3 Development Drilling

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Introduction

Data obtained from development drilling provide the basic input for open pit mine planning and design. Development drilling is defined as delineation of the size, mineral content, and disposition of an ore body by drilling boreholes (Thrush, 1968).

The objectives of development drilling are: (1) determining the geometry of the mineralization, (2) determining the grade and tonnage, (3) obtaining samples for metallurgical testing, and (4) obtaining geotechnical data for mine design.

To accomplish these objectives, an appropriate drilling plan must include the number of holes, the spacing and orientation of the holes, and a suitable data collection program. The data collection program covers sample collection, hole logging, and data presentation. This chapter will present some guidelines for development drilling and data collection techniques. The operational aspects of drilling will be covered in another chapter.

Geologic Interpretation and Statistics

The importance of geologic interpretation in development drilling cannot be overemphasized. With the widespread use of mathematical models for ore reserve calculation, it is often assumed that the computer center needs only the assays to come up with a statistical analysis of the data and an accurate estimate of the reserves. Although there are statistical methods for making inferences and for assessing the precision of the estimates, use of these methods is often restricted to certain methods of sampling and types of data.

Cochran, Mosteller, and Tukey (1954) distinguish between the target population and the sampled population in statistical analysis. The target population consists of all items about which inferences are to be made or from which conclusions are to be drawn. In the case of development drilling, the target population would be all of the minable units, e.g., each truckload of material within the pit limits. The sampled population, on the other hand, is the population which is actually sampled. Because of access limitations and restrictions imposed by any realistic drilling pattern, not all of the target population is included in the sampled population. The difference between sampled and target populations is important because "the step from sampled population to target population is based on subject matter knowledge and skill, general information, and intuition, but not on statistical methodology" (Cochran, Mosteller, and Tukey, 1954).

Thus, the validity of an analytical model must ultimately be determined by geologic interpretation, not by statistical tests. Statistics can be used as a guide for evaluation but cannot be substituted for sound judgment based on geologic information and reasoning.

A set of cross sections and a set of level maps are essential for geologic interpretation. Information such as surface geology and drill-hole intercepts should be plotted, without interpretation, on reproducible sheets. From these, copies can be made for use in interpretation. This process will maintain the distinction between observed fact and interpreted geology. Also, as new holes are drilled and as interpretations need to be revised, a new print of the factual sheet can be made. This avoids the messy procedure of erasing and redrafting the well-worn original.

Sections and level maps provide the best means to communicate information to mine planners on rock type and structure. Consequently, geologic sections and level maps should be drawn at the same scale as the mine planning maps. Couzens (1978) suggests 1 in.= 100 ft (1 mm=1.2 m) or 1 in.=200 ft (1 mm= 2.4 m) and 1:1000, 1:1250, or 1:2000 in metric ratios. Detailed geologic mapping and interpretation may be necessary on a large scale such as 1:500; however, maps on this scale can be reduced to a standard scale for use in planning.

