GEOLOGICAL INTERPRETATION AND PROSPECTING

Earth Science Engineering MSc

2020/2021 I. semester

COURSE COMMUNICATION FOLDER

University of Miskolc
Faculty of Earth Science and Engineering
Institute of Mineralogy and Geology

Course datasheet

Course Title: Geological interpretation and prospecting **Instructor:** Dr. Földessy János professor emeritus	**Code:** MFFAT730026 **Responsible department/institute: ÁFI**
Position in curriculum (which semester): 3	**Pre-requisites (if any):** Mineral deposits (MFFTT720021)
No. of contact hours per week (lecture + seminar): 2+2	**Type of Assessment (examination/ practical mark / other):** examination
Credits: 4	**Course:** full time

Competencies to evolve:
Knowledge: T1, T2, T3, T4, T5, T7, T8, T9,
Ability: K1, K2, K3, K5, K6, K7, K8, K9, K10, K11, K12, K13,
Attitude: A1, A2, A3, A4, A5, A7,
Autonomy and responsibility: F1, F2, F3, F4, F5

Acquired store of learning:

Study goals:To develop ability interpreting results of observations and data acquisition regarding exploration of geological media and mineral raw materials, sampling during mapping, drilling exploration. It makes capable to evaluate the geological data from mining and processing aspects, and making economic decisions regarding exploration and exploitation based upon the results.
Gaining experience in using softwares for geological documentation and evaluation. Preparation o f geological models in sample databases using professional softwares, like Rockworks.
Course content:

- Short summary of the most important mineral exploration techniques and methods in the field and in the office.
- Study of statistical evaluations, the effect of natural variability
- Processing of archive geological exploration data to reveal the types of errors in geological interpretation and the way of their mitigation.
- Mineral resource assessment, preparation of comprehensive geological reports,
- Geoinformatic processing of mineral raw material exploration data,
- Thematic map preparation and reading,
- Determining statistical parameters

Education method: Lectures and parallel exercises - exercises are prepared from real archive geological data-
Working in teams (3 students each):

- Assignment of evaluation of complex thematic map series regarding mineral potential of unexplored areas,
- Geostatistical processing of mineral exploration data,
- regional development database and map series evaluation, preparation of a raw material utilization plan,

Type of Assessment(exam. / pr. mark. / other): **pr. mark**
During the semester the following tasks should be completed: two quizes (30-30%), one ppt presentation of a technical report (20%), completing tasks on (20%).

Grading limits:
>80%: excellent,
70-79%: good,
60-69%: medium,
50-59%: satisfactory,
<50%: unsatisfactory.

Compulsory or recommended literature resources:

- Földessy J (2006): Ásványi nyersanyag kutatás és földtani értelmezés (CD és Internet, www.tankonyvtar.hu)
- Benkő F (1970): Asvanykutatas es banyaföldtan. Műszaki Konyvkiado Budapest.451 p.
- Reedman J. H. (1979): Techniques of Mineral Exploration – Applied Science Publishers London 533 p.
- Bíró L. (szerk): Teleptan. Geolitera, Szeged
- Dill H. G. (2010): The „chessboard" classification schene of mineral deposits. Elsevier, 2010.
- Végh Sné (1967): Nemércek földtana. Tankönyvkiadó, 281.p.

Syllabus of the semester

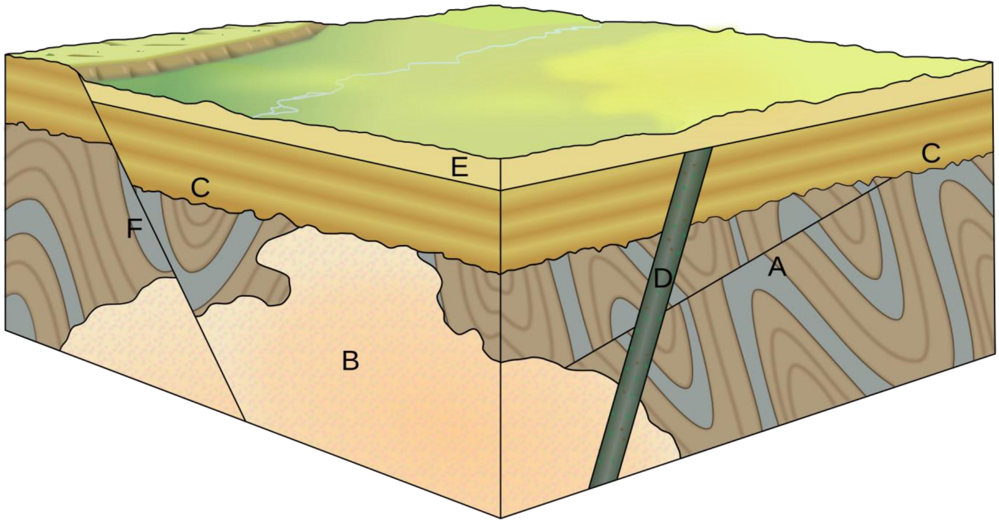
Geological interpretation and prospecting
2020.09.08. – 2019.12.08.
Lecture: Tuesday, 12:00 – 16:00, Lectures are ONLINE subject to pandemia situation. Practices are held on seperate days from lectures, thus 7 lecture days and 6 practice days are in schedule.

Date	Lecture
2020.09.08.	**Lecture: Short summary of the most important mineral exploration techniques and methods in the field and in the office**
2020.09.15.	**Lecture: Project generation and planning**
2020.09.22.	Field trip related to Practice teamwork: Rudabanya and Martonyi
2020.09.29.	Field trip related to Practice teamwork: Izsofalve core-store
2020.10.06.	Laboratory works – sample preparation
2020.10.13.	Laboratory work: Processing of geochemical exploration data
2020.10.20.	PARTICIPATION ON THE RAW MATERIALS UNIVERSITY DAY
2020.10.27.	Laboratory work – chemical analysis methods and evaluation - XRF
2020.11.03.	Laboratory works – ROCKWORK modelling project atart
2020.11.10.	**Lecture: Geological works during drilling exploration**
2020.11.19.	**Lecture: Geological Data Processing**
2020.11.26.	**Lecture: Geological Data in Space**
2020.12.01.	**Lecture: Resource Estimation Basics**
2020.12.08.	**Lecture: Financial evaluation**

Quiz sample task sheet

Geological interpretation test1 18 October 2017	Name	

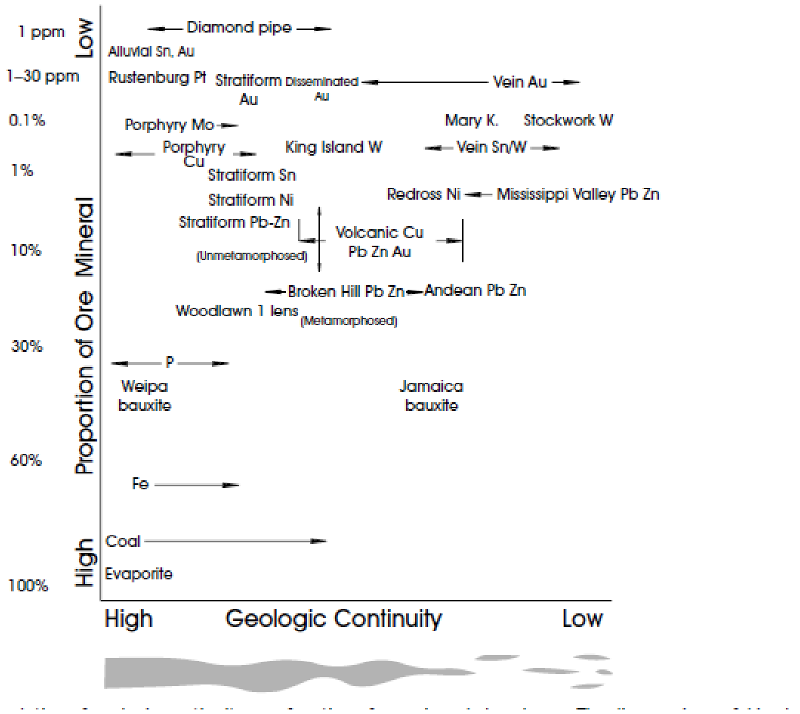
1. Please fill the table with the possible respective geological age names (epochs), according to the relative age relationships shown on the block diagram, giving also the absolute age in Million years



