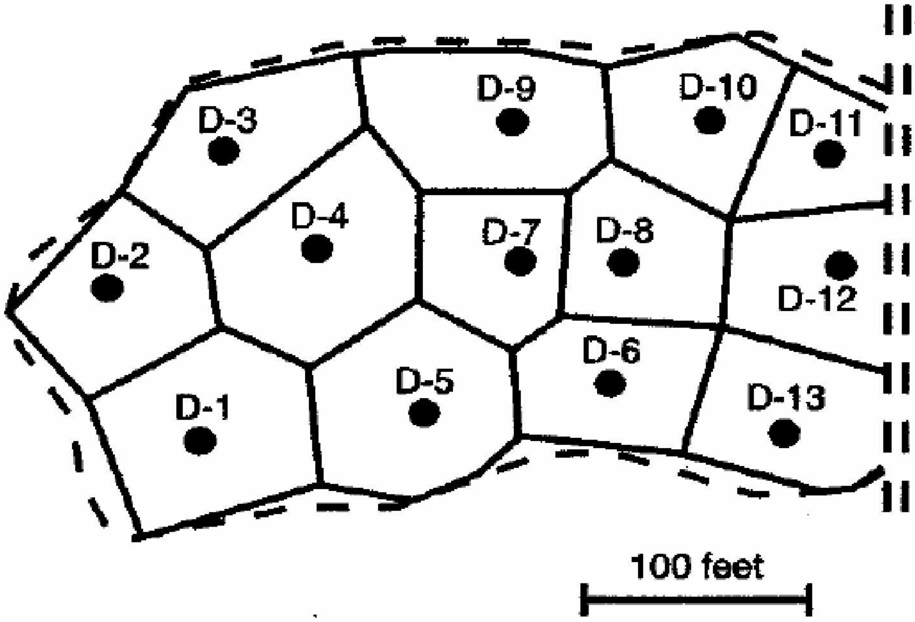


Figure 6.7. Diamond drill hole plan and polygons for the Bonanza copper deposit.

Table 6. Assay Data for Drill Hole D-1

Interval (ft)	Thicknes s (ft)	Grade % Cu	Grade * Thickness	
0-100	100	0.31		Below Cutoff
100-110	10	0.47	4.70	
110-122	12	0.72	8.75	
122-130	8	0.96	7.68	
130-150	20	1.04	20.80	
150-200	50	0.82	41.00	
200-220	20	0.54	10.80	
220-250	30	0.42	12.60	
250-270	50	0.35		Below Cutoff
	150		106.43	Thickness and Grade * Thickness above cutoff

$$\text{Average Grade Drill Hole D} - 1 = \frac{\sum \text{Thichness}_i * \text{Grade}_i}{\sum \text{Thickness}_i} = \frac{106.43}{150} = 0.71\%\text{Cu}$$

Table 7. Ore Reserves for Bonanza Copper Deposit

Polygon	Area (ft^2)	Thickness (ft)	Volume (ft^3)	Tonnage Factor	Tons	Grade % Cu	Tons * Grade
D-1	5320	150	798,000	12.5	63,840	0.71	45,326
D-2	5300	135	715,500	12.5	57,240	0.66	37,778
D-3	4400	180	792,000	12.5	63,360	0.82	51,955
D-4	5520	175	966,000	12.5	77,280	0.75	57,960
D-5	6800	155	105,400	12.5	84,320	1.00	84,320
D-6	4960	180	892,800	12.5	71,424	0.97	69,281
D-7	4520	250	1,130,000	12.5	90,400	1.21	109,384
D-8	4640	240	1,113,600	12.5	89,088	1.36	121,159
D-9	5840	150	876,000	12.5	70,080	0.93	65,174
D-10	4840	135	653,400	12.5	52,272	0.87	45,476
D-11	3760	120	451,200	12.5	36,096	0.81	29,237
D-12	4270	165	637,200	12.5	50,976	0.75	38,232
D-13	4800	135	648,800	12.5	51,840	0.68	35,251
Total					858,216		790,553

$$\text{Average Grade Entire Deposit} = \frac{\sum \text{Tons}_i * \text{Grade}_i}{\sum \text{Tons}_i} = \frac{790{,}533}{858{,}216} = 0.92\,\%\text{Cu}$$

