003252

UNIVERSITY OF WATERLOO

DEPARTMENT OF GEOLOGY

PREDICTION OF GRADE DISTRIBUTION BY CROSS-SECTIONS

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1B Applied Geology

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

I would like to thank Randy Lopaschuk for his advice on the procedures for making cross-sections, and also Reid Glenn for proof-reading and suggesting changes.

SUMMARY

This report deals with the development and study of mine model cross-sections, for an ore body, used for ore grade distribution.

The cross-sections and data to be tested are described. A description of the cross-section techniques and data is given. The results from the ore grade comparisons in relation with rock types and tonnage are shown, conclusions drawn, and interpretations made.

It was concluded that from the cross-section, certain rock types have a high frequency with an average percentage grade, while other rock types have a lower frequency, but a higher percentage grade. The tonnage with the highest frequency has a certain grade range.

The grade distribution shown on the cross-sections will be useful in mine planning.

CONCLUSIONS

The cross-sections will be useful in mine planning, as the grade distributions are shown on the cross-sections. An ore forecast can be accomplished with the help of the cross-section by evaluating the consistency, availability of the ore and waste material present with respect to the grade of ore. From this, the best mine plan can be developed; breaking the ore body into separate mining units for the most economic way to develop the mine.

Rock types 2B, 2C, 2D and 2E, 2F, 2J have the highest frequency, with an average grade of 6.0% and 6.4% respectively. The grade range of 6% to 8% has the most available tonnage.

INTERPRETATIONS

Across a 1400 foot interval, the general orientation of the ore body can be determined. With each cross-section within a 140 foot interval, ten cross-sections were made; cross-sections 124 to 133. The cross-sections are on an angle of approximate 45^o from north. The ore body is dipping. The ore body is closer to the surface at cross-section 133 compared to cross-section 124. This is evident since the ore body begins on bench 3890 on cross-section 133, and does not begin on cross-section 124 until bench 3630. The distance between these two cross-sections of the ore body is 260 feet. The ore body is also still apparent after bench 3470 on cross-section 124, but on cross-section 133, the ore body ends at bench 3790, a difference of 320 feet. On cross-section 130, the whole ore body is shown, with a width of 300 feet or 16 benches. (See Appendix 2 for cross-sections 124, 130, 133).

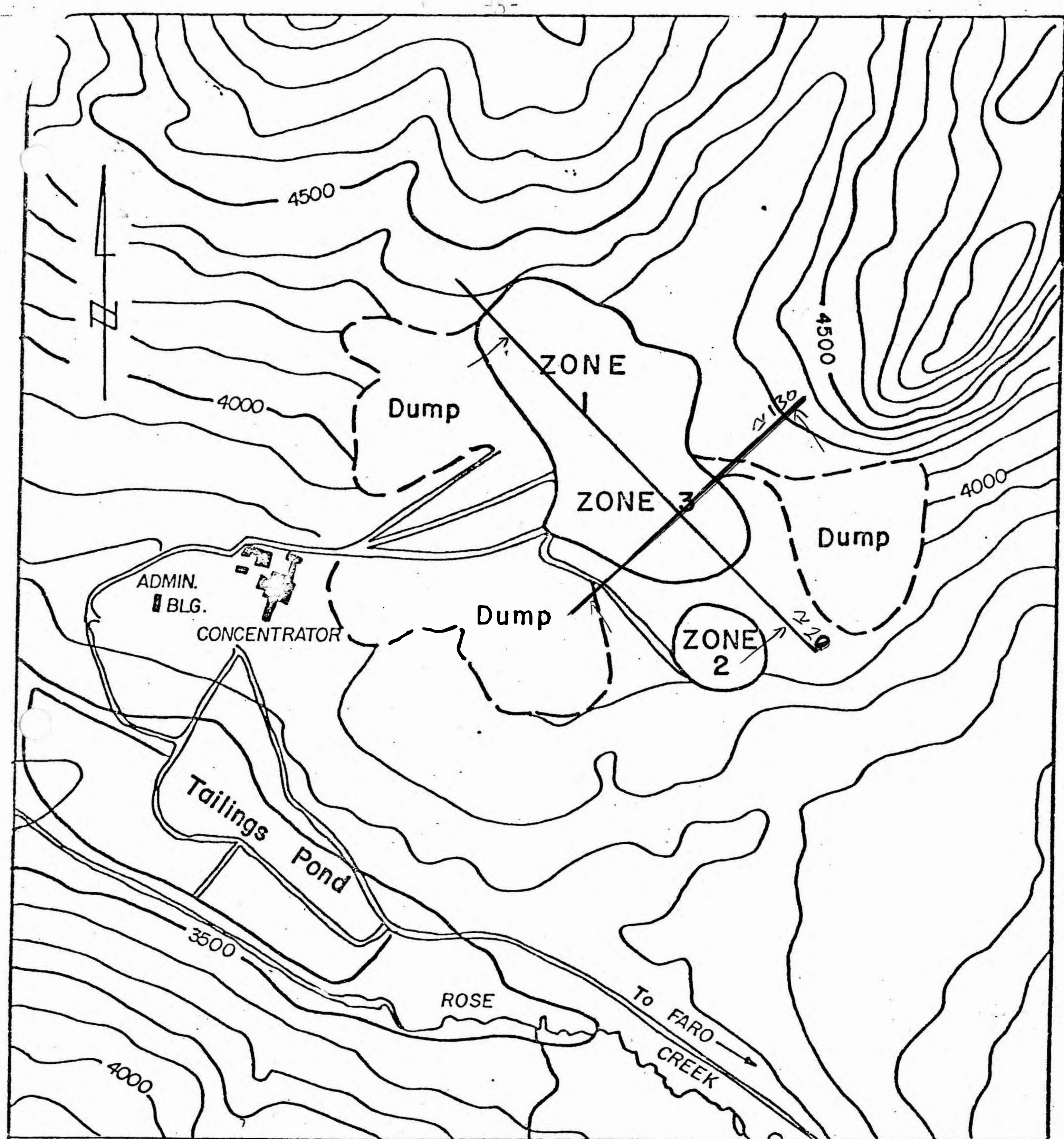
On the longitudinal-section 20, the dipping ore body is much more evident. It dips down from cross-section 133 to 124. (See Appendix 2 for longitudinal-section 20).

1. INTRODUCTION

The field of geology is an integral part of the mining business. Whether in exploration, where all mines begin, or mine geology, geologists play an important part in mining. Given enough information, geologists can predict areas of possible minable sites. Once a mine has been located, from analysis of cross-sections and longitudinal-sections, rock types, grades and tonnages can be found. This gives various parts of the mine knowledge of what type of ore to expect next, and the advantage for the mill to treat it the best for the best production possible.

At the large pyritic lead and zinc deposits at Cyprus Anvil Mining Corporation the ore is mined by open pit methods. The deposit is associated with quartzite layers of Cambrian age. The Faro deposit has been through three major regional dynathermal periods of metamorphism, which were followed by deformational events. The Faro deposit consists of massive sulfide zones. The Large Faro deposit has a lenticular ore body, with a length of a 5,000 foot cross-section, 1,600 foot width, and an average thickness of 150 feet. The major sulfide minerals in the Faro ore body are pyrite, sphalerite, galena, pyrrhotite and chalcopyrite. The Large Faro deposit is separated into Zone I and Zone III by faults.