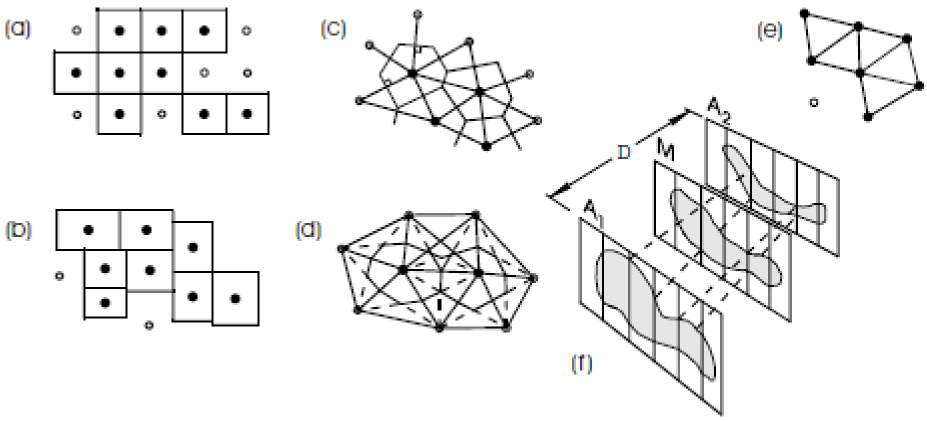
C	?
B	?
D	Cretaceous
A	?
E	?
F	?

2. Minerals and chemical compositon
A mineral sample produced 10 % Cu assay. What is its chalciopyrite content, if all copper is in chalcopyrite? What is the estimated specific density of the sample if the other component is quartz. The necessary data are: Chalcopyrite chemical composition: 35 % Cu, 30 % Fe, 35 % S,   specific densities: chalcopyrite 4,3 g/cm3, quartz 2,6 g/cm3.

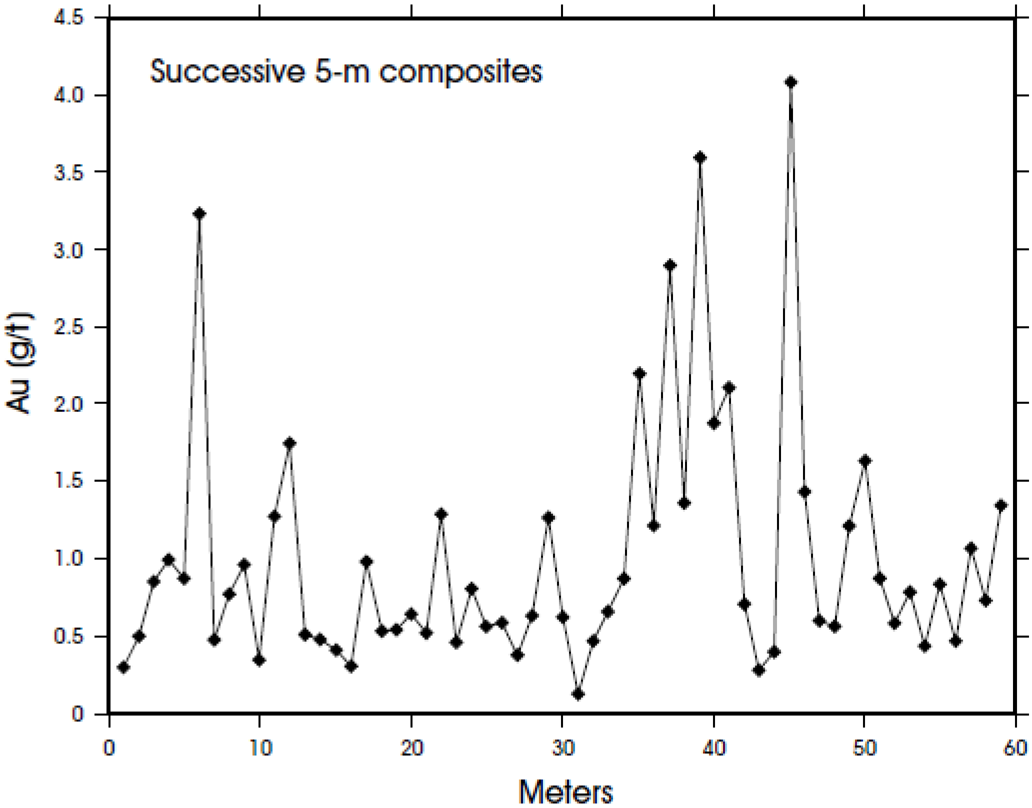
3. Continuity. The diagram shows geological continuites. There are two entries for bauxite, Weipa and Jamaica. Can you explain why it is low the one and why it is high the other?



4. There are the classical volume estimation techniques shown in the diagrams below. Please explain them briefly, indicate the optimal geological situation to use them. Also indicate what volume/grade estimation errors may be introduced by using the different methods.



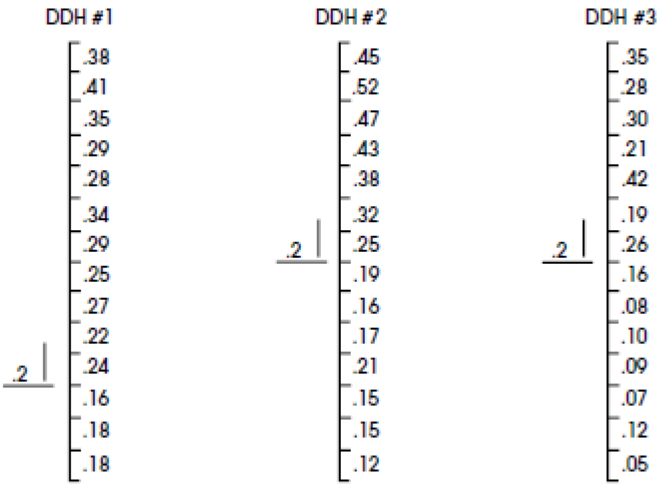
5. Cut-off grade



Explain how cut-off grade effects continuity of gold veins – give the continuous intervals above cut-off grade at 0.2 and 0.5 g/t.