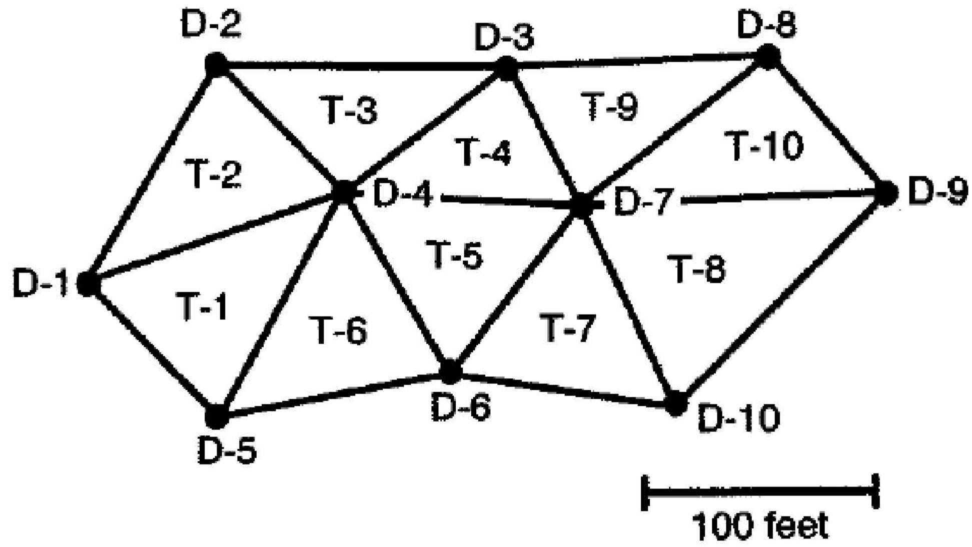


Figure 6.8. Triangle Construction.

Table 8. Assay Data for the Ojala Copper Deposit

Drill Hole	Thicknes s (ft)	Grade % Cu
D-1	50	0.93
D-2	75	0.77
D-3	60	0.82
D-4	100	1.05
D-5	75	0.72
D-6	60	0.49
D-7	105	1.63
D-8	80	0.91
D-9	70	0.86
D-10	75	0.74

Given this data, the tonnage and grade calculation for triangle T1 would be as follows:

Area = 4400 ft^2 (by geometry)

Table 8a. Grade and Tonnage Calculation for Triangle T1.

Drill Hole	Thicknes s (ft)	Grade % Cu	Grade * Thickness
D-1	50	0.93	46.5
D-4	100	1.05	105.0
D-5	75	0.72	54.0
Total	225		205.5

$$\text{Average Grade} = \frac{\sum \text{Thichness}_i * \text{Grade}_i}{\sum \text{Thickness}_i} = \frac{205.5}{225} = 0.91\%\text{Cu}$$

Tonnage = area * average thickness * tonnage factor = 4400 *(225/3)/12.5 = 26,400 tons.

Table 9. Ore Reserves for the Ojala Copper Deposit.

Triangle	Drill Holes	Tons	Avg. Grade % Cu	Tons * Grade
T-1	D-1, D-4, D-5	26,400	0.91	24,024
T-2	D-1, D-2, D-4	26,400	0.94	24,816
T-3	D-2, D-3, D-4	22,500	0.91	20,475
T-4	D-3, D-4, D-7	22,260	1.23	27,380
T-5	D-4, D-6, D-7	18,550	1.15	21,332
T-6	D-4, D-5, D-6	27,260	0.79	21,535
T-7	D-6, D-7, D-10	26,240	1.07	28,076
T-8	D-7, D-9, D-10	40,500	1.15	46,575
T-9	D-3, D-7, D-8	24,418	1.20	29,301
T-10	D-7, D-8, D-8	28,917	1.19	34,411
Total		263,445		277,927

$$\text{Average Grade Entire Deposit} = \frac{\sum \text{Tons}_i * \text{Grade}_i}{\sum \text{Tons}_i} = \frac{277{,}927}{263{,}445} = 1.05\ \%\text{Cu}$$

Average Grade = 277,927/263,445 = 1.05 % Cu

7.8 Calculation by Section

The basis of this method is to calculate a block of ore that is bounded by regularly spaced cross sections (see Tables 10 and 11). The following equation illustrates the detailed calculation of a typical block of oreby the cross section method. The ore outline of each bounding section is divided into areas of influence based on the drill hole or other sample data. The areas of influence are then either planimetered or calculated geometrically. The individual areas are totaled for each section and the volume calculated by the average and area formula:

$$V = (A_1 + 2A_2 + 2A_3 \ldots A_n)/2 * L$$

where A is area on section and L is a constant section spacing, or when using only two adjacent sections:

$$V = (A_1 + A_2)/2 * L$$

The volume is then converted to tons by application of the appropriate tonnage factor.

Figure 6.10 shows two cross sections spaced 30.48 m (100 ft) apart. These sections show a tabular dipping vein sampled by a surface trench, two drill holes per section, and one crosscut per section. The vein is assumed to be copper ore with a tonnage factor of 9.5 cu ft per ton.