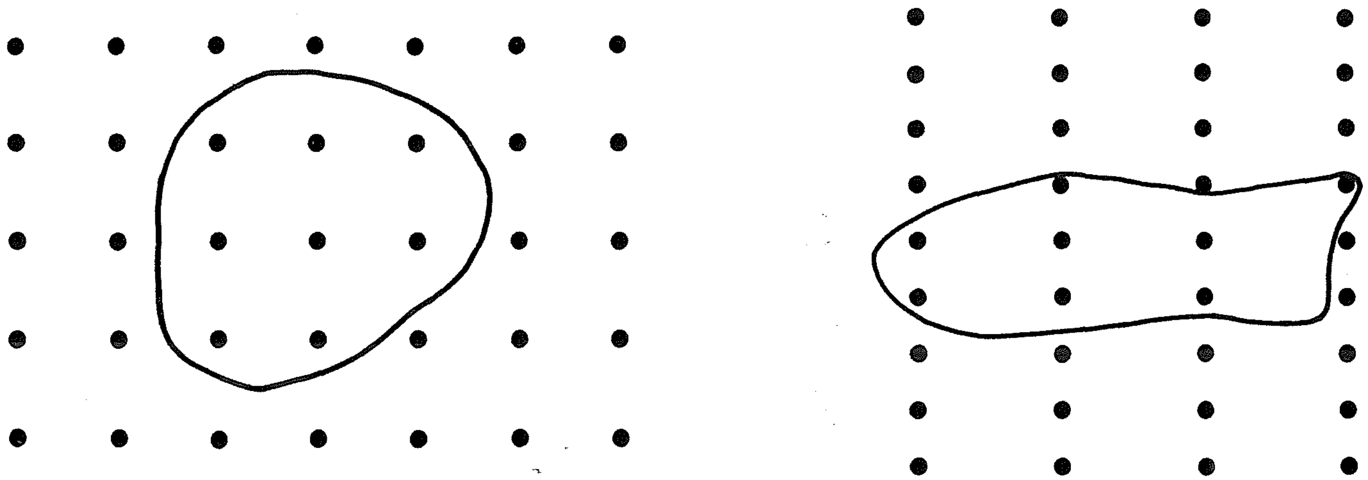
To use sections and level maps in slope design, they must be extended beyond the edge of the ore body to include the rock in the pit wall. As a rule of thumb, one pit depth beyond the edge of the pit is sufficient.

Drilling Patterns

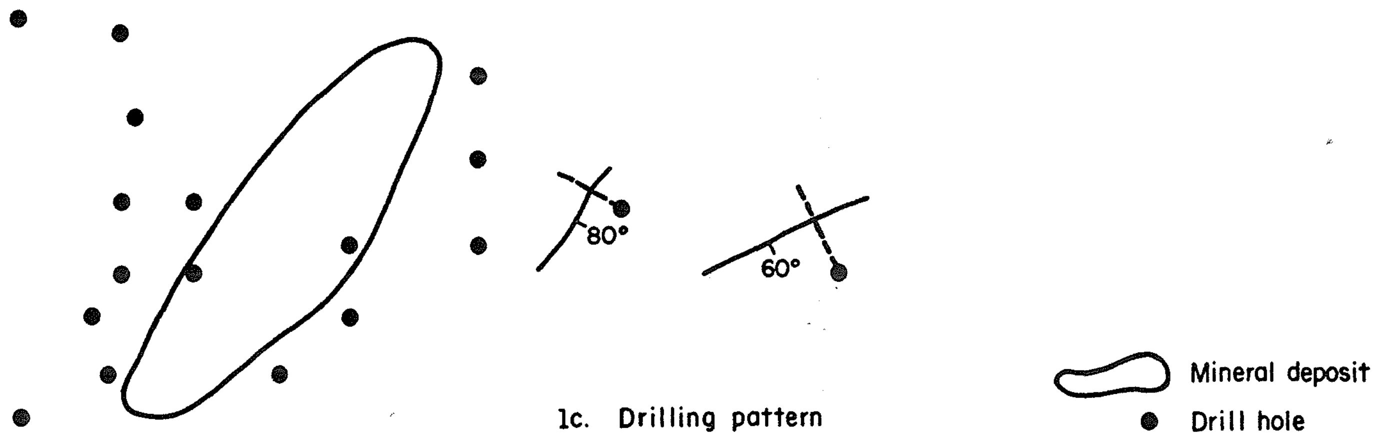
There are three basic types of drilling patterns: a systematic grid (Fig. 1a), a statistically random pattern (Fig. 1b), and an arbitrary hole location based on geologic evidence (Fig. 1c). There are relative advantages and disadvantages associated with each of these drilling patterns (Koch and Link, 1970; and Bailly, 1968).

Random sampling is a classical statistical technique for obtaining an unbiased sample of a population. With true uniform random sampling, every member of the population has an equal chance of being sampled. To apply random sampling to the drilling pattern, the x and y coordinates of the drill-hole locations are chosen from a table of random numbers so that every location has an equal chance of being drilled.