To determine the grade distribution for an area, which encompassed cross-sections 124-133, approximately 1,400 feet, grade distribution cross-sections were developed from the mine model. Only part of Zone III was studied, which included the cross-section area between 124 and 133. The depth of the study was 440 feet, from bench 3910 to 3470. Grade comparisons were also made for rock types and tonnage.



CYPRUS ANVIL MINING CORPORATION

FARO DEPOSIT

YUKON TERRITORY

FARO MINESITE

NTS 105 K – 6
SURVEY BY
DRAWN BY. C. L. C.

DATE. MARCH 25, 1981

FIGURE 1

1000 0 1000 2000

SCALE 1" = 2000'

2. OBTAINING CROSS-SECTION DATA

2.1 MINE MODEL:

The cross-sections ranging from 124 to 133 were developed from the mine model. (See Appendix 1 for Mine Model). The mine model is a computerized prediction of the ore and where it will be present on each separate bench. The mine model is a plan view of the ore body, cut into benches. The mine model begins at bench 3910 and decreases by 20 foot intervals for each bench. The last bench used for the cross-section was bench 3470. Benches are based on the difference in height from sea level. The bases from the mine model come from diamond drill holes, which are marked on the cross-sections (see Appendix 2 for Cross-Sections), with the year being the first two numbers and the hole number being the second set. Much interpolation goes into the mine model when it is computerized, so the prediction from the mine model is not always correct. The mine model does give an idea where the ore should be and helps in mine planning. The mine model is divided into blocks where the ore is present, and in each block the percentage of lead and zinc and rock type is given. The number of blocks present is also related to the tons of ore available. The cross-sections made from the mine model give the combined lead and zinc percentages, or grade of ore. The rock type associated with the grade on each bench is also present on the cross-sections. Waste is also noted on the mine model, since only blocks are ore.

The diamond drill holes for the mine model used in the cross-section 124 to 133 were drilled in the years 1966, 1967, 1970, 1971, 1972, 1974, 1975, 1976 and 1977. The area of concern in cross-section 124 to 133 is in Zone III, which is the newest development of the mine.

2.2 MINE MODEL TO CROSS-SECTION MAKING TECHNIQUES:

The techniques used to make the cross-sections from the mine model are fairly basic. First, sepia copies, resembling tissue paper, of the Large Faro deposit cross-section original were made. The original cross-section had benches marked on them. On the first sepia cross-section 124 the topography and diamond drill holes were traced on it from geological cross-sections. The topography and diamond drill holes were traced on all the cross-sections remaining from 125 to cross-section 133. The ore in the mine model is in a different location for each bench. On the first bench 3910 to be used to make a cross-section, the co-ordinates of the cross-section 124, cross-section 125, cross-section 126, cross-section 127, cross-section 128, cross-section 129, cross-section 130, cross-section 131, cross-section 132, cross-section 133 and longitudinal-section 20 were marked on bench 3910 of the mine model in the appropriate places. Then the sepia copy of cross-section 124 was placed over the mine model, bench 3910. The matching cross-section and co-ordinates of 124 were lined up along bench elevation 3910 and also with longitudinal section 20. After cross-section 124 was set in place the type of lithology was traced onto the cross-section. The lithology was represented by numbers on the mine model; cross-section code (see Table 1) numbers 1, 2, 3, 4, 5, 6 represent waste rock types and numbers 7, 8, 9, 10, 11, 12 represent sulfide bearing ore rock types. Where a block of ore was met in the mine model, when transferring it to the cross-section the combination of lead and zinc percentages were calculated to determine the grade of ore. The grades of ore were separated in different ranges, less than 2%, 2% to 4%, 4% to 6%, 6% to 8%, and greater than 8%. Each grade range was assigned a specific colour (see Appendix 2 Cross-Section Legends for Grade Colour). Ore with combined lead and zinc percentage grade of less than 2% is regarded as waste, from 2% to 4% low grade ore, and ore of grade 4% and greater is classified as high grade ore. After the grade, found in the mine model ore blocks was coded by its proper colour, the bench was separated by its lithology. The type of rock represented by the rock code on the cross-section on each side of a dividing lithology line.

TABLE 1

DETAILED LITHOSTRATIGRAPHIC CODE

Mine Model Cross-Section Code	Lithostratigraphic Equivalent	Detailed Lithostratigraphic Code	Zone
1	Undetermined Unit		Waste Rock
2	Alluvium		
3	3B	Chloritic phyllite/schist	
	3C	Metabasite	
	3D	Calc-silicate phyllite/schist	
	3E	Graphitic phyllite/schist	
	3F	Marble and silicated marble	
4	3A + 1D + 3D, etc.	Transition zone	
5	1D4	Altered, pyritic (white mica envelope)	
	1D	Carbonaceous, biotite-muscovite-andalusite/schist	
	1C	Quartzo-feldspathic, biotite-muscovite gneiss/schist	
	1E	Graphitic schist	
	1F	Metabasite	
6	1CD	Intrusive Rocks	X
7	2A	Sulfide-bearing, ribbon-banded, graphitic quartzite	Sulfide-Bearing Ore Zone
8	2B	Pyrite-free quartzite (may contain base metal sulfides)	
	2C	Base metal-poor, pyritic quartzite	
	2D	Base metal-bearing, pyritic quartzite	
9	2CE		
10	2E	Massive pyritic sulfides	
	2F	Buckshot facies, massive sulfides	
	2J	Non-pyritic, massive sulfides/oxides	
	Minor 2G, 2H		
11	2H	Pyrrhotitic facies, massive sulfides	
12	2G	Baritic facies, massive sulfides/sulfates (> 10% $BaSO_4$)	

The next cross-section 125 was placed on the mine model for the same bench 3910. The co-ordinates for 125 and cross-section 125 were lined up, along with longitudinal section 20 on bench 3910 of cross-section 125. The grades were coloured depending on the combined percentage of the mine model ore block. The lithology was recorded by separating the different types and placing the correct rock type code. This was for 3910 bench. After cross-section 125 was completed with 3910 bench, cross-section 126 was lined up appropriately on the 126 cross-section co-ordinates, and so was longitudinal-section 20. The grades were noted and the appropriate colour was assigned and the lithology recorded on the cross-section. After cross-section 126 was finished, cross-section 127, cross-section 128, cross-section 129, cross-section 130, cross-section 131, cross-section 132, and cross-section 133 were all done in the same fashion as the preceeding ones for bench 3910.

After the cross-sections 124 to 133 were completed for bench 3910, for the next bench 3890, the co-ordinates of cross-sections 124 to 133 and longitudinal section 20 were marked on the mine model bench 3890. Then cross-section 124 was lined up with the cross-section 124 co-ordinates, and longitudinal-section 20 on bench 3890 of the sepia cross-section 124. The grades were coloured appropriately and the lithology of bench 3890 was recorded on the cross-section. Cross-section 125 was worked on next and the cross-section co-ordinates from 125 and longitudinal-section from 20 were lined up on bench 3890. The grades were coloured their proper code and the lithology code taken down. Cross-sections 126 to 133 were all done in the same manner for bench 3890.

Once bench 3890 was completed, bench 3870 was worked on. The co-ordinates of cross-section 124 to 133 and longitudinal section 20 was drawn on the mine model from bench 3870. The sepia cross-section 124 was lined up using the 124 cross-section co-ordinates on bench 3870 and longitudinal-section 20. The grades were noted and coloured, and the lithology marked off by the representing codes. The next cross-section was taken, cross-section 125, and was lined up with the 125 cross-section co-ordinates on bench 3870 of cross-section 125. Longitudinal section 20 was also placed in the right position. The percentage grade was coloured for each ore block, and the lithology separated for bench 3870.