Block Average Grade:

Section	Area (sq ft)	Average Grade, % Cu	% Cu Ft²
100*N*	3260	1.81	5901
200*N*	4896	1.75	8563
	8156		14463

$$\text{Average block grade} = \frac{14463}{8156} = 1.77\%\ \text{Cu.}$$

Volume of Ore Block:

$$v = \frac{\left(\begin{array}{c}\text{area section } 100N + \text{area section } \times \\ 200N \times \text{section spacing}\end{array}\right)}{2}$$

$$v = \frac{3260 + 4896 \times 100}{2} = 407{,}800 \text{ cu ft}$$

$$\text{Tonnage} = \frac{407800}{9.5} = 42{,}926 \text{ st}$$

The geologic reserve of this deposit between 100N and 200N is 38934 ton (42,926 st) with an average grade of 1.77% Cu. Similarly, the reserve calculations can be extended north and south to cover the entire minable strike length of the vein by adjacent pairs of sections.

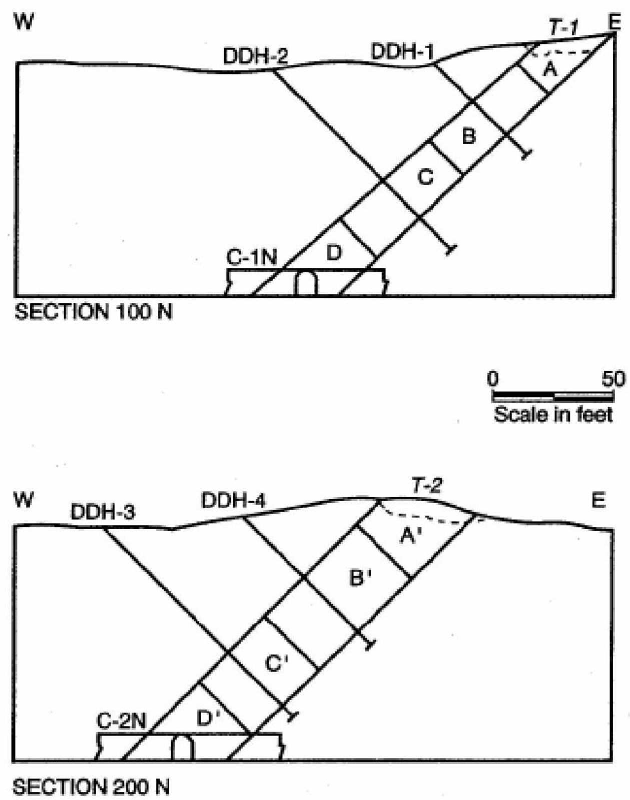


Figure 6.10

Table 10. Assay Data for Section 100N, Big Rat Copper Vein.

Sample	Area of Influence (ft^2)	Grade % Cu	Grade * Area
T-1	A = 510	0.80	408
DDH-1	B = 1000	2.55	2550
DDH-2	C = 1040	1.66	1726
C-1N	D = 710	1.70	1207
Total	3260		5891

Average Grade = 5891/3206 = 1.81% Cu

Table 11. Assay Data for Section 100N, Big Rat Copper Vein.

Sample	Area of Influence (ft^2)	Grade % Cu	Grade * Area
T-2	A′ = 848	0.92	780
DDH-4	B′ = 1792	2.32	4157
DDH-3	C′ = 1280	1.59	2035
C-2N	D′ = 976	1.63	1519
Total	4896		8563

Average Grade = 8563/4896 = 1.75% Cu

Ore Reserve Estimation

Tonnage Factor
Basic Principles of Ore Reserve Calculation
Sample Weighting
Mining Dilution
Calculation by Polygons
Cutoff Grade Calculation

Tonnage Factor

The tonnage factor provides the mechanism for the conversion from volume of ore to weight of ore.

In the English system, the tonnage factor is normally expressed as cubic feet per ton of ore.

In the metric system, the tonnage factor is the specific gravity of the ore.

Probably the most accurate method of determining specific gravity of an ore is to calculate an average specific gravity using the specific gravities of individual minerals (Table 4), provided the relative percentages of ore minerals present are accurately known.

For example, if a massive sulfide ore is 10% galena, 35% sphalerite, and 55% pyrite, the specific gravity would be:

7.6 * 0.10 = 0.76

4.1 * 0.35 = 1.44

<u>5.0 * 0.55 = 2.75</u>

4.95 = sp gr of ore

If the ore volume has been computed in cubic meters, the volume multiplied by the specific gravity is the tonnage in metric tons directly.

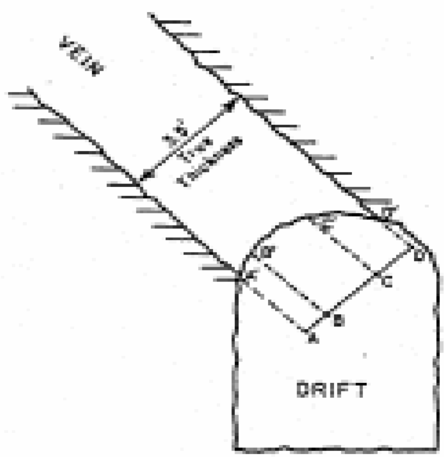
Basic Principles of Ore Reserve Calculation

All methods for the calculation of ore reserves make use of two basic principles:

1) Samples taken close to each other are likely to have the same value.
2) Average grades are calculated using some form of a weighted average:

$$\bar{x} = \frac{\Sigma x_i w_i}{\Sigma w_i}$$

Average Grade by Arithmetic Average



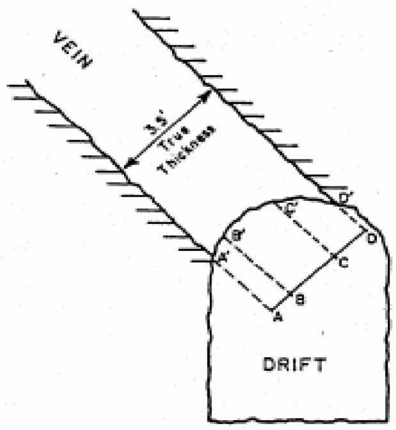
Channel sampling

Sample Interval	Assay, oz. Au/ton
A-B	1.09
B-C	0.50
C-D	0.13

$$\text{Average grade} = \frac{\Sigma A_i}{n} = \frac{1.09 + 0.50 + 0.13}{3} = 0.57 \text{ oz.Au/ton}$$

Is this correct?

Average Grade by Weighted Average



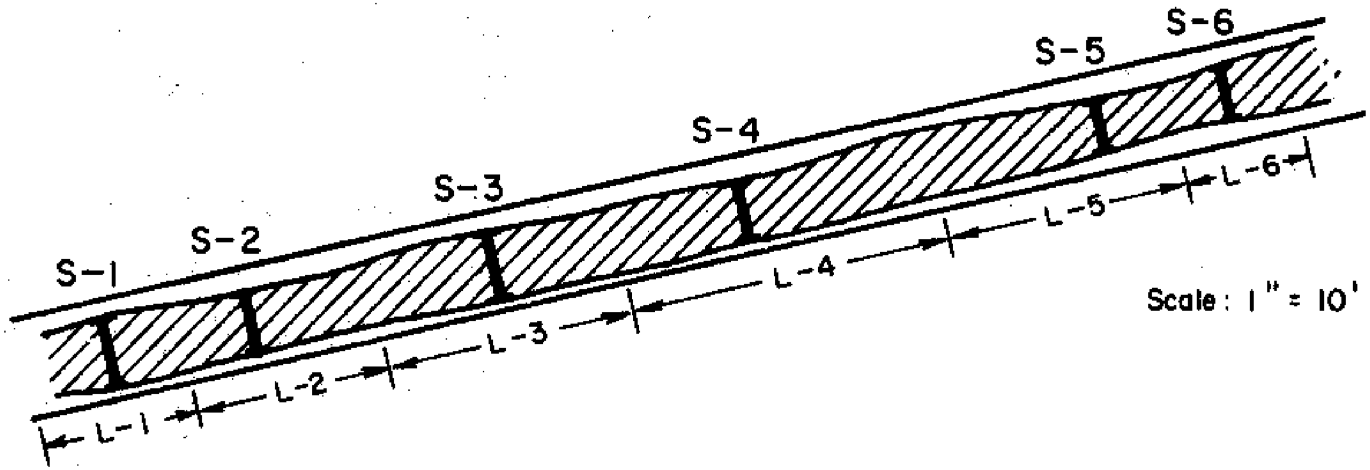
Sample Interval	Length, ft	Assay, oz. Au/ton
A-B	0.6	1.09
B-C	1.6	0.50
C-D	1.3	0.13

$$\text{Average grade} = \frac{\Sigma A_i L_i}{\Sigma L_i}$$

$$= \frac{(1.09*0.6)+(0.50*1.6)+(0.13*1.3)}{0.6+1.6+1.3}$$

$$= 0.46\,\text{oz.Au/ton}$$

Sample Weighting



Sample No.	Area of Influence, L, Ft*	Width, W, Ft	W × L, Ft	% Pb	Pb × W × L
S–1	6.0	3.0	18.0	6.4	115.20
S–2	7.5	2.5	18.75	7.6	142.50
S–3	10.0	3.0	30.00	5.6	168.00
S–4	12.5	2.3	28.75	8.8	253.00
S–5	10.0	2.0	20.0	8.2	164.00
S–6	5.0	2.6	13.0	6.7	87.10
Total	51.00	15.40	128.50		929.80

$$\text{Average grade} = \frac{\Sigma(W*L)_i * Pb_i}{\Sigma(W*L)_i} = \frac{929.80}{128.50} = 7.2\%\ \text{Pb}$$

Mining Dilution

Using the previous example, assume that the minimum mining width is 3 ft. in order to accommodate the mines extraction equipment. Assume that the density of vein material is 9 ft^3/ton and the density of the wallrock is 12 ft^3/ton. Table 3 shows the pertinent calculations, for determining dilution under these conditions.

Table 3. Calculation of dilution from mining width.