An obvious drawback in random sampling is inadequate areal coverage, as shown in Fig. 1b. There is also a theoretical objection. For random sampling and subsequent statistical analysis to be valid, all the samples must be drawn from a single population, and each must be statistically independent. This is rarely the case in drilling an ore body as there are usually several types



1a. Systematic drilling patterns.



1b. Random drilling pattern.

1c. Drilling pattern based on geology.

Fig. 1. Drilling patterns.

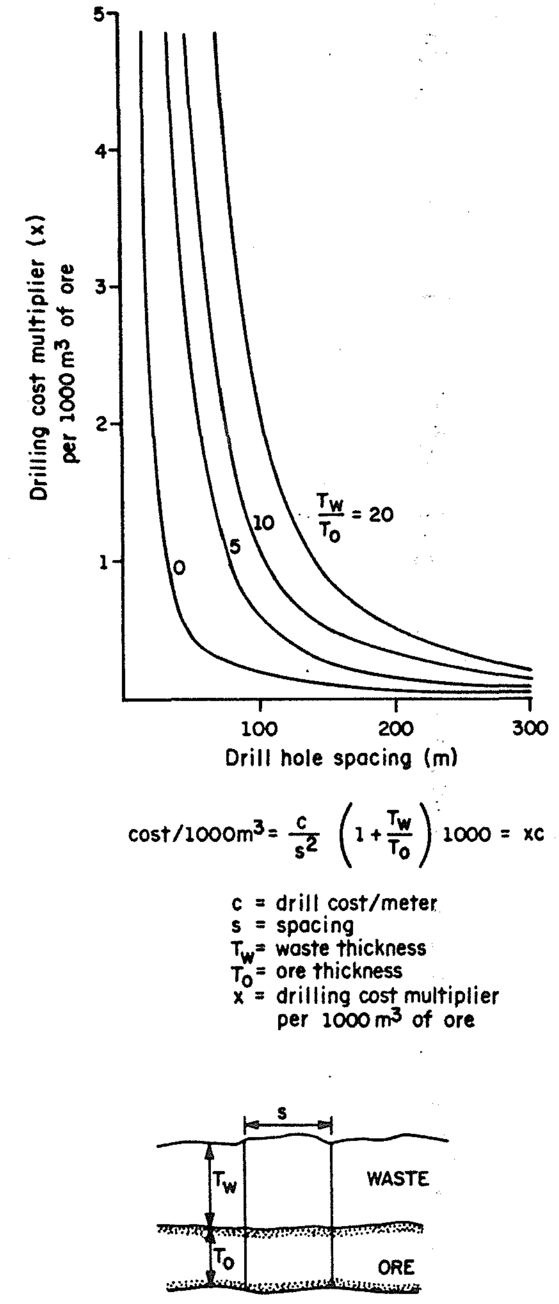
of mineralization. Also, because of grade trends, the assays of two closely spaced holes are not independent of each other. For these reasons, random drill patterns are not suitable for development drilling.

Arbitrary drill-hole locations based on geologic reasoning are more appropriate at the exploration stage than during development drilling. Locating drill holes on the basis of alteration trends or favorable structural and lithological environments greatly enhances the probability of finding ore with a minimum amount of drilling. This is not the case with random or regular grid drilling. In development drilling, however, a representative sampling of the ore body is desired, and geologically controlled drilling tends to produce biased results. Submitting the assay results from a drill hole located in waste or low-grade areas does not make a geologist a candidate for promotion; thus, there is a temptation to cluster holes in the high-grade areas. Locating holes for geologic reasons cannot be ruled out of development drilling, however. Defining the edge of the structurally controlled ore body is best done by geologic drilling.

Grid drilling is generally the preferred pattern for obtaining a representative sample with good areal distribution. An advantage of grid drilling in geologic interpretation is that cross sections can be constructed with a minimum of projection. The chief disadvantage of grid drilling is that a regular spatial variation in the ore body could coincide with the drill-hole spacing. This would result in a major bias in the grade estimation. If the drill holes happen to coincide with high-grade zones, the grade of the deposit would be overestimated. Thus, it is prudent to break the pattern occasionally with a hole at an intermediate spacing and at a different angle, if possible.