After all the cross-sections 124 to 133 were completed for bench 3870, then bench 3850 was worked on. When 3850 bench was finished the next bench would be worked on for each cross-section from cross-section 124 to 133. Once bench 3850 had its cross-section co-ordinates and longitudinal-section marked on it, each cross-section from 124 to 133 would be done one by one.

Each cross-section from cross-section 124 to cross-section 133 was done systematically changing each bench after the cross-section 124 to 133 were completed, with grade coloured and lithology marked off for each bench. The benches were done one by one after cross-sections 124 to 133 were completed. This was done until bench 3470 was reached.

2.3 LONGITUDINAL-SECTION CREATED FROM CROSS-SECTIONS:

Upon completion of cross-sections 124 to 133 a longitudinal-section of section 20 was made. (See Appendix 2 for Longitudinal Section 20). The blank longitudinal-section 20 was matched along the longitudinal co-ordinate 20 from cross-section 124. The grade was coded appropriately and the lithology marked off. After cross-section 125 was placed under longitudinal-section, the longitudinal co-ordinate 20 from cross-section 125 was matched up with the cross-section co-ordinate 125 on the longitudinal section presently being worked on. The grade and the lithology were recorded on the longitudinal section. Next cross-section 126 was placed under the longitudinal section 20. The longitudinal section 20 from cross-section 126 was lined up with the cross-section co-ordinate 126 on the longitudinal section 20. The grade was coded and the lithology traced from the present cross-section being used. This same procedure was used for the rest of the cross-sections 127 to 133.

The longitudinal-section after completion, presented the ore body the way it was orientated at right angles from the cross-section, along the longitudinal co-ordinate 20.

3. RESULTS OF CROSS-SECTION GRADE STUDY

3.1 ROCK TYPES AND TONNAGE:

Graphs of the rock types and tonnage were made to compare the grade they were associated with for the ore present in the mine model from cross-section area 124 to 133. (See Figures 2, 3, 4 for Graphs). The mine model is divided into blocks when ore is present. In each block, the percentage of lead and zinc, and the rock type is given. (See Appendix 1 - Mine Model). The average percentage the rock types and the tonnage refers to the area only, encompassed by the cross-sections 124 to 133. Relative frequency graphs were also made for the different ore rock types and the tonnage relating to grades. These again only pertain to the area of cross-sections 124 to 133.

3.2 OBTAINING ROCK TYPES DATA:

To determine the average percentage for each rock type, all the blocks of ore that had a percentage in the area of cross-sections 124 to 133 were used. The average percentage was the combined lead and zinc percentages. (See Table 2 for Rock Type Averages).

Rock type (code) 7 (see Table 1 for Rock Type) had the least combined lead and zinc grade. Rock type (code) 8, 9 and 10 were each respectively higher than 7. Rock type (code) 11 and 12 had the highest percentage grade.

A relative frequency graph was made showing the comparison between ore rock types. The relative frequency was calculated by adding all the rock types for 7 used in the study, between cross-sections 124 and 133 and bench 3910 to 3470. The total for rock type (code) 7 was used, then divided by the sum of all the blocks of ore, giving the relative frequency for rock type (code) 7. This procedure was done for rock types (code) 8, 9, 10, 11 and 12. The data was plotted as a relative frequency diagram.

Rock type (code) 8 and 10 had the highest frequency, well above the other rock types. Rock type (code) 9 had the next highest frequency.

3.3 OBTAINING TONNAGE DATA:

For the tonnage relating to each grade range, each bench was calculated separately and graphed (see Appendix 3). Because each rock type has a different tonnage factor, the blocks for each rock type were added up separately. (See Appendix 3 for Actual Tonnage Calculations).

The tonnage for each bench in the specified grade ranges were calculated for the area in the cross-sections 124 to 133.

A tonnage grade relative frequency diagram was graphed. This was done by taking the total tonnage for each grade range and adding the tonnage from each bench for the grade range and then dividing by the total tonnage, from cross-sections 124 to 133.

The 6% to 8% grade range had the highest frequency, while the greater than 8% and 4% to 6% grades were a bit lower for the amount of tonnage available.

TABLE 2

COMBINED LEAD AND ZINC AVERAGE GRADES

FOR CROSS-SECTIONS 124-133

	Rock Type Code					
	7	8	9	10	11	12
Grade Percentage	5.1	6.0	6.0	6.4	8.1	8.1
# of Same Rock Types	232	886	463	883	192	93

Total Blocks Used: 2,749

FIGURE 2

AVERAGE COMBINED LEAD AND ZINC GRADE GRAPH

(CYPRUS ANVIL----- Data Graphing)