Sample	L	Wo	Ww	LxWo	LxWw
SI	6.0	3.0	0.0	18.00	0.00
S2	7.5	2.5	0.5	18.75	3.75
S3	10.0	3.0	0.0	30.00	0.00
S4	12.5	2.3	0.7	28.75	8.75
S5	10.0	2.0	1.0	20.00	10.00
S6	5.0	2.6	0.4	13.00	2.00
				128.5	24.5

Weight of vein material per vertical foot:

$128.5\ ft^2 * 1\ ft * 1\ ton/ 9\ ft^3 = 14.28\ tons$

Weight of dilution per vertical foot:

$24.5\ ft^2 * 1\ ft * 1\ ton/12\ ft^3 = 2.04\ tons$

Weight of combined material:

14.28 + 2.04 = 16.32 tons per vertical ft. mined at 3.0 wide

Lead grade = $\Sigma(\%Pb_i * tons_i)/\Sigma tons_i$

= [(7.2% Pb * 14.28)+(0.0% Pb * 2.04)]/16.32

= 6.3 % Pb

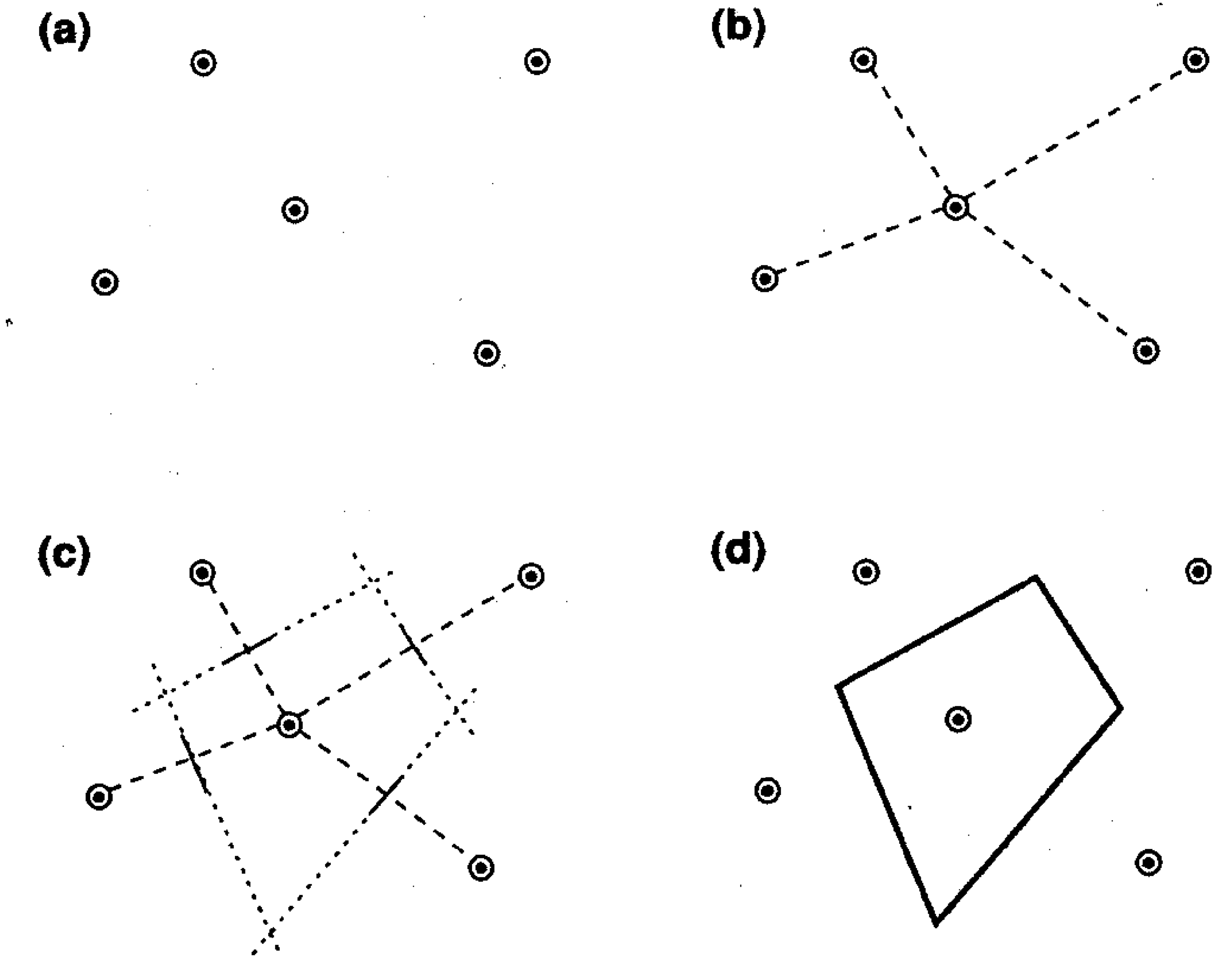
Some operators would consider the dilution to be