Drill-Hole Spacing

The optimum spacing of drill holes is a trade-off between the confidence in tonnage and grade results, and the costs of drilling. As the drill spacing decreases, the costs increase geometrically. This increase is shown in Fig. 2 for drilling vertical holes into a flat-lying ore body. For this example, the cost per 1000 m^3 increases rapidly for spacings less than 150 m when ore to waste ratios are high and for spacings less than 50 m when drilling is in ore only.



$$\text{cost}/1000\text{m}^3 = \frac{c}{s^2}\left(1+\frac{T_W}{T_O}\right)1000 = xc$$

c = drill cost/meter
s = spacing
T_W = waste thickness
T_O = ore thickness
x = drilling cost multiplier per 1000 m^3 of ore

Fig. 2. Drilling cost related to drill-hole spacing.

There are two aspects to confidence in the ore estimates. One is the probability of missing a high- or low-grade zone, and the other is a statistical confidence of the mean problem.

When an ore zone consisting of small pods or high-grade zones is the target, there is a possibility of missing the ore zone entirely. The probability of missing a small circular target when drilling on a square grid is shown in Fig. 3. Again, detailed geologic interpretation is probably the most useful tool in locating deposits of this type.

The spacing of holes for grade definition within the boundaries of a large deposit can often be determined by the use of geostatistics. Initial drill holes should be sufficient for the calculation of a variogram in several horizontal directions and in the vertical direction.

The variogram is a graph that displays the relationship between the squared difference in sample grades and the distance between the sample points. Generally, the greater the distance between samples, the greater the expected square difference in their grades, i.e., the farther apart two samples are, the more statistically independent they are likely to be.

The variogram is a directional plot in that the distances between samples are measured in a single direction. By calculating variograms in several directions, the directional variability of the deposit can be measured.

Fig. 4 is an example variogram from a uranium deposit (Knudsen and Kim, 1977). The curve fit to the

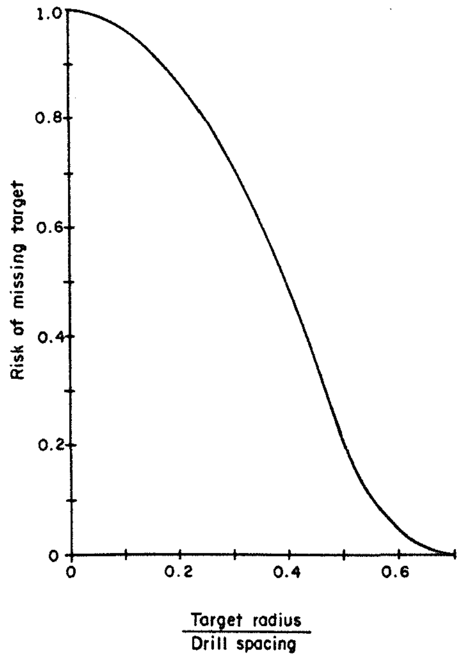


Fig. 3. Probability of missing circular target with a square drilling grid.

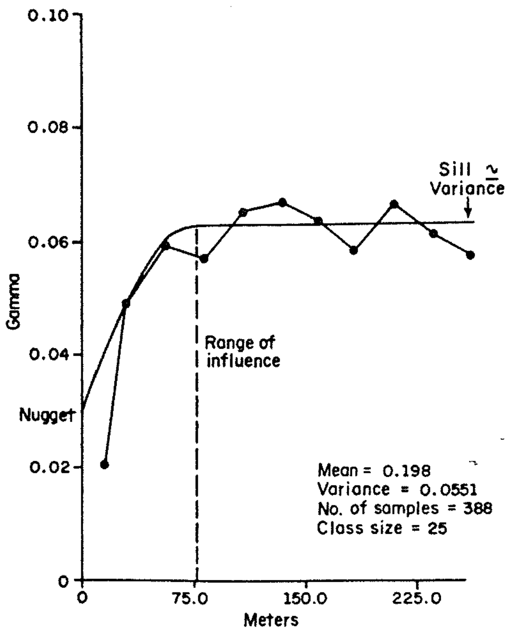


Fig. 4. Example variogram from uranium (Knudsen and Kim, 1977).

data indicates the mean squared difference for samples separated by a given distance. The distance where the curve breaks over is the range or radius of influence of a sample. Samples spaced farther apart in the given direction than this range are considered statistically independent. The range is a good estimate of the required drill spacing for adequate grade definition.