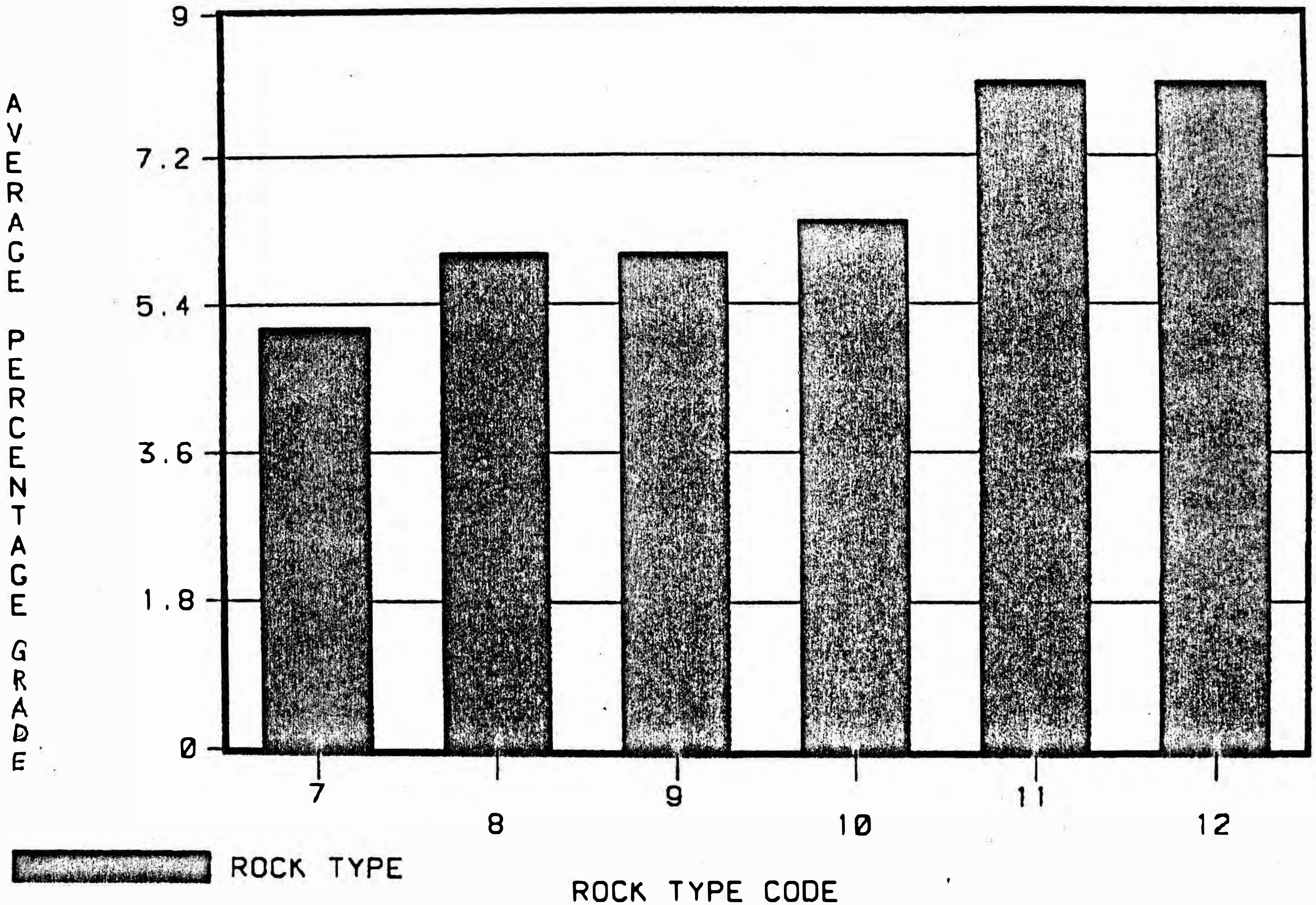


FIGURE 3

RELATIVE FREQUENCY DIAGRAM FOR ROCK TYPES

(CYPRUS ANVIL----- Data Graphing)

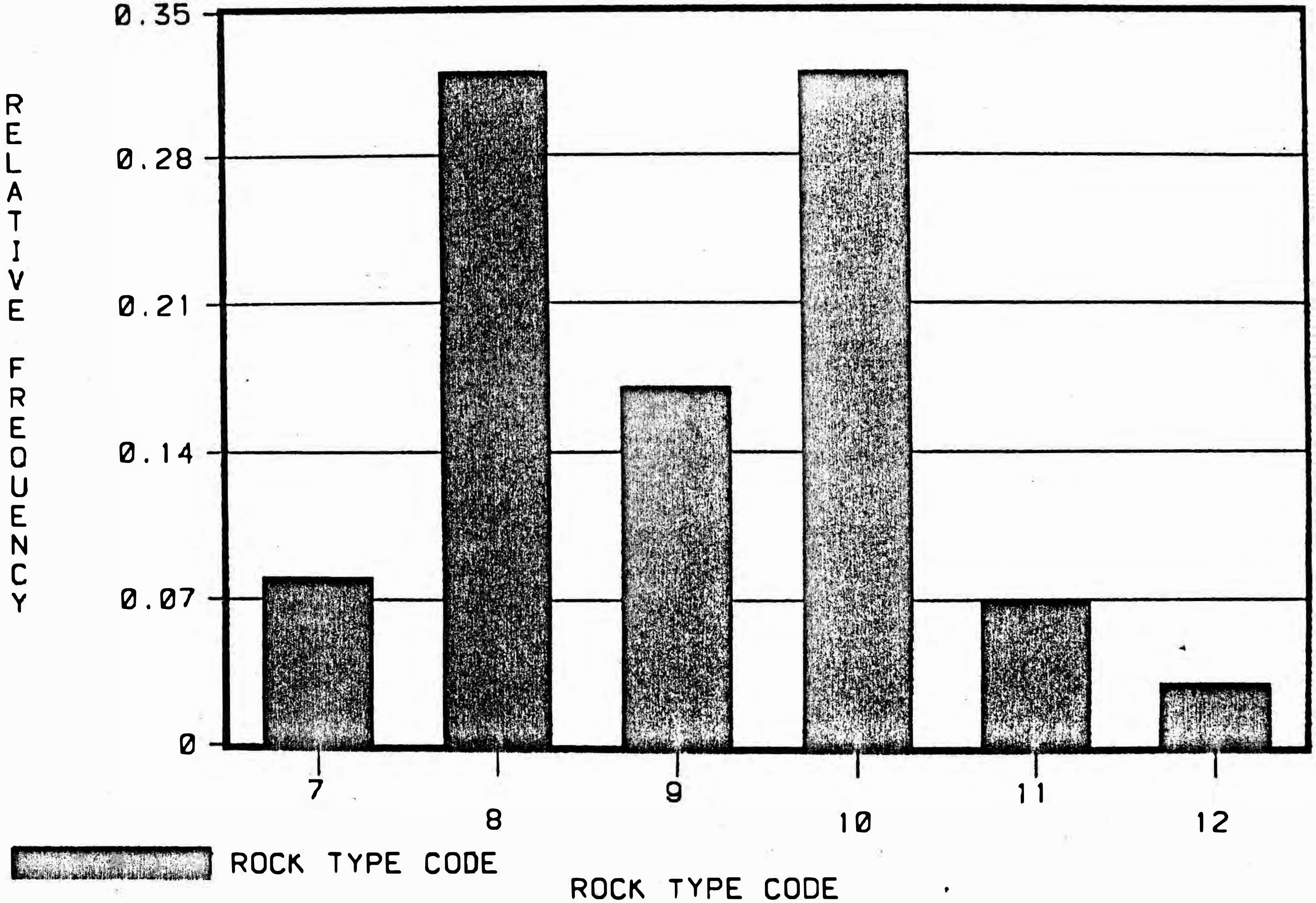


TABLE 3

TONNAGE-GRADE COMPARIOSN (TONS OF ORE)