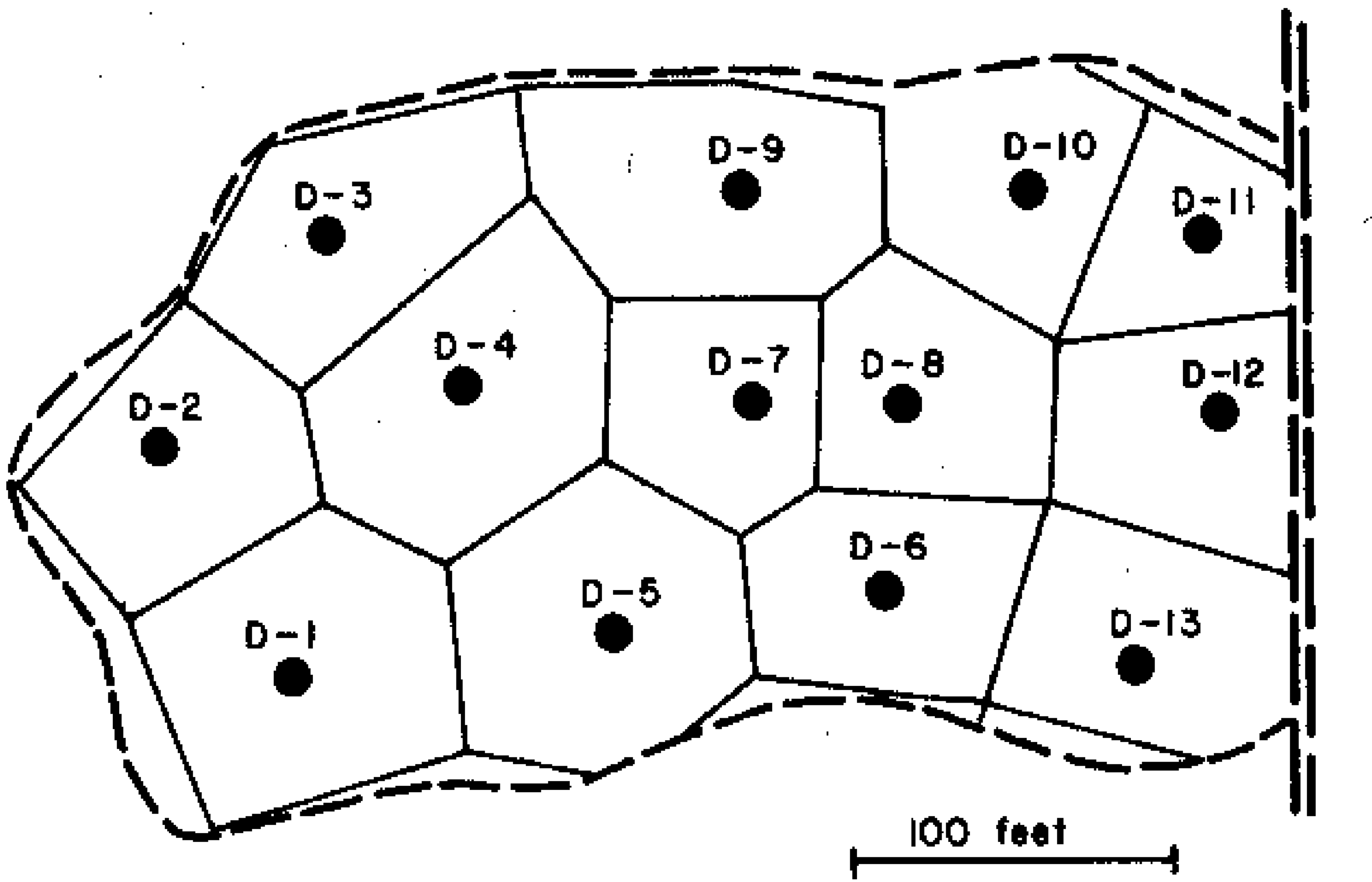
2.04 tons waste / 14.28 ton vein material = 14.3%