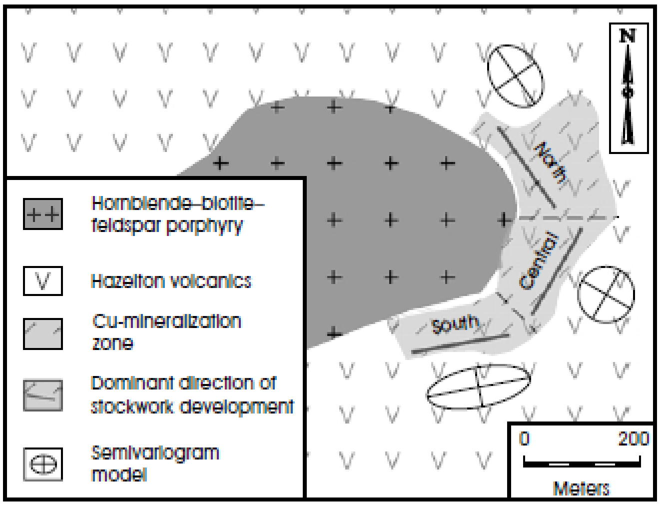
6. Orebody boundary

The orebody boundary in many cases depends upon the cut-off grades used. The one below indicates the 0.2 % MoS_2 cut off grade. Please indicate the boundary of the same orebody at 0.25 % and 0.15 % MoS_2. Draw the boundary where three consecutive sample values are below the cut-off grade.

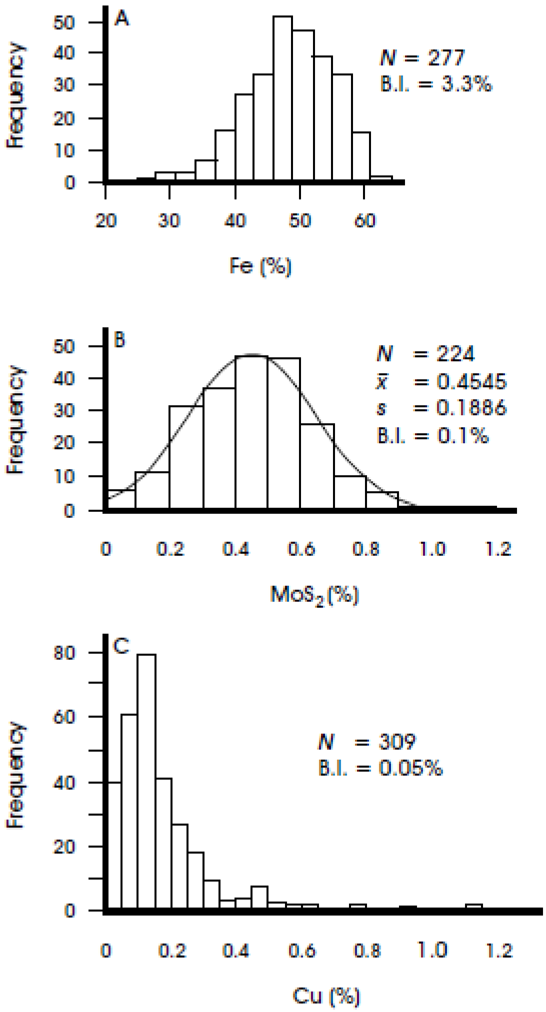


7. Contrast the different character of geologic continuity and value continuity in each of the following scenarios:
(a) A zone of sheeted veins versus a stockwork zone
(b) Massive Cu–Ni versus network Cu–Ni in ultramafic rocks
The problem can be answered effectively by constructing sketches of the various mineralization styles and superimposing ellipses to represent geologic and value continuity in a relative manner.

8. This is a map of the contact zone of a porphyry copper mineralization. Please recommend sampling grids for the Central, Southern and Northern zones, according to the semivariogram model. Give also explanation of your decision



9. Normal distribution and skewness. Please choose from the diagrams below the one showing the approximate normal distribution, and the one with negative and other with positive skewness.



10. Please describe what is described by the following relationship? Indicate an geological ore formation which would give a positive example of this relationship.

$$s_{xy} = \sum[(x_i - m_x)(y_i - m_y)]/n$$

<u>Értékelés:</u>

Minden helyes válasz 3 pont, részben helyes válaszokra 1-2 pont adható

Elérhető maximum: 30 pont

Elérendő minimum a beszámoló teljesítéséhez: 10 pont

Complex evaluation task sheet

Geological interpretation – Exercises

Test **Lab** **Home**

1/1. In mine development and in producing mines, it is common practice to stockpile material that is below cutoff grade but above some other arbitrary lower threshold. For example, in a porphyry copper deposit with a cutoff grade of 0.35% Cu, material in the range 0.25–0.35% Cu might be stored for subsequent easy retrieval. Explain why this “low-grade stockpile” material might, at some future date, be fed through the mill.

1/2. (a) Estimate an optimal cutoff grade for the grade–tonnage scenario summarized in Table 1.2 using 90 percent recovery and a metal price of $1.00 per unit. Note that the tabulation is based on short tons of 2,000 lbs. The calculations should be tabulated as in Table 1.3.
(b) Estimate an optimal cutoff grade for the grade–tonnage scenario summarized in Table 1.2 using mining costs of $0.84/ton and other parameters as in question 2(a). The results should be tabulated as in Table 1.3.
(c) Compare the results of question 2(a) with the results of question 2(b). The combined scenario of questions 2(a) and 2(b) can be compared by estimating a cash flow using the revenue data determined in question 2(a) and the operating costs calculated in question 2(b).
Suggestion: These questions are dealt with conveniently using a spreadsheet.

Table 1.2 Grade–tonnage relations that simulate a typical porphyry copper deposit

Cutoff grade	*Tons of ore (millions)*	*Average grade ore*	*Strip ratio*
0.18	50.0	0.370	1.00:1
0.20	47.4	0.381	1.11:1
0.22	44.6	0.391	1.24:1
0.24	41.8	0.403	1.39:1
0.26	38.9	0.414	1.57:1
0.28	35.9	0.427	1.78:1
0.30	33.0	0.439	2.03:1
0.32	30.0	0.453	2.33:1
0.34	27.2	0.466	2.68:1

Source: After John (1985).

Table 1.3 Calculation of cash flow (dollars per ton milled) for example in Table 1.1[a]

Cutoff grade	*Average ore grade*	*Strip ratio*	*Operating cost ($/t)*	*Total revenue*	*Operating cash flow*
0.18	0.370	1.00:1	3.50	5.24	1.74
0.20	0.381	1.11:1	3.58	5.38	1.80
0.22	0.391	1.24:1	3.68	5.54	1.86
0.24	0.403	1.39:1	3.80	5.70	1.90
0.26	0.414	1.57:1	3.93	5.86	1.93
0.28	0.427	1.78:1	4.09	6.04	1.95
0.30	0.439	2.03:1	4.28	6.22	1.94
0.32	0.453	2.33:1	4.50	6.40	1.90
0.34	0.466	2.68:1	4.76	6.59	1.83

[a] Results in Table 1.3 can be obtained from information in Table 1.2 with $MC = 0.76$, $FC = 1.98$, recovery = 0.83, and a metal price of $0.85/lb in formulas 1.1 and 1.3.
Source: After John (1985).

1/3. Construct a close-spaced regular grid (e.g., 1 × 1mm2 cell) on transparent paper (e.g., photocopy appropriate graph paper onto a transparency). Use the grid to estimate in two dimensions the effect that dilution will have in reducing the grade of mined material relative to the expected grade in the hypothetical example of Fig. 1.12.