FOR CROSS-SECTIONS 124-133

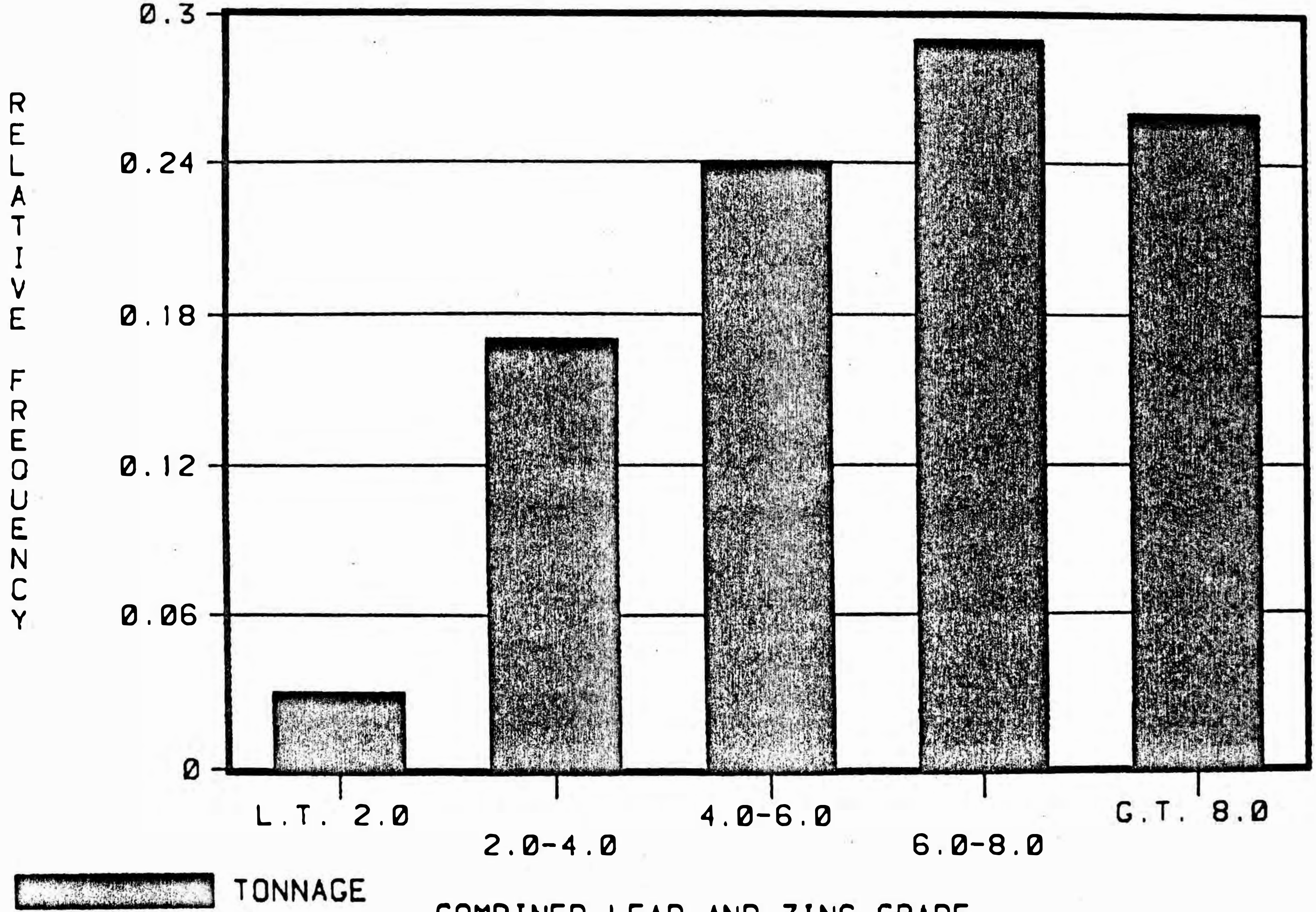
Bench	< 2.0%	2.0%-4.0%	4.0%-6.0%	6.0%-8.0%	> 8.0%
3910			40,556		
3890					59,000
3870				69,815	120,556
3850		21,703	77,778	32,222	80,370
3830	48,333	64,444	102,037	55,556	10,852
3810		179,444	37,074	62,333	40,556
3790			100,278	48,833	197,481
3770		84,740	66,000	30,278	119,981
3750		33,889	126,296	116,111	50,500
3730		77,111	154,074	214,000	6,759
3710	11,778	86,852	187,778	192,889	68,037
3690	84,444	167,556	146,667	143,111	43,852
3670	66,000	105,204	272,333	231,111	5,426
3650	71,019	111,681	161,296	151,556	225,889
3630	17,333	255,111	402,000	110,130	27,407
3610	37,074	83,056	202,111	289,167	352,593
3590	32,556	169,352	123,667	271,741	433,167
3570	18,056	269,815	233,333	247,519	481,500
3550	17,667	120,685	532,037	673,444	108,611
3530	13,519	314,500	292,444	488,630	337,037
3510	76,481	312,963	306,481	362,741	647,778
3490	60,093	316,389	230,222	770,000	273,778
3470	24,444	169,000	288,889	281,778	715,333
Total From All Benches	578,802	2,943,499	4,083,345	4,842,957	4,406,468

Total Tonnage: 16,855,071

FIGURE 4

TONNAGE - GRADE RELATIVE FREQUENCY DIAGRAM

(CYPRUS·ANVIL----- Data Graphing)



4. DISCUSSION OF RESULTS

4.1 ROCK TYPES:

The average percentage grade for rock types (codes) 7, 8, 9, 10, 11 and 12 increased respectively, except 8 and 9 had the same grade of 6.0% and 11 and 12 had the same grade of 8.1%. The relative frequency of rock types (code) 8 and 10 had a much higher frequency than any other rock type, and their average percentage of combined lead and zinc were 6.0% and 6.4% respectively. Rock type (code) 11 and 12 had the highest grade, both 8.1%, but they had the lowest frequency. Rock type (code) 9 had an average grade of 6.0% with also an average frequency. Rock type (code) 7 had the lowest grade and also a low frequency.

From this information for the area designated by cross-sections 124 to 133, the most common and valuable rock types (codes) are 8 and 10. They occur the most and have a consistent average grade.

4.2 TONNAGE:

For tonnages from benches (see Appendix 3 for Graphs of Tonnage and Grade Ranges) in the area of cross-section 124 to 133, the tons of ore in the less than 2% category is approximately 2,400,000 tons less than all other grade ranges. In the grade range of 2% to 4% there is about 2,900,000 tons of ore, with much more ore available below bench 3650. The tonnage in the 4% to 6% grade range has about 2,000,000 more tons than the 2% to 4% grade range, with the tonnage increasing on each bench below 3670. In the grade range of 6% to 8% the tonnage available is the highest at 4,842,957. The amount of tonnage increases below bench 3730. At bench 3550 and 3490 the tonnage available is drastically increased relative to previous and benches following. The increase is by approximately 200,000 tons on bench 3550 and 300,000 tons on bench 3490. For the grade range of greater than 8%, the tonnage is still high relative to other grade ranges. The bulk of the tonnage comes from benches lower than 3590. Bench 3470 has the highest available ore. The ore is spaced sporadically through the benches in the greater than 8% grades. An example, bench 3510 has 647,778 tons of ore and bench 3550 has 108,611 tons of ore. This is a difference of 539,167 tons of ore in only a 40 foot interval.

From the relative frequency graph comparing the tonnage and the grade, it is seen that the 6% to 8% grade has the highest frequency. The greater than 8% grade range has the next highest frequency, followed by 4% to 8%, then 2% to 4%. The less than 2% grade range was the least frequent.

The fact that the 6% to 8% grade range is the most frequent is ideal, since the cutoff grade for ore is 4%, meaning that the grade range for the most frequent amount of tonnage is much higher than the cutoff grade. The greater than 8% grade range of tonnage is frequent, but it occurs very sporadically. The next most frequent tonnage available is in the 4% to 6% grade range.

4.3 ROCK TYPES AND TONNAGE:

For the area encompassed by the cross-section 124 to 133, rock type (code) 8 and 10 have the highest frequency with grades of 6.0 and 6.4 respectively. According to the cross-section 124 to 133, the most important rock types (code) are 8 and 10. In terms of tonnage, the 6% to 8% grade range has the most available ore.

BIBLIOGRAPHY

1. Bragg, Gorden M., Principles of Experimentation and Measurements, Prentic-Hall Inc., New Jersey, 1974

2. Pazour, Donald A, World Mining, 1979

APPENDIX 1

For Appendix 1, refer to the mine model (Bench 3910-3470).

APPENDIX 2

For Appendix 2, refer to the grade distribution cross-sections made from the mine model (cross-section 124-133).

APPENDIX 3

FINDING TONNAGE (EXAMPLE)

Because each rock type has a different tonnage factor, due to the weights of various rocks, the blocks for each rock type were added up separately. Then the number of blocks for each rock type was multiplied by the tonnage factor for the rock type. This was then added up and divided by the number of blocks, which gave the tonnage factor for that section of blocks of ore. After the tonnage factor was calculated, it was multiplied by the total number of blocks, the cut, divided by a constant, then multiplied by the block area. Examples are found below.