While others would consider it to be

2.04 tons waste / 16.32 tons product = 12.5%

Calculation by Polygons

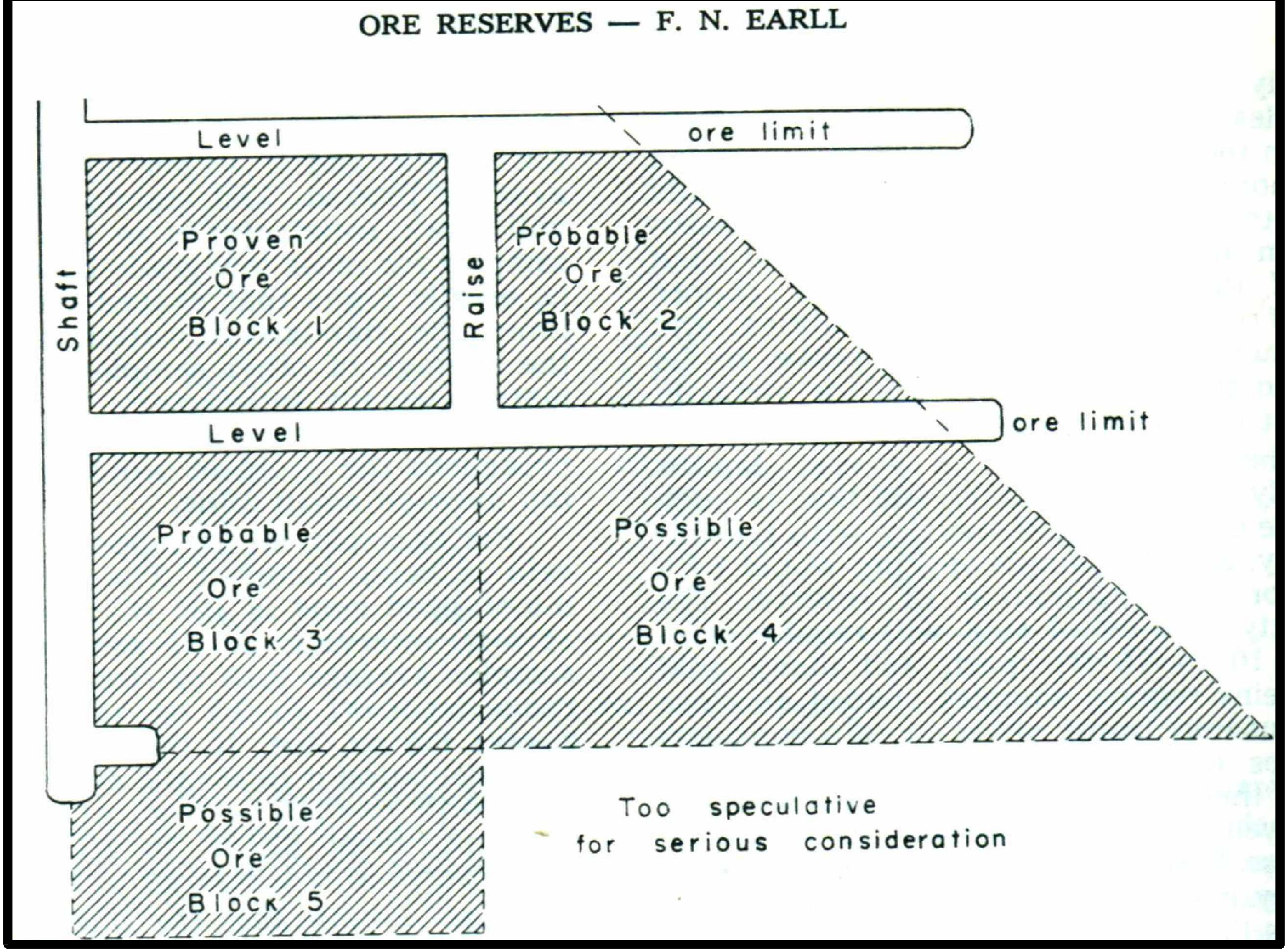



D-9
D-10
D-3
D-11
D-4
D-7
D-8
D-12
D-2
D-6
D-5
D-13
D-1
100 feet

Ore Reserve Classification

Original definitions were related to vein type deposits:

- **Proved:** Blocked out (sampled) on four sides by mine workings and surface exposures.
- **Probable:** Blocked out on two or three sides
- **Possible:** Exposed on one side or no exposure and geologic projection



Handbook for Small Mining Enterprises, Montana Bureau of Mines & Geology, 1976, PG. 36

Cutoff Grade Calculation

Break-even grade – the grade at which the mineral resource can no longer be mined and processed at a profit.

Cutoff grade – similar to break-even grade but for some reason may be set at a point other than the break-even grade. Mineralization below cutoff grade is not considered ore.

For most practical purposes the cutoff grade and the break-even grade are the same.

Profits = Revenues – Costs

At break-even grade, profit = 0, therefore

Revenues = Costs

Cutoff Grade Calculation, Example 1

The operating costs for a gold mine are 55 $/ton. The recovery at the mill is 90%. At a gold price of $400/oz, what is the break- even cutoff grade in oz Au/ton?

The cost per ton is given as $55/ton.

The mill will recover 90% of the contained Au. Therefore, 1 ton of ore yields G*0.9 oz Au, where G is the ore grade in oz Au/ton. At a gold price of $400/oz, the revenue per ton is $400 * G * 0.9.

The cutoff grade G can now be calculated from the equation: Revenue/ton = cost/ton

$400/oz Au * G * 0.9 = $55/ton, G = 0.15 oz Au /ton

Cutoff Grade Calculation, Example 2

The operating costs for a gold mine are 55 $/ton. The recovery at the mill is 90% and the mining dilution is 10%. At a gold price of $400/oz, what is the break-even cutoff grade in oz Au/ton?

