 per ounce gold value and a gravel value of \$0.30 per yard. This would involve mining a total yardage of 110 million cubic yards, processing 62 million cubic yards of gravel yielding 745,000 ounces of gold and 55 million yards of usable gravel. The operating return (before depreciation, depletion and taxes) would be \$64,300,000. The pit configuration for such an operation is illustrated in figure 21.

Figure 21. - Ultimate pit limits yielding highest rate of return and maximum economic size for gold at \$70 per ounce and a gravel value of \$.90 per cubic yard.

If a lesser rate of return were acceptable, say 10%, a larger operation would be indicated. For example, an operation as indicated by the \$35 gold - \$.90 gravel pit. Such an operation would yield a 10.69% ROI and a \$71,000,000 total operating return. (See table 8 and figure 21)

The results of this analysis indicate that there exists a significant potential for an economical mining venture in the Six-Mile Deposit which is consistent with the objective of maximum utilization of our natural resources.

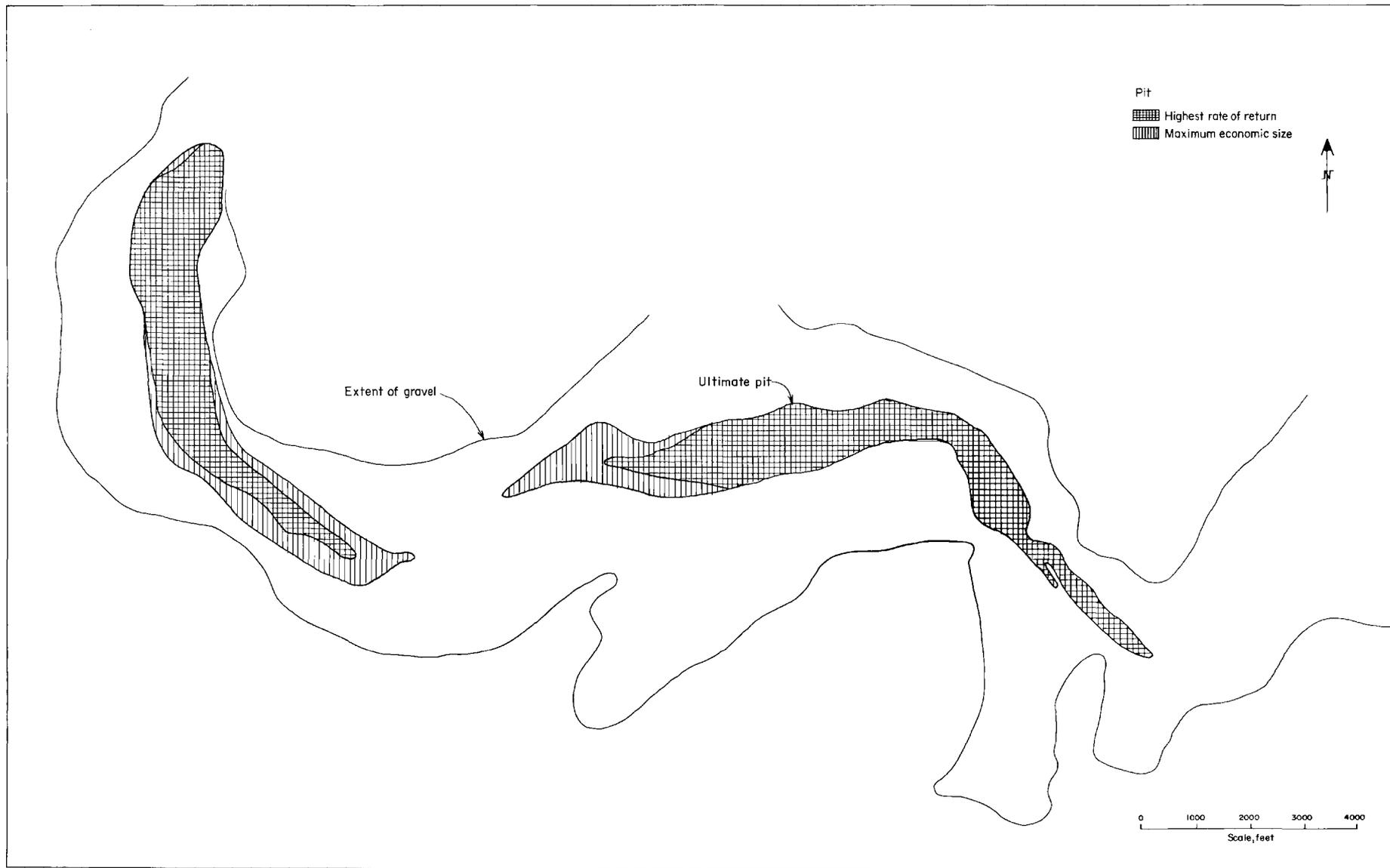


FIGURE 21.-Ultimate Pit Limits Yielding Highest Rate of Return and Maximum Economic Size for Gold at \$70 Per Ounce and a Gravel Value of \$.90 Per Cubic Yard.

TABLE 9. - Discounted cash flow rates of return for various minable reserves for Six-Mile gold-bearing gravel deposit with \$70 gold and \$0.90 gravel.

Gold Price (\$/oz)	Gravel Values (\$/yd.)			
	0.0	0.30	.60	.90
35	12.16	18.12	13.53	10.69
40	15.19	18.12	13.53	9.82
50	14.11	18.31	13.04	9.13
60	15.48	19.48	14.01	7.47
70	14.50	18.41	14.11	6.69

Proper mine planning and scheduling such that mining waste is dumped back into the excavation would also yield an operation consistent with the national goal of minimum land degradation from mining. Due to the configuration of the Six-Mile Deposit such a plan appears feasible, assuming 55 million yards of gravel will be marketed leaving 55 million cubic yards for disposal. With a 50% swell factor ($55 \times 1.5 = 82.5$) this requires disposal space for 82.5 million cubic yards, considerably less than the total mined volume of 110 million cubic yards.