Tonnage Factors Rock Type Code	Tonnage Factor
7	2.69
8	2.93
9	3.18
10	3.65
11	3.39
12	3.74

Example:

On bench 3870, greater than 8.0% grade range

# of Blocks	Rock Type Code		Tonnage Factor		
6	(10)	x	3.65	=	21.90
4	(7)	x	2.69	=	10.76
5	(9)	x	3.18	=	15.90
6	(8)	x	2.93	=	17.58

$$\frac{21.90 + 10.76 + 15.90 + 17.58}{\text{Total \# of Blocks } 21} = 3.1 \text{ Tonnage Factor for These Blocks}$$

1" = 100'

1 Block = 1/2" x 1/2"

Area	Cut	Constant	Tonnage Factor	# of Blocks		
50 x 50 x	20 ÷	27 x	3.1 x	21	=	120,556 Tons of Ore

Example:

On bench 3750, in 6% to 8% grade range

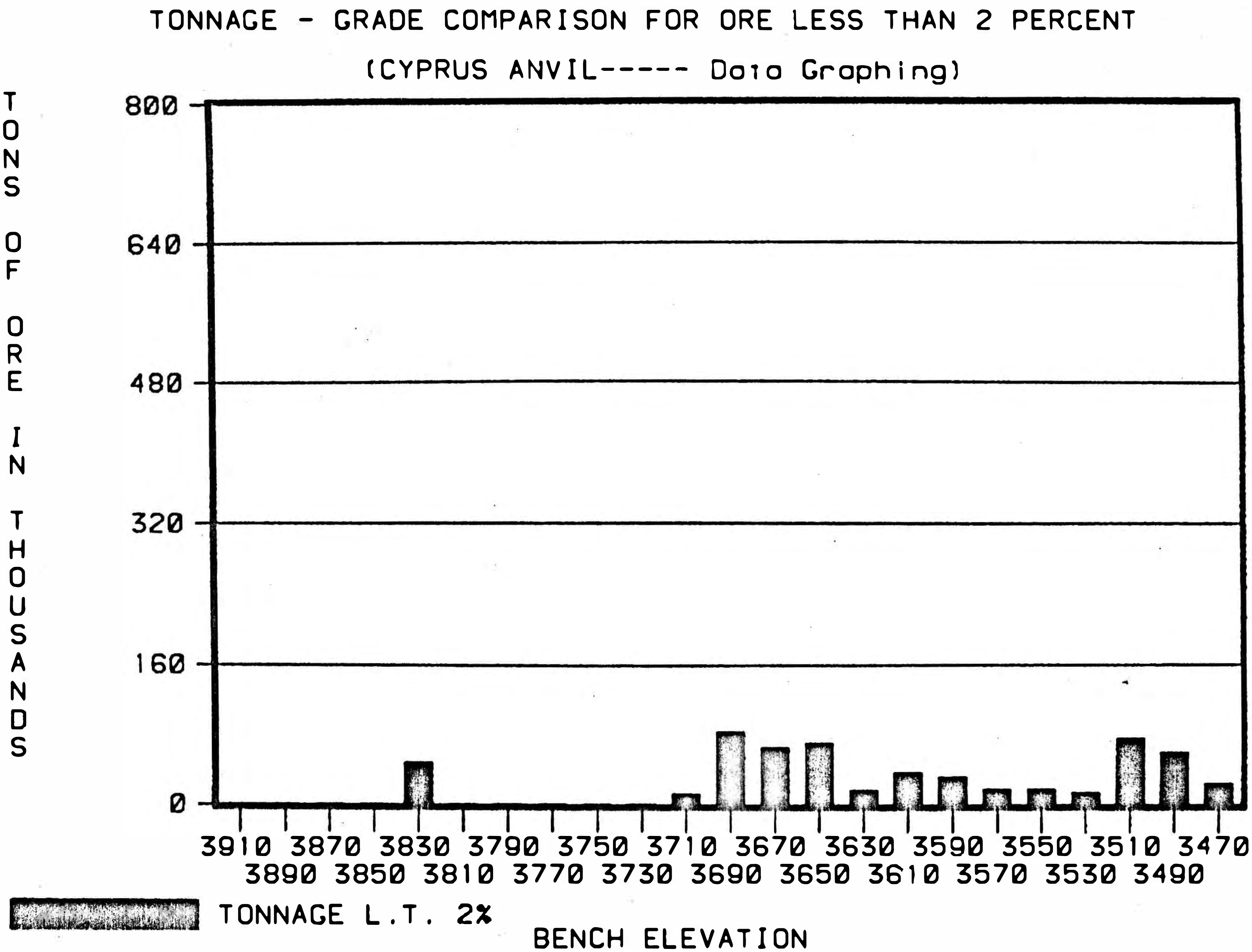
# of Blocks	Rock Type Code		Tonnage Factor		
5	(10)	x	3.65	=	18.25
7	(11)	x	3.39	=	23.73
1	(9)	x	3.18	=	3.18
6	(8)	x	2.93	=	17.58

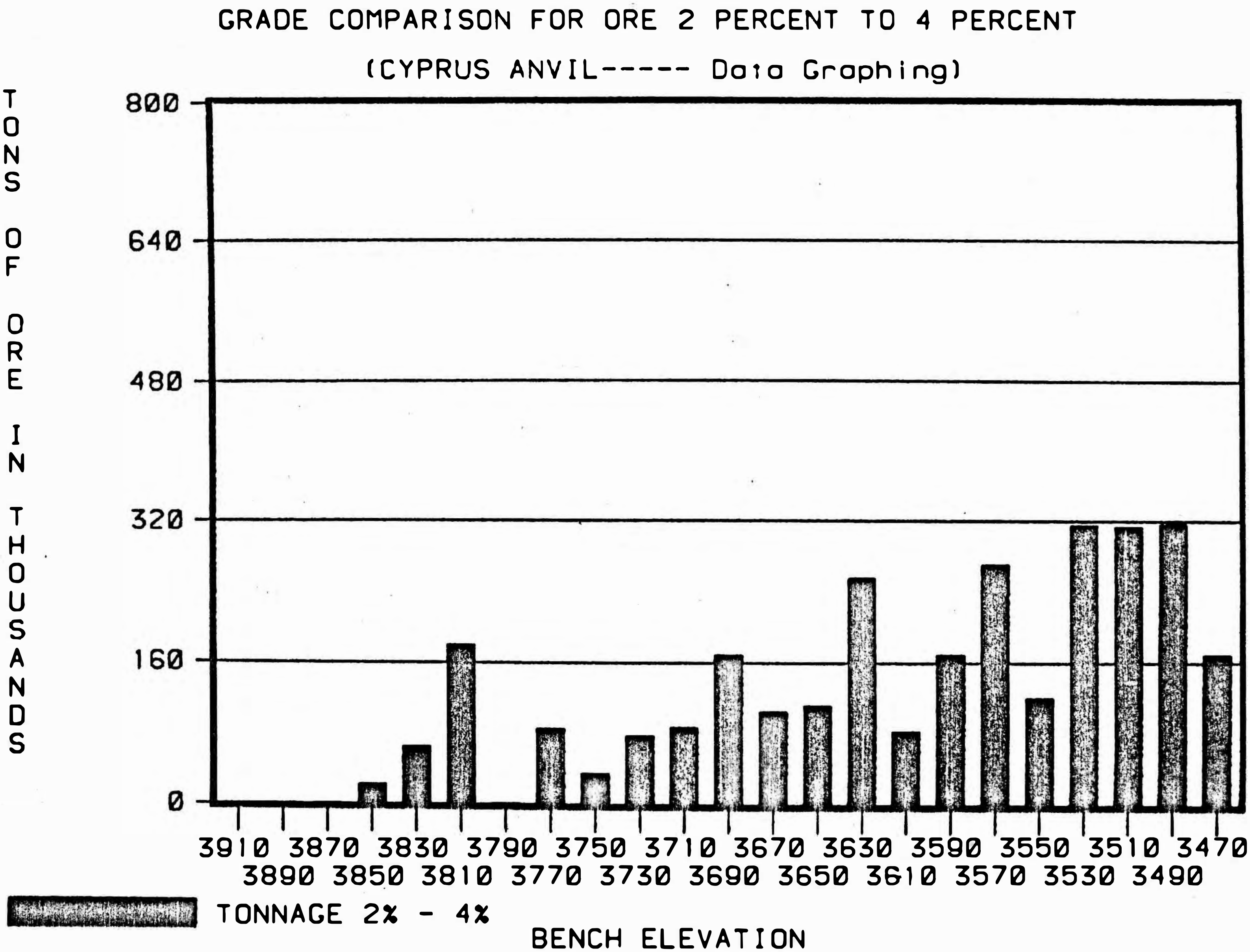
$$\frac{18.25 + 23.73 + 3.18 + 17.58}{\text{Total \# of Blocks } 19} = 3.3 \text{ Tonnage Factor for These Blocks}$$