One ton of run-of-mine ore at 10% dilution contains 0.9 tons of ore and 0.1 tons of waste. The mill will recover 90% of the contained Au.

Therefore, 1 ton yields G*0.9*0.9 oz Au.

The cutoff grade G can be calculated from the equation: Revenue/ton = cost/ton

$400/oz Au * G * 0.9 *0.9 = $55/ton,   G = 0.17 oz Au /ton

Cutoff Grade Calculation, Example 3

The operating costs for a gold mine are 55 $/ton. The recovery at the mill is 90%. The smelting and refining costs are $10/ oz Au.

At a gold price of $400/oz, what is the break-even cutoff grade in oz Au/ton?

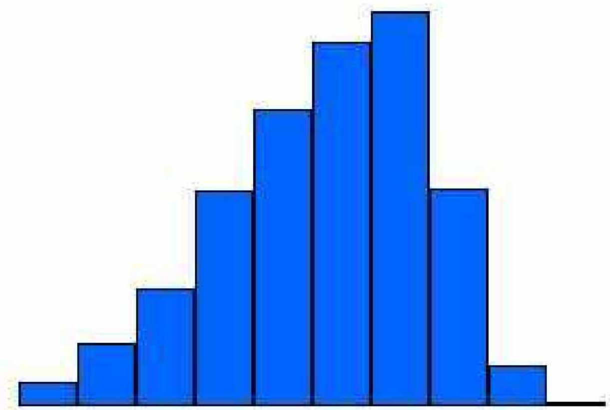
The mill will recover 90% of the contained Au.
Therefore, 1 ton of ore yields G*0.9 oz Au, where G is the ore grade in oz Au/ton.
The refining cost is $10/oz Au. At a gold price of $400/oz, the revenue per ton is

($400-$10)oz Au * G * 0.9.

The cutoff grade G can be calculated from the equation: Revenue/ton = cost/ton
($400/oz Au -$10/oz Au) * G * 0.9 = $55/ton, G = 0.16 oz Au /ton

Frequency Histogram

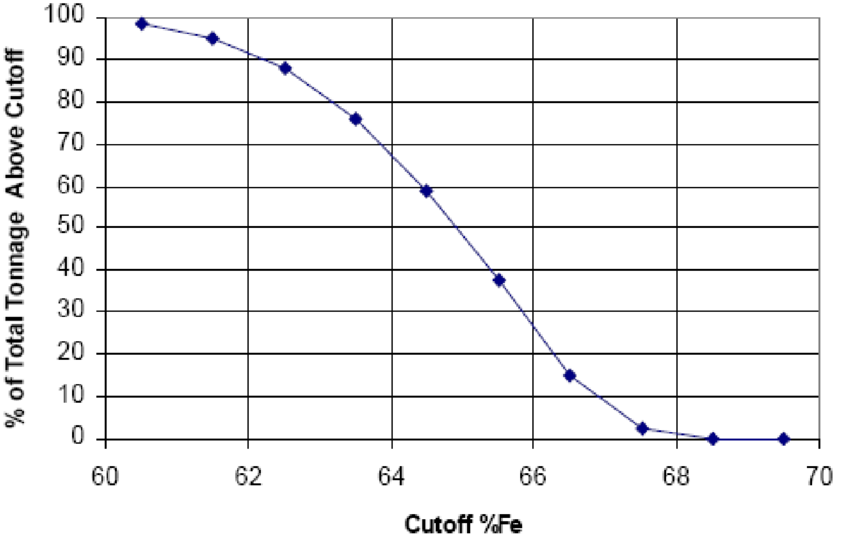
Number of Samples	996
Arithmetic Average	65.2544
Variance	2.9787
Standard Deviation	1.7259
Coefficient of Skewness	-0.4927
Coefficient of Kurtosis	-0.2724
Geometric Mean	65.2314
Median	65.5000
10% Trim Mean	65.3155
Midrange	64.6000
Mean Absolute Deviation	1.4135



Cell	Interval	Frequency(f)	Relative f	Cummulative f
1	60.00 .. 61.00	14	1.41	1.41
2	61.00 .. 62.00	36	3.61	5.02
3	62.00 .. 63.00	68	6.83	11.85
4	63.00 .. 64.00	123	12.35	24.20
5	64.00 .. 65.00	170	17.07	41.27
6	65.00 .. 66.00	209	20.98	62.25
7	66.00 .. 67.00	226	22.69	84.94
8	67.00 .. 68.00	125	12.55	97.49
9	68.00 .. 69.00	23	2.31	99.80
10	69.00 .. 70.00	2	0.20	100.00

Frequency distribution of Fe grades

Grade Tonnage Curve



Average Grade Above Cutoff vrs. Cutoff