Confine your estimate to the area between the two drill holes. Assume average grades of 1.0% Ni for drill hole No. 1, 1.5% Ni for drill hole No. 2, and 0.2% Ni for the diluting material. Assume further that mining will be constrained exactly between the dashed lines of Fig. 1.12. Estimate relative areas by counting squares with the transparent grid and use relative areas as weights. Using a similar counting technique, estimate the relative amount of ore left unmined between the two drill holes. In place of gridded paper, this problem could be solved using a planimeter or a digitizer and appropriate software.

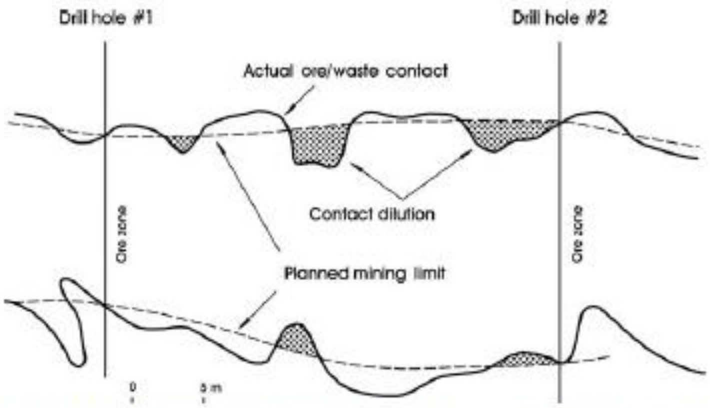


Figure 1.12: Depictions of an irregular ore–waste contact approximated by smooth dashed lines that are interpreted using information from drill holes (on sections), but that are interpolated between drill holes. With such irregular contacts, the method of sections must necessarily be incorrect (i.e., it can only coincidently result in the correct grade estimate for the interpolated zone because some waste is included within the interpreted zone of mineralization). Modified from Stone and Dunn (1994).

1/4. A stope with rectangular outline on a vertical section has been defined on the longitudinal section of a near-vertical gold–quartz vein cutting basaltic rocks. Stope definition is based on 25 vein intersections by exploratory diamond-drill holes. The stope has a horizontal length of 24 m, a verticalheight of 15 m, an average thickness and standard deviation of 2.7 ± 0.4 m, and an average grade of 19.5 g Au/t. Estimate the effect of dilution on grade and tonnage of mined material if the mining method overbreaks the ground byan average of 0.4 m on both sides of the vein and the wallrock averages (a) 0.05 g Au/t, and (b) 5.3 g Au/t. Ignore any complications that arise because of a minimum mining width, and assume that bulk densities of ore and wallrock are thesame.

1/5. Use of the polygonal approach to block estimation (cf. Figs. 1.11 and 1.13) is in conflict with the recognition that the dispersion of average grades decreases as the volume being considered increases (the support effect, see Fig. 1.8).With this difficulty in mind, comment on the two following situations:

(a) Continuous samples from vertical drill holes on a square 50-m grid are used to estimate an array of blocks, each 500 m^3 (i.e., 10 × 10 × 5 m^3).

(b) Blocks to be estimated (500 m^3) each contain a roughly regular array of four blasthole samples. Constructing plans of the two estimation scenarios is useful.

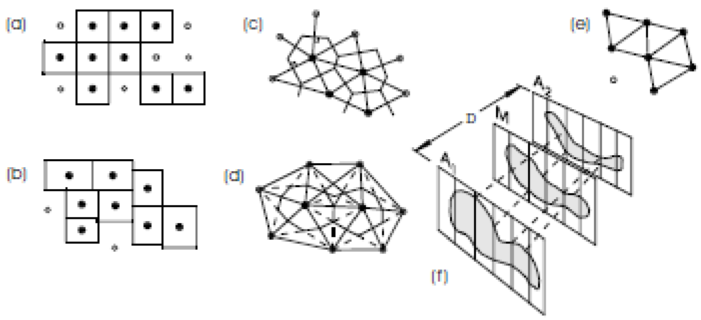


Figure 1.11: Examples of some common methods of grade estimation (after Patterson, 1959). (a) Polygonal: uniform rectangular blocks centered on uniformly spaced data. (b) Polygonal: nonuniform rectangular blocks centered on irregularly spaced data. (c) Polygonal: polygons defined by perpendiculars at midpoints between data points. (d) Polygonal: polygons about data points defined by bisectors of angles in a mesh of contiguous triangles. (e) Triangular: each polygon is assigned an average of grades at three vertices. (f) Method of sections: ore outlined on drill sections and weighted average grade determined on individual sections. Ore between sections is interpolated, commonly by a simple linear interpolation between neighboring sections.

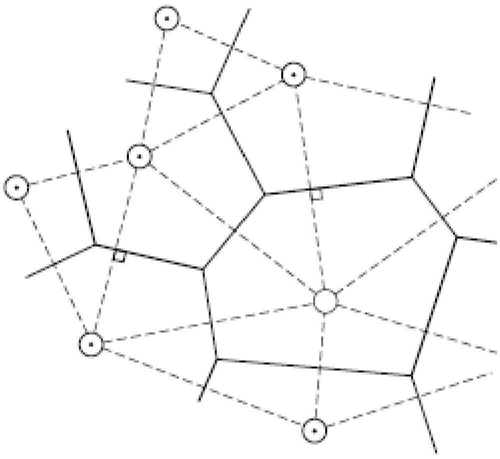


Figure 1.13: Details of the construction of a polygonal area to which a single contained grade is applied (i.e., the contained sample grade is extended to the polygon). Circles are data points; dashed lines join adjacent data points and form Delaunay triangles; thick lines defining a polygon (Voronoi tesselations) are perpendicular to the dashed lines and divide the dashed lines into two equal segments.

1/6. Use the data of Table 1.6 and Fig. 1.9 to estimate the mean grade of the large block of Fig. 1.9 and each of the "quadrant blocks" using 1/*d* and 1/*d*2 weighting schemes. Compare results with the estimate interpolated from contours and comment on the similarities or differences.

Table 1.6 Coordinates and data values for estimation of the panel in Fig. 1.9

Sample no.	*x Coordinates*[a]	*y Coordinates*[a]	*Grade (% Cu)*
1	15	75	0.3
2	90	90	0.8
3	90	50	0.5
4	65	15	0.2
5	60	45	0.6

[a] Distances in meters.

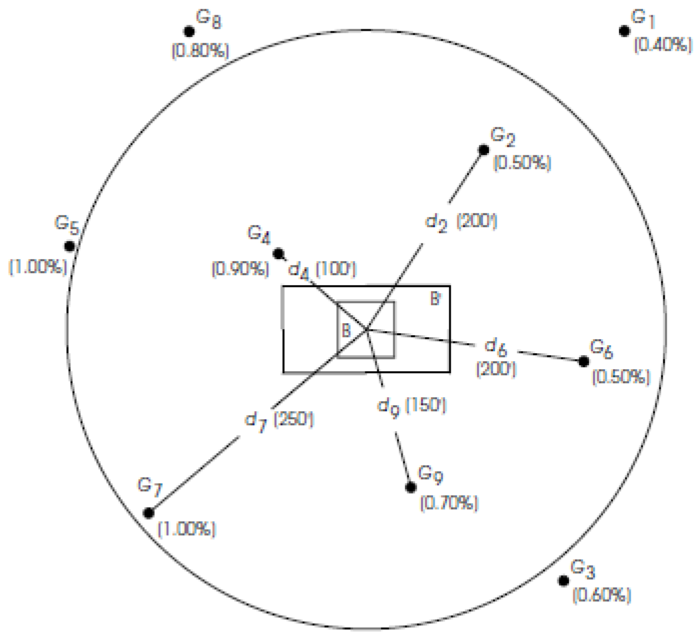


Figure 1.15: Illustration of block estimation using the method of inverse distance weighting (IDW) with hypothetical data (after O'Brian and Weiss, 1968). This is a common method of point interpolation (i.e., the central point of the blocks) but is used routinely for block estimation (e.g., B or B'). (Refer to Table 1.7.) Note that a given data array produces the same block estimate regardless of block shape and/or size.