CONCLUSIONS

Based on the confidential data furnished by the San Juan Gold Co., the BuMines sampling program at Badger Hill and cost estimates determined by the BuMines Research Centers from their field work at Badger Hill, the analysis conducted as reported in this study concluded:

1. Considerably more exploration drilling is required to accurately determine the quantity and distribution of gold values throughout the entire extent of the Six-Mile Deposit. Further drilling should be conducted to check the validity of previous drilling results and to sample areas where no present sampling is available. The gold value estimates used for the present evaluation are felt to be conservative.
2. Considerably more sampling and testing work is needed to determine the quality and quantity of sand and gravel within the Six-Mile Deposit. The estimates utilized in this study are felt to be conservative.
3. Underground mining of the Six-Mile Deposit appears uneconomical. Also, if economical, only a small portion of the entire deposit would be included in the minable reserve, hence this type of operation would not meet the objective of maximum utilization of our natural resources.
4. Open-pit mining appears to meet all the objectives set forth in this study.
5. An open-pit mining operation for gold alone appears marginal up to a gold price of \$80 per ounce using the operating and capital cost estimates as given in this study.

6. A 20-year open-pit mining operation, recovering gold and gravel appears economically sound with a gold price of \$70 per ounce and \$.90 per yard of gravel. The best operation would involve mining a total of 110 yards yearly and about 55 million yards of usable gravel.
7. The minimum minable volume would be 110 million cubic yards and the maximum 284 million cubic yards.