1" = 100'

1 Block = 1/2" x 1/2"

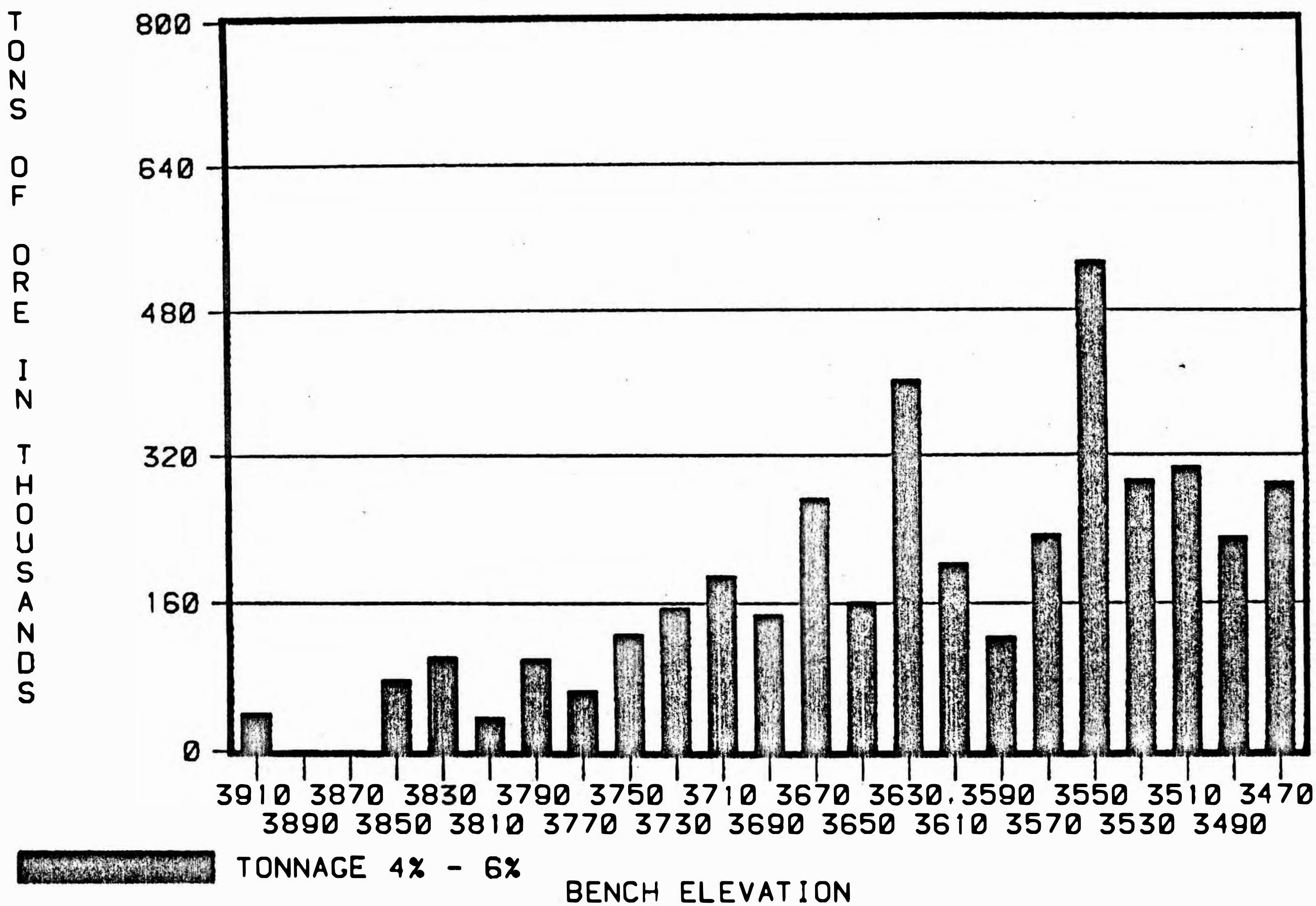
Area	Cut	Constant	Tonnage Factor	# of Blocks		
50 x 50 x	20 ÷	27 x	3.3 x	19	=	116,111 Tons of Ore