1/7. The data of Table 1.7 and Fig. 1.15 have been used to determine a block estimate using $1/d^2$ as the weighting procedure.

Table 1.7 Grades, distance, and weights used for the inverse squared distance block estimate of Fig. 1.15[a]

Sample	Cooper (%)	d^b	$1/d$	$1/d^2$	$1/d^3$
G1	0.4	360			
G2	0.5	200	0.005	0.000025	0.125×10^{-6}
G3	0.6	290			
G4	0.9	100	0.01	0.0001	1.0×10^{-6}
G5	1.0	275			
G6	0.5	200	0.005	0.000025	0.125×10^{-6}
G7	1.0	250	0.004	0.000016	0.064×10^{-6}
G8	0.8	320			
G9	0.7	150	0.0067	0.000044	0.195×10^{-6}
Sum			**0.0307**	**0.00021**	$\mathbf{1.609 \times 10^{-6}}$
[b]Estimated block grade			0.74	0.77	0.81

[a] Nearest-neighbor grade estimate = 0.9; local average (five nearest grades) = 0.72.
[b] Distance to block center.

(a) Calculate the estimated block grade using a weighting factor of $1/d$ and again with a weighting factor $1/d^3$.
(b) Compare results with those given in Table 1.5 and the nearest neighbor estimate. Comment on any systematic pattern to the variation in estimated grades as a function of change in the power, x, of the weighting factor ($1/d^x$).

Table 1.5 Examples of the information base required for a mineral inventory study

Location	Surveyed maps: cross sections showing locations of geologic control, mineral showings, sample locations, drill-hole locations/orientations, exploration pits, and underground workings; an indication of the quality of location data of various types.
Geologic	Detailed geologic maps and sections showing rock types, structural data, alteration, mineralization types, etc.; reliability of geologic information; description of supporting geochemical and geophysical survey data/intepretations; factual data distinguished from interpretation; documentation of drill-hole logging procedures (including scales and codes used); detailed drill logs; textural and mineralogic features of importance to mill design; spatial variability of geologic features that have an impact on mill and mine design, including effects on metal/mineral recovery and determination of cutoff grade; ore deposit model with supporting data; geologic influence on external and contact dilution; justification for separate domains to be estimated independently.
Sampling/assaying	Descriptions of all sampling methods, including quantification of sampling variability; sample descriptions; sample reduction procedures and their adequacy; bulk sampling design/results; duplicate sampling/assaying program.

1/8. Construct graphs of distance, d (abscissa), versus $1/d$, $1/d^2$, $1/d^3$, and $1/d^4$ for $0<d<200$. Assuming a case of three samples with distances from a point (block) to be estimated of 10, 50, and 150 units, comment on the relative importance of the data with $d = 10$.

1/9. A press release by a mineral exploration company contained the following statement regarding a mineral occurrence in a remote part of South America: “An immediate drilling program is planned to expand the existing reserves of 5,132,306tons of ore grading .07 oz/t gold 6.9 oz/t silver, which is open in all directions.” Discuss the content of this statement in detail.

2/1. Select a well-described ore-deposits model from one of the many compilations of such models (e.g., McMillan et al., 1991; Roberts and Sheahan, 1988; Sheahan and Cherry, 1993). Write a three- to five-page account of the model and
include specific discussion of those features that have a direct impact on mineral inventory estimation.

2/2. The proceedings volumes of symposia on the geology of mineral deposits invariably contain cross sections of the individual deposits considered. Select one such deposit/paper and provide a critique of the cross sections or plans from the perspective of their use in separating fact from interpretation and their potential use for resource/reserve audit purposes.

3/1. Contrast the different character of geologic continuity and value continuity in each of the following scenarios:
(a) A zone of sheeted veins versus a stockwork zone
(b) Massive Cu–Ni versus network Cu–Ni in ultramafic rocks
(c) A feeder zone of a volcanogenic massive sulphide deposit versus an upper, stratified sulphide sequence of the same system. The problem can be answered effectively by constructing sketches of the various mineralization styles and superimposing ellipses to represent geologic and value continuity in a relative manner.

3/2. Table 3.1 provides U_3O_8 data (%) for contiguous samples from eight drill holes (after Rivoirard, 1987). Construct a grade profile for any three consecutive drill holes and comment on the continuity of both low and high grades (see also Fig. 7.9). Assume that individual values are for 2-m samples and that the drill holes are vertical, collared on a flat surface, spaced at 25-m intervals, and numbered consecutively across a mineralized field of flatly dipping sandstone beds.

Table 3.1 Sample values of simulated U_3O_8 grades in eight drill holes[a]

No. 1	*No. 2*	*No. 3*	*No. 4*	*No. 5*	*No. 6*	*No. 7*	*No. 8*
0.79	0.09	0.10	0.62	1.13	0.08	0.12	0.16
0.19	0.09	0.94	0.52	1.32	0.08	0.12	0.16
0.51	0.09	0.10	0.27	2.13	0.00	1.52	0.16
0.56	0.83	0.53	0.35	2.82	0.08	0.62	0.18
1.26	0.16	0.10	0.28	0.62	0.08	0.12	0.42
1.14	0.09	0.10	0.30	2.35	0.08	0.12	0.16
2.47	0.09	0.97	5.46	19.17	0.06	0.12	0.1
5.86	0.82	0.45	25.47	1.81	0.08	0.12	0.45
26.89	1.14	3.16	0.15	9.06	0.08	0.12	0.16
24.07	6.52	5.41	0.15	10.98	0.08	0.12	0.16
20.59	0.24	50.43	0.15	12.05	0.08	0.12	0.16
10.30	0.09	11.17	0.15	3.66	2.10	0.12	0.16
5.31	0.20	0.23	0.88	6.76	0.98	0.12	0.16
57.94	0.09	0.20	0.99	3.37	3.53	0.12	0.16
26.04	0.09	0.33	0.15	0.23	9.63	0.12	0.16
22.34	1.82	0.10	0.56	1.74	20.33	0.12	0.16
11.52	0.09	0.19	0.53	0.21	12.11	0.12	0.16
42.79	0.09	0.22	4.51	0.17	4.17	0.12	0.16
1.50	18.07	0.20	0.25	2.57	1.25	0.12	2.17
9.89	38.72	1.14	0.15	2.68	0.08	0.12	0.23
2.33	27.98	1.04	0.15	0.92	0.69	0.94	0.16
0.67	3.93	0.10	5.00	1.94	0.08	5.60	0.16
1.48	5.81	0.10	4.54	0.17	0.08	0.82	0.16
0.15	0.65	0.10	1.64	0.17	0.19	1.40	0.16
0.42	0.09	0.10	0.15	0.17	0.08	6.77	0.26
0.82	0.09	0.10	0.15	0.17	0.20	18.26	3.36
1.48	0.09	0.10	0.15	0.17	0.30	11.14	1.43
4.72	0.09	0.10	0.15	0.17	0.56	4.82	5.00
6.57	0.09	0.10	0.15	0.17	0.69	3.98	17.88
3.31	0.09	0.10	0.15	0.17	0.08	1.67	1.79
4.13	1.43	0.25	3.04	0.17	0.08	1.42	1.36
11.31	0.32	0.10	9.57	0.17	0.08	0.23	11.84
12.48	0.09	0.10	6.67	0.17	0.08	1.61	1.73
7.68	5.19	0.10	5.95	0.17	0.08	1.58	0.23
12.17	1.74	0.10	0.96	0.17	0.08	1.96	0.53
0.59	0.09	0.10	5.66	0.17	0.08	3.72	0.16
0.15	1.52	0.57	0.58	0.17	0.08	9.16	0.16
1.04	12.20	0.55	0.15	0.17	0.08	3.09	0.16
1.05	2.19	0.10	0.15	0.17	0.08	0.49	0.16
1.73	1.28	0.10	0.15	0.17	0.08	0.12	0.16
1.98	0.21	0.96	0.15	0.17	0.08	0.12	0.16
3.54	0.09	1.08	0.59	0.17	0.71	0.12	0.16