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APPENDIX A. - Within 5-ft sample variation for typical
drill hole in Six-Mile Deposit

Sample Interval Ft	Volume Yd ³	No. of Gold Particle	Gold Value Mg/Yd ³	Standard Deviation Mg/Yd ³	No. of Samples
	surface				
0 to 5	.0074	7	4.8	--	1
5 to 10	.0074	7	4.8	--	1
10 to 15	.0237	40	24.0	43.8	2
15 to 20	.0326	15	24.0	43.8	2
20 to 25	.0210	7	17.6	8.0	2
25 to 30	.0286	16	26.4	19.7	3
30 to 35	.0274	13	3.3	2.5	3
35 to 40	.0289	3	2.2	4.6	3
40 to 45	.0315	24	25.1	85.2	3
45 to 50	.0315	29	30.2	78.7	3
50 to 55	.0304	14	19.8	14.7	3
55 to 60	.0267	30	39.6	50.0	3
60 to 65	.0210	17	26.4	19.7	3
65 to 70	.0205	20	17.6	8.0	2
70 to 75	.0207	11	25.1	45.9	2
75 to 80	.0237	20	30.2	78.7	3
80 to 85	.0430	30	50.3	45.9	2
85 to 90	.0370	20	30.2	22.5	3
90 to 95	.0316	6	2.9	1.3	2
95 to 100	.0299	3	2.9	6.1	3
100 to 105	.0300	17	17.6	19.7	3
105 to 110	.0204	5	17.6	19.7	3
110 to 115	.0409	6	2.6	2.0	3
115 to 120	.0409	5	2.6	2.0	3
120 to 125	.0385	4	2.9	6.1	3
125 to 130	.0359	6	2.9	6.1	3
130 to 135	.0278	21	48.0	125.1	3
135 to 140	.0252	30	72.0	115.2	3
140 to 145	.0225	23	35.2	64.2	2
145 to 150	.0179	36	63.3	101.4	3
150 to 155	.0202	12	8.8	4.0	2
155 to 160	.0235	14	13.2	9.8	3
160 to 165	.0262	11	7.5	5.6	3
165 to 170	.0198	13	12.6	11.5	2
170 to 175	.0213	13	21.1	15.7	3
175 to 180	.0348	5	21.1	15.7	3
180 to 185	.0241	8	10.6	7.9	3
185 to 190	.0296	12	10.6	7.9	3
190 to 195	.0374	10	26.4	68.8	3
195 to 200	.0327	18	26.4	68.8	3
200 to 205	.0389	15	14.4	23.0	3
205 to 210	.0404	13	9.6	25.0	3
210 to 215	.0378	8	14.4	10.7	3

APPENDIX A. - Within 5-ft sample variation for typical
drill hole in Six-Mile Deposit
(Continued)

Sample Interval Ft	Volume Yd ³	No. of Gold Particle	Gold Value Mg/Yd ³	Standard Deviation Mg/Yd ³	No. of Samples
	surface				
215 to 220	.0481	29	43.2	21.5	3
220 to 225	.0474	35	62.5	42.8	3
225 to 230	.0333	16	23.5	61.2	3
230 to 235	.0422	14	10.6	7.9	3
235 to 240	.0459	13	10.6	7.9	3
240 to 245	.0467	5	13.2	9.8	3
245 to 250	.0370	10	8.8	18.4	3
250 to 255	.0326	7	28.8	36.4	3
255 to 260	.0296	8	28.8	36.4	3
260 to 265	.0322	16	97.7	179.5	3
265 to 270	.0315	17	87.9	43.7	3
270 to 275	.0247	8	21.1	15.7	3
275 to 280	.0368	11	21.1	15.7	3
280 to 285	.0574	42	110.7	273.1	5
285 to 290	.0404	24	128.1	194.8	5
290 to 295	.0985	95	433.8	315.1	5
295 to 300	.0281	62	153.8	169.4	5
300 to 305	.0322	74	371.1	1000.4	5
305 to 310	.0241	260	2061.2	650.6	5
310 to 315	.0393	550	7110.3	9748.3	5
315 to 320	.0485	232	3118.7	5517.6	5
320 to 325	.0404	90	531.2	465.9	5
325 to 330	.0930	455	3778.6	9938.4	5
330 to 335	.0363	77	704.3	846.8	5
335 to 340	.0300	82	1124.9	1966.0	5
340 to 345	.0189	631	42045.5	109659.9	5
345 to 350	.0159	386	21429.5	44676.4	5
350 to 355	.0030	18	1125.0	1591.0	2
	Bed		Rock		