Geostatistics is not a substitute for detailed recording of geologic data and interpretations. It is, however, a tool to use in conjunction with more conventional geologic methods. The problems become obvious if geostatistics is applied without regard to geology. Lumping of several separate geologic populations together for statistical analysis can produce misleading results.

When the range determined from the variogram is greater in one direction than in another, the holes can be spaced farther in that direction. For example, in roll front uranium deposits where the mineralization is controlled by buried stream channel deposits, the best pattern consists of a series of fences at relatively closely spaced holes across the channel but with greater distance between fences.

Since the first years of mine production have the greatest impact on cash flow, there is justification for using a closer spacing in areas that will be mined first. The need for precisely defining the grade of ore to be mined 20 years in the future is questionable because the estimated commodity price, mining costs, and other financial factors, such as taxes, approach pure speculation.

Types of Drilling

A number of drilling methods are available, such as diamond core, rotary, and churn, etc. Peters (1978) discusses types of drilling and summarizes their characteristics (Table 1). The drilling method to be used is a function of the type of information required, the costs involved, and the condition of the rock to be drilled. For example, in uranium deposits where the primary need is a hole for downhole geophysical logging, a low cost noncoring method is preferable. On the other hand, for a strataform sulfide deposit in folded and metamorphic rock, core drilling is required for geologic interpretation. Where ore minerals are predominantly along fractures and core recovery is low, reverse circulation drilling can obtain more representative samples.

Data Collection During Drilling

Pertinent information can be obtained during drilling. Drilling pressure and rate can be used to evaluate rock properties. Oriented core can be taken for slope design. Information on water loss or gain, and water level in holes, can help define the hydrology. Preserving the hole for subsequent water level and temperature measurements can greatly aid hydrologic studies.

Orientation surveys of the holes are often required. Drilling on 100-m spacing is questionable if the position of the bottom of the hole is not known within 200 m.

Data Collection from Drill Core

Of all the drilling methods, coring supplies the best data. It is, however, one of the most expensive methods. Consequently, data collection must be planned in advance to ensure that the core is in a form suitable for each phase of data collection. As most of the serious logging and sampling occurs at the core shed, a core handling procedure should be established for transfer of the core from the barrel to the core box to the core shed. The use of split- and triple-tube core barrels has advantages in minimizing core breakup; however, these systems also increase drilling cost. Data such as RQD (rock quality designation) and fracture frequency are affected by handling. However, if core is handled in a consistent and specified manner, the conclusions drawn should be the same regardless of the type of core barrel used. Drillers should be instructed to minimize the hitting of the inner tube to get the core out and to set core boxes down without dropping to prevent excessive breakage. All core boxes should have firmly fixed lids, especially during transport from the drill site to the core shed. In wet localities, waterproof core boxes should be specified.

Table 1. Drilling Methods and Normal Characteristics*

	Diamond core	Rotary	Reverse circulation	Downhole rotary	Downhole hammer	Percussion	Churn
Geologic information	Good	Poor	Fair	Poor	Poor	Poor	Poor
Sample volume	Small	Large	Large	Large	Large	Small	Large
Minimum hole diameter	30 mm	50 mm	120 mm	50 mm	100 mm	40 mm	130 mm
Depth limit	3000 m	3000 m	1000 m	3000 m	300 m	100 m	1500 m
Speed	Low	High	High	High	High	High	Low
Wall contamination	Variable	Variable	Low	Variable	Variable	Variable	Variable
Penetration—broken or irregular ground	Poor	Fair	Fair	Fair	Good	Good	Good
Site, surface, and underground	S + U	S	S	S + U	S + U	S + U	S
Collar inclination, range from vertical and down	180°	30°	0°†	30°	180°	180°	0°
Deflection capability	Moderate	Moderate	None	High	None	None	None
Deviation from course	High	High	Little	Little	Little	High	Little
Drilling medium, air or liquid	L	A + L	L	A + L	A	A + L	L
Cost per unit depth	High	Low	Moderate	Low	Low	Low	High
Mobilization cost	Low	Variable	Variable	Variable	Variable	Low	Variable
Site preparation cost	Low	Variable	Variable	Variable	Variable	Low	High

* Peters, 1978.