[a] After Rivoirard (1987).

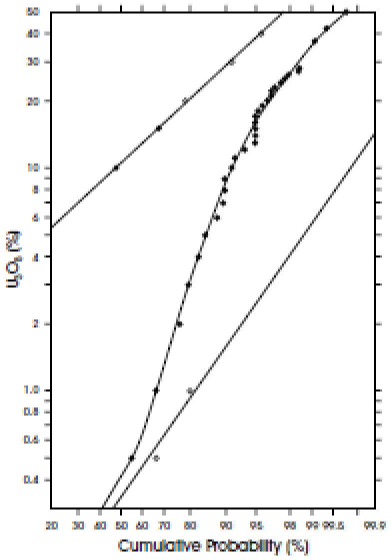


Figure 7.9: Probability graph for 336 simulated U_3O_8 values for eight diamond-drill holes (data from Rivoirard, 1987). The raw data (dots) are approximated by a smooth curve (bimodal model) that has been partitioned into upper ($A = 17$ percent) and lower ($B = 83$ percent) lognormal subpopulations, separated by a threshold of about two. Circles are partitioning values used to derive the two ideal subpopulations. Note that values have been cumulated from low to high, a variation common in technical literature.

3/3. Figure 2.1 is a geologic plan of the surface pit, Endako molybdenum mine, central British Columbia (after Kimura et al., 1976). Assuming this level to be representative of the deposit, comment on geologic and value continuity models for the deposit.

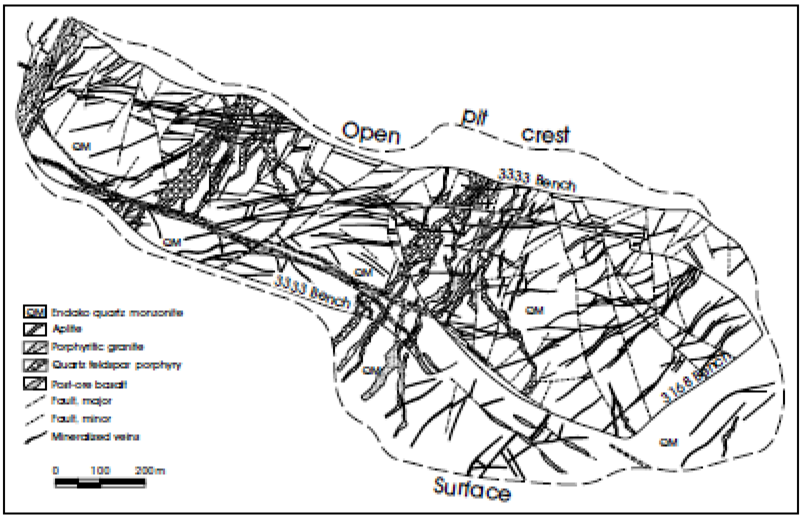


Figure 2.1: Detailed geologic plan of the open pit at Endako porphyry-type molybdenum mine, central British Columbia. Note the different trends of principal veins from place to place in the deposit (i.e., different structural domains with gradational boundaries) and premineral and postmineral dykes. Mineral zoning (not evident on this diagram) is emphasized by a pyrite zone along the south margin of the pit. After Kimura et al. (1976).

3/4. Consider a 100-m (northerly) by 30-m horizontal zone of vertical, sheeted veins striking N–S. Individual veins are 2–4 cm wide, can be traced for 20–30 m along the strike, and are spaced at 10–15 cm intervals across strike. Three lines of samples have been taken across strike: 25, 50, and 75 m north of the south boundary. Each line crosses the entire 30-m width of the deposit and is composed of six contiguous 5-m samples.
(a) Comment on the quality of the sampling plan, assuming it to be an early stage evaluation.
(b) The grade estimation problem is two-dimensional at this stage. How would you arrange an array of 5 × 10 m^2 blocks for estimation? Why?
(c) Categorize the blocks in your array into several groups of relative quality of estimate.

4/1. Given three contiguous drill core samples of lengths 2, 3, and 5 m that assay 3%, 6%, and

12 percent Zn, respectively, compare the arithmetic mean of the assays with the weighted mean, assuming that density is uniform throughout. What is the weighted mean Zn grade if the respective specific gravities are 3.2, 3.7, and 4.1?
Compare the unweighted standard deviation with the weighted standard deviation.

4/2. (a) Calculate the mean and variance of the 60 integer values of Fig. 4.1. Construct a lognormal distribution with the same mean and variance.

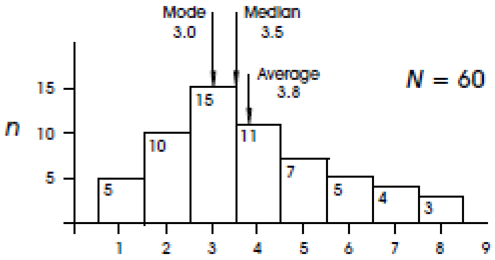


Figure 4.1: Histogram of a hypothetical data set of integer values (abscissa) illustrating that modes, medians, and means can differ for a single data set. Numbers of data within each class are listed in each bar.

(b) Assuming perfect lognormality and a cutoff grade of 3.5, determine (1) the proportion of volume above cutoff grade and (2) the average grade of the material above cutoff grade. Compare these estimates with those determined directly from the data.
(c) Suppose that the spread of original values includes an abnormally high sampling plus analytical variance (%2) that has been reduced by an absolute amount of 0.55 through the implementation of an improved sampling procedure.
Recalculate the proportion of volume above cutoff and the average grade of material above cutoff (assuming lognormality) using the new dispersion. The difference between these estimates and those of part (b) provide an indication of false tonnage and grade that can result from large errors in assay data.

4/3. A grain count of 320 grains of heavy mineral concentrate yielded 7 grains of cassiterite (SnO_2). Calculate the error of the estimate. What is the likelihood that the true grain count is 4 or less?

4/4. Calculate the probability of 0, 1, 2, 3, . . . nuggets of gold in a sample of 2,000 grains known to contain, on average, 2 nuggets per 5,000 grains?

4/5. A 0.5-kg sample of a placer sand has an average grain size of 2 mm, and grain counts show that the average scheelite content is 3 grains. What is the proportion of random samples that on average contain 0, 1, 2, . . . grains of scheelite? What is the expected WO_3 content of samples with a weight of 3 kg, assuming that only quartz and scheelite
are present?

4/6. A sample of approximately 2,500 grains yields 0 grains of gold in a region where other samples contained some gold grains. What is the probability that the 0-grain result is simply an expected sampling variation of a material that contains an average of 0.5 grains of gold per 2,500 grains? What would the probability be of 0 gold grains if the sample size were doubled?

4/7. The following tabulation contains class interval and cumulative percentages for 120 Au analyses from a polymetallic, massive sulphide deposit:

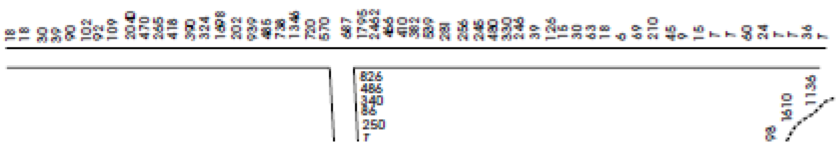
Grade (%U_3O_8) of Data	Cumulative %
0.2	22.0
0.3	34.0
0.5	46.0
1.0	54.0
1.5	60.0
2.5	69.0
5.0	75.0
82.0	90.0
20.0	94.7

(a) Construct the histogram and fit by a normal or lognormal probability density function.
(b) Calculate the mean and standard deviation of the data. Note that this can be done using frequencies (specifically, Freq/100) as weights.
(c) Plot the data on both arithmetic and logarithmic probability paper. Estimate the parameters in each case and compare with the results of (b).
(d) Assuming that the histogram is unbiased, use a normal or lognormal approximation (whichever is best) to calculate the proportion of tonnage above a cutoff grade of 2.25 g/t Au.

4/8. The gold data (inch-pennyweight) of Fig. 4.19 (cumulated in Table 4.4) are shown in a simple and widely used form of presentation for planning purposes in tabular deposits (Royle, 1972). Plot the data on arithmetic and log probability paper and interpret. Interpretation should include comment on the form of the distribution, the possibility of
the presence of two or more subpopulations, and, if possible, a rough estimate of thresholds between subpopulations.

Table 4.4 Tabulation of assay data (in dwt) shown in Fig. 4.19

Value (in dwt)	*Lower drift*	*Number in upper drift*	*Raise*	*Total number*	*Cumulative number*	*Cumulative percent*
Trace	3	5	5	13	13	9.42
<10	1	2	0	3	16	11.59
10–20	1	5	4	10	26	18.84
20–30	4	3	0	7	33	23.91
30–40	0	3	0	3	36	26.09
40–50	0	1	0	1	37	26.81
50–60	5	1	1	7	44	31.88
60–70	0	2	1	3	47	34.06
70–80	1	0	0	1	48	34.78
80–90	3	1	1	5	53	38.41
90–100	0	1	0	1	54	39.13
100–200	7	3	0	10	64	46.38
200–300	1	7	1	9	73	52.90
300–400	2	4	1	7	80	57.97
400–500	3	6	3	12	92	66.67
500–600	2	2	0	4	96	69.57
600–700	3	1	0	4	100	72.46
700–800	4	2	2	8	108	78.26
800–900	1	0	2	3	111	80.43
900–1,000	4	1	1	6	117	84.78
1,000–1,100	3	0	2	5	122	88.41
1,100–1,200	0	0	1	1	123	89.13
1,200–1,400	3	1	3	7	130	94.20
1,400–1,600	0	0	0	0	130	94.20
1,600–1,800	3	2	0	5	135	97.83
1,800–2,000	1	0	0	1	136	98.55
2,000–3,000	0	2	0	2	138	100.0



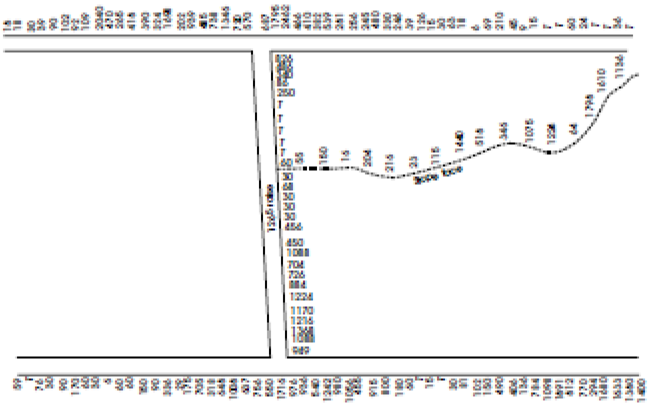


Figure 4.19: Data for underground workings of a gold-bearing quartz vein. Values are in dwt at regular intervals along underground workings and along a stope face. Redrawn from Royle (1972).

4/9. The following cumulative data (U_3O_8) represent 1,081 analyses for a uranium deposit (Isaaks, 1984). Parameters are: *m* =4.87%, *s* =7.84, *CV* =1.61. Plot the data on both arithmetic and log probability paper. Comment on the probable number of subpopulations and the problem(s) that arises in determining this number.

Grade (%U_3O_8) of Data	Cumulative %
0.2	22.0
0.3	34.0
0.5	46.0
1.0	54.0
1.5	60.0
2.5	69.0
5.0	75.0
82.0	90.0
20.0	94.7

5/1. The following sampling protocol for a gold ore (after Davis et al., 1989) can be plotted graphically, either manually or using GYSAMPLE software (which can be downloaded through publisher's website). A 3- to 5-kg sample of blasthole cuttings was dried and crushed to 95 precent −2 mm. A 1-kg split is pulverized to 100 μ, and 500 g is taken for assay. Of the 500 g split, 50 g were used for fire assay. Construct and evaluate the sampling diagram. Compare your interpretation with the conclusion of Davis et al. (obtained by independent experimentation) that "assay repeatability
in the Colosseum ores would be enhanced by a particle size reduction before the initial sample split" (1989, p. 829).

5/2. Plot and comment on the adequacy of the following subsampling protocol for the Mt. Hope molybenum prospect (Schwarz et al., 1984): each 3-m segment of drill core is split and one-half (approximately 10,000 g) is bagged; this sample is crushed to 2 mesh (jaw crusher) and further crushed to 10 mesh (cone crusher). The conecrushed product is reduced to about 1/8th volume (about 1,200 g) with a riffle splitter. The split is pulverized to 80 mesh, rolled, and further split to produce two 100-g subsamples. One of the 100-g subsamples is further pulverized to 200 mesh and a 25-g split is taken for commercial assay. Metric equivalents of mesh sizes are given in Appendix 2.