APPENDIX B. - Stratified samples by material properties
 for 5-ft drill hole samples within
 Six-Mile Deposit

Material Code			N	Mean	Statistics (Mg/Yd ³)		
Drill Size	Mat.	(Refer to Code Table)			Std Dev	Std Err	Coef Var
(A)	(B)	(C)					
Total			1169	338.6	148.7	4.3	0.4
1	1	1	6	284.5	65.1	26.6	0.2
1	1	3	11	542.2	235.3	70.9	0.4
1	1	4	4	269.7	104.4	52.2	0.4
1	2	2	1	611.0			
1	2	3	1	420.0			
1	2	4	4	213.0	37.4	18.7	0.2
1	3	4	2	390.5	201.5	142.5	0.5
2	1	1	20	242.0	84.0	18.8	0.3
2	1	2	60	342.9	166.7	21.4	0.5
2	1	3	71	340.7	122.6	14.6	0.4
2	1	4	159	353.8	199.6	15.8	0.6
2	2	1	4	297.5	129.5	64.7	0.4
2	2	2	8	268.0	75.2	26.6	0.3
2	2	3	17	382.6	111.8	27.1	0.3
2	2	4	85	328.2	136.2	14.8	0.4
2	3	2	5	316.8	126.3	56.5	0.4
2	3	3	7	353.0	88.4	33.4	0.3
2	3	4	27	363.0	117.1	22.5	0.3
3	1	1	18	327.7	119.3	28.1	0.4
3	1	2	29	370.0	125.8	23.4	0.3
3	1	3	41	342.8	128.6	20.1	0.4
3	1	4	141	347.6	162.5	13.7	0.5
3	2	1	7	207.9	128.6	48.6	0.6
3	2	2	13	413.7	215.1	59.7	0.5
3	2	3	14	292.4	81.3	21.7	0.3
3	2	4	170	343.4	121.8	9.3	0.4
3	3	2	4	423.2	113.2	56.6	0.3
3	3	3	14	244.2	46.6	12.5	0.2
3	3	4	26	348.3	165.3	32.4	0.5
4	1	1	4	374.0	242.9	121.4	0.6
4	1	2	1	326.0			
4	1	3	6	316.0	114.6	46.8	0.4
4	1	4	34	341.2	143.3	24.6	0.4
4	2	1	1	259.0			
4	2	2	8	364.0	187.2	66.2	0.5
4	2	3	5	231.2	96.1	43.0	0.4
4	2	4	47	315.2	134.7	19.7	0.4
4	3	1	1	248.0			
4	3	2	4	428.5	196.4	98.2	0.5
4	3	3	2	211.0	52.3	37.0	0.2

APPENDIX B. - Stratified samples by material properties
for 5-ft drill hole samples within
Six-Mile Deposit (continued)

Material Code Drill Size Mat. (Refer to Code Table)			N	Mean	Statistics (Mg/Yd ³)			
(A)	(B)	(C)			Std Dev	Std Err	Coef	Var
Total								
4	3	4	15	312.6	61.5	15.9	0.2	
5	1	2	1	241.0				
5	1	3	8	368.1	164.0	58.0	0.4	
5	1	4	10	296.5	87.8	27.8	0.3	
5	2	1	2	159.0	15.6	11.0	0.1	
5	2	4	13	312.1	100.8	28.0	0.3	
5	3	3	1	311.0				
5	3	4	8	382.7	101.1	35.7	0.3	

CODE TABLE

Drilling Characteristics (A)

<u>Code</u>	<u>Description</u>
1	Running ground
2	Loose ground
3	Tight ground
4	Very tight ground
5	Cemented ground

Material Size (B)

1	Fine
2	Medium
3	Coarse

Material Type (C)

1	Clay
2	Sandy clay
3	Sand
4	Gravel
5	Bed rock (Schist)
6	Bed rock (Granite)