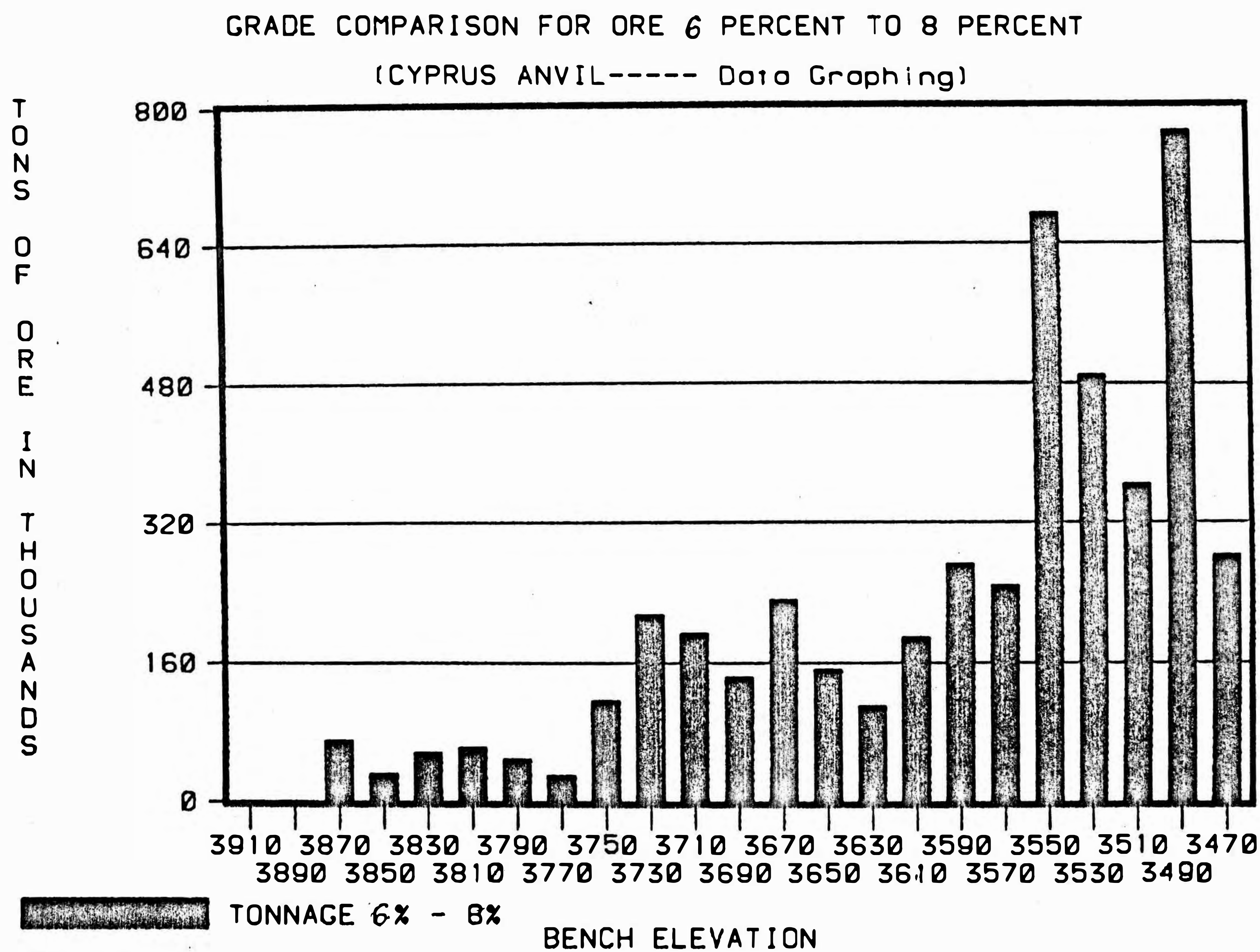

TONNAGE - GRADE COMPARISON FOR ORE LESS THAN 2 PERCENT
(CYPRUS ANVIL----- Data Graphing)
TONS OF ORE IN THOUSANDS
800
640
480
320
160
0
3910 3870 3830 3790 3750 3710 3670 3630 3590 3550 3510 3470
3890 3850 3810 3770 3730 3690 3650 3610 3570 3530 3490
TONNAGE L.T. 2%
BENCH ELEVATION


GRADE COMPARISON FOR ORE 2 PERCENT TO 4 PERCENT
(CYPRUS ANVIL----- Data Graphing)
TONS OF ORE IN THOUSANDS
800
640
480
320
160
0
3910 3870 3830 3790 3750 3710 3670 3630 3590 3550 3510 3470
3890 3850 3810 3770 3730 3690 3650 3610 3570 3530 3490
TONNAGE 2% - 4%
BENCH ELEVATION

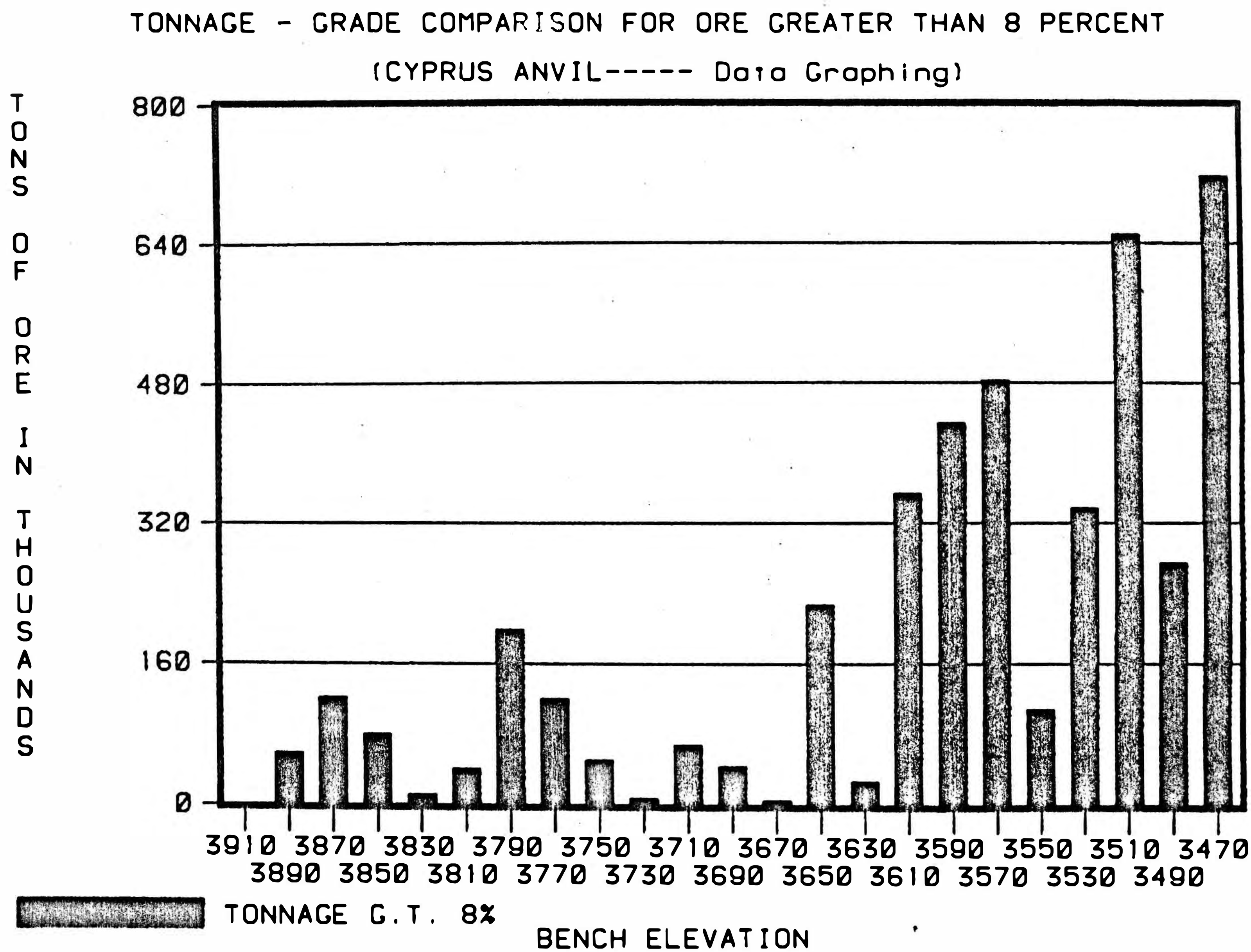
GRADE COMPARISON FOR ORE 4 PERCENT TO 6 PERCENT

(CYPRUS ANVIL----- Data Graphing)





GRADE COMPARISON FOR ORE 6 PERCENT TO 8 PERCENT
(CYPRUS ANVIL----- Data Graphing)
TONS OF ORE IN THOUSANDS
800
640
480
320
160
0
3910 3870 3830 3790 3750 3710 3670 3630 3590 3550 3510 3470
3890 3850 3810 3770 3730 3690 3650 3610 3570 3530 3490
TONNAGE 6% - 8%
BENCH ELEVATION


TONNAGE - GRADE COMPARISON FOR ORE GREATER THAN 8 PERCENT
(CYPRUS ANVIL----- Data Graphing)
TONS OF ORE IN THOUSANDS
800
640
480
320
160
0
3910 3870 3830 3790 3750 3710 3670 3630 3590 3550 3510 3470
3890 3850 3810 3770 3730 3690 3650 3610 3570 3530 3490
TONNAGE G.T. 8%
BENCH ELEVATION