5/3. The data file J&L.eas (which can be downloaded through the publisher's website) contains 55 quadruplicate samples, each set of quadruplicate samples representing coarsely crushed material from one drill round (ca. 30 short tons). Each set of quadruplicate samples were cut as material passed into a sampling tower, and all four subsamples
were passed through the same subsampling protocol and analyzed in the sameway for five elements: Au, Ag, As, Zn, and Pb. Evaluate the quality of the assay data using the program ERRORZ, available through the publisher's website.

5/4. Annels (1991, p. 61) discusses the comparative efficiencies of square and offset (triangular) grids for drilling patterns and concludes in part that an "offset grid is . . . more efficient in that drillholes are further apart . . . 29.9% fewer holes to cover the same area with the same degree of confidence." Evaluate the comment "with the same degree of confidence" by discussing the estimation of a central point in each of the basic arrays using a single aureole of data. Assume the patterns and dimensions of Fig. 5.23.

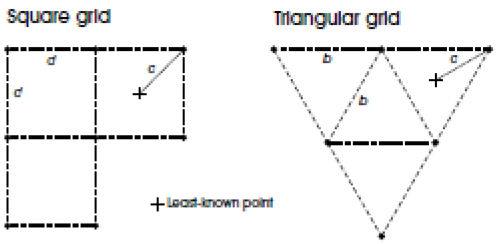


Figure 5.23: Square and triangular grid patterns (cf. Annels, 1991) arranged such that the central point in each case is the same distance from all data in the first surrounding aureole.

6/1. Calculate the values of 10-m composites for each of the following two drill holes:

ddh # 1 From (m)	To (m)	Grade (% Cu)	ddh # 2 From (m)	To (m)	Grade (g Au/mt)
27	28.5	.74	157	159	1.3
28.5	31.5	.60	159	161	3.3
31.5	41.3	.11	161	163	2.2
41.3	43	.44	163	165	4.0
43	45	.16	165	167	4.9
45	47	.51	167	169	1.7
47	49.5	.46	169	171	5.9
49.5	53	.23	171	173	1.5
53 = end of hole			173 = end of hole		

ddh = diamond-drill hole.

6/2. Simulate a single drill hole consisting of 30 successive samples of 1 m, to each of which an assay value has been attributed. For this purpose, it is adequate to select values using random number tables. Construct 2-m, 5-m, and 10-m composites from this simulated data set. Comment on the means and standard deviations for the various data/composite lengths.

6/3. Develop a general algorithm for the formation of bench composites from vertical, exploration, and diamond-drill-core assays. Allow for variable length of core assays, variable starting elevation for a bench, variable bench height, and lost core.

6/4. Plot the data of Table 4.4 on both arithmetic and logarithmic probability paper. Interpret the results.

Table 4.4 Tabulation of assay data (in dwt) shown in Fig. 4.19

Value (in dwt)	*Lower drift*	*Number in upper drift*	*Raise*	*Total number*	*Cumulative number*	*Cumulative percent*
Trace	3	5	5	13	13	9.42
<10	1	2	0	3	16	11.59
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20–30	4	3	0	7	33	23.91
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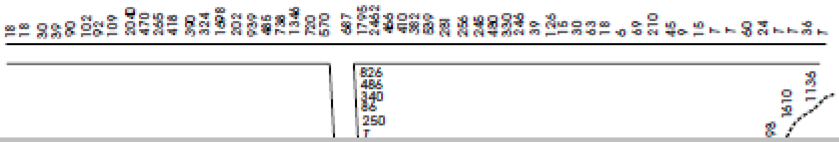
40–50	0	1	0	1	37	26.81
50–60	5	1	1	7	44	31.88
60–70	0	2	1	3	47	34.06
70–80	1	0	0	1	48	34.78
80–90	3	1	1	5	53	38.41
90–100	0	1	0	1	54	39.13
100–200	7	3	0	10	64	46.38
200–300	1	7	1	9	73	52.90
300–400	2	4	1	7	80	57.97
400–500	3	6	3	12	92	66.67
500–600	2	2	0	4	96	69.57
600–700	3	1	0	4	100	72.46
700–800	4	2	2	8	108	78.26
800–900	1	0	2	3	111	80.43
900–1,000	4	1	1	6	117	84.78
1,000–1,100	3	0	2	5	122	88.41
1,100–1,200	0	0	1	1	123	89.13
1,200–1,400	3	1	3	7	130	94.20
1,400–1,600	0	0	0	0	130	94.20
1,600–1,800	3	2	0	5	135	97.83
1,800–2,000	1	0	0	1	136	98.55
2,000–3,000	0	2	0	2	138	100.0



7/1. Construct an idealized scenario in which a 20 × 20×10 m3 block in a porphyry copper deposit is to be estimated by five blasthole samples with values 0.25, 0.35, 0.3, 1.90, and 0.3. Assume that high values in general have been found by geologic investigations to represent 1-m-wide vertical veins that cut the block in a direction parallel to one of the sides and have an extent in the plane of the vein, equivalent to about half the cross-sectional area of the block side. (a) What is the true grade of the block if the high value is outside the block and the other values have equal weight? (b) What is the true grade of the block if the high-valued structure is entirely within the block and the other four samples have equal weight? (c) What is the estimated grade of the block if the high value has a weight of −0.04 and other samples have equal weight?

7/2. The following cumulative data represent 1,081 uranium grades greater than 0.1 percent U, for an unconformity-type uranium deposit in northern Saskatchewan (data from Isaaks, 1984) with a mean of 4.87 percent U and a standard deviation of 7.84. Plot the data on log probability paper and interpret.

U (wt%)	*Cum. freq. (%)*
0.2	22
0.3	34
0.5	46
1.0	54
1.5	60
2.5	69
5.0	75
10.0	82
15.0	90
20.0	94

7/3. The following cumulative gold data (grade vs. cumulative percent) are for an epithermal gold deposit (cf. Stone and Dunn, 1994). Plot the data on log probability paper and interpret.

Au (g/t)	Cum. (%)	Au (g/t)	Cum. (%)	Au (g/t)	Cum. (%)
0.1	30.8	2.1	94.3	4.1	98.0
0.2	47.0	2.2	94.9	4.2	98.2
0.3	59.6	2.3	94.9	4.3	98.5
0.4	68.5	2.4	95.1	4.4	98.8
0.5	74.4	2.5	95.4	4.5	99.0
0.6	77.4	2.6	96.0	4.6	99.0
0.7	80.2	2.7	96.2	4.7	99.0
0.8	82.0	2.8	96.2	4.8	99.0
0.9	84.8	2.9	96.2	4.9	99.0
1.0	86.9	3.0	96.2	5.0	99.5
1.1	89.0	3.1	96.9	.	
1.2	89.5	3.2	96.9	.	
1.3	90.4	3.3	97.2	.	
1.4	90.9	3.4	97.2	.	
1.5	91.4	3.5	97.5	.	
1.6	91.8	3.6	97.5	6.8	100.0
1.7	92.1	3.7	97.7		
1.8	92.7	3.8	97.7		
1.9	92.7	3.9	98.0		
2.0	93.7	4.0	98.0		

8/1. Calculate the *F* function for a 20 × 20 × 10m3 block of ore for which the spherical semivariogram model is C_0 equals 0, C_1 equals 0.08, and *a* equals 40 m.

8/2. Calculate the estimation variance for a twodimensional block 20m × 10m using a centered datum and a datum located at one corner of the block. Use the semivariogram model from Question 1.

Miskolc, 2020. augusztus 31.

Dr. Földessy János
professor emeritus