† Reverse circulation has recently been used at inclinations up to 40°.

Core Recovery and RQD

Core recovery is the length of core footage recovered divided by the length of core footage drilled expressed as a percent. Core recovery is needed to evaluate ore reserves and should be measured prior to core splitting.

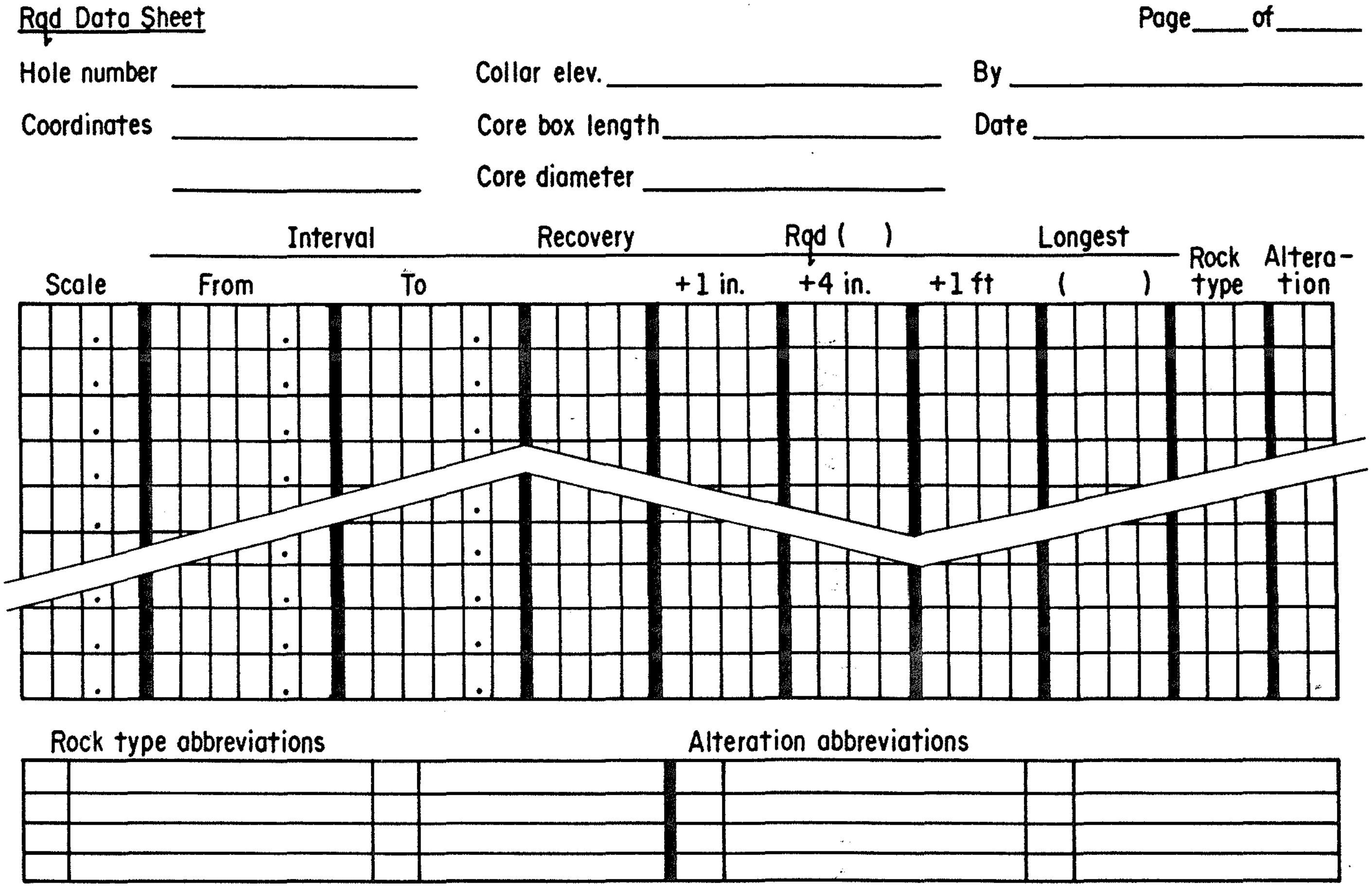
The rock quality designation, RQD, which is a modified core recovery, should be measured in addition to core recovery. This consists of measuring the total length of those core pieces greater than 101.6 mm (4 in.) long for NX core in a run and expressing this length as a percent. For core diameters other than NX, the length of core measured should be twice the diameter of the core in order to minimize the effect of core diameter on RQD. Where a fracture breaks the core diagonally, the length should be measured along the centerline of the core. If the core is split longitudinally by a fracture, it should not be included in the +101.6-mm (+4-in.) lengths. For convenience, RQD can be measured over the assay interval or drill-run interval.

In conjunction with the RQD previously mentioned, three additional measurements should be taken: (1) the +25.4-mm (+1-in.) material, (2) the +0.3048-m (+1-ft) material, and (3) the longest piece. Measurements of core pieces that are +25.4 mm (+1 in.) and +0.3048 m (+1 ft) in length, in addition to the regular RQD [101.6 mm (4 in.)], can be used to estimate the distribution of fragment sizes. Work is in progress to correlate this estimated fragmentation with fragmentation in caving and in situ leaching operations. The longest piece measurement helps to define the extreme limit of the core fragment size distribution. The problem with the longest piece measurement is that the maximum length measured can only equal the length of the core box, unless the break can be defined as nonstructurally controlled. These additional measurements will help to define the range and distribution of core lengths.

Fig. 5 presents a format that can be used to measure core recovery and RQD data from drill core. It may be possible to incorporate this format into either drill log or assay data sheets. Because large amounts of data are produced, it is best that core recovery and RQD data be stored on computer magnetic tape along with drillhole number, interval, and rock type. It may be possible to include this information in with assay data storage tapes.

Core Photography

Prior to splitting, the core should be photographed. This gives a permanent record of the breakage. It is also a handy way to look at the core when reviewing the logs, particularly when the core is stored elsewhere. By building a frame to hold the camera and then taking



Rqd Data Sheet

Page____ of ______

Hole number ________________ Collar elev. ______________________ By ________________________

Coordinates ________________ Core box length __________________ Date ________________________

________________ Core diameter __________________

Scale	Interval: From	Interval: To	Recovery	Rqd ( ): +1 in.	Rqd ( ): +4 in.	Rqd ( ): +1 ft	Longest ( )	Rock type	Alteration
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.	.	.							
.	.	.							
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.	.	.							
.	.	.							
.	.	.							
.	.	.							

Rock type abbreviations				Alteration abbreviations			

Fig. 5. Example data collection form for core recovery and RQD. Metric equivalents: 1 in.×25.4=mm; 1 ft×0.304 8=m.

35-mm color slides of the boxed core, the time and cost involved are minimal. All photographs should include drill-hole number, core interval, and a scale. If the blocks identifying depth are dirty or otherwise illegible, they should be made readable.

Geologic Logging

The basic information required during geologic logging consists of lithology, alteration, mineralization, and structure. Logging forms need to be developed for each property. For good record keeping, each log should include the following information: project name, hole number, coordinates, collar elevation, hole bearing and inclination, hole diameter, date of logging, and name of person doing the logging. This information is usually recorded at the top of the log. The format for the body of the logging form depends on the type of deposit and personal preferences. Many logs contain columns for a sketch of the core, general remarks, and information on depth interval, recovery, assays, rock types, and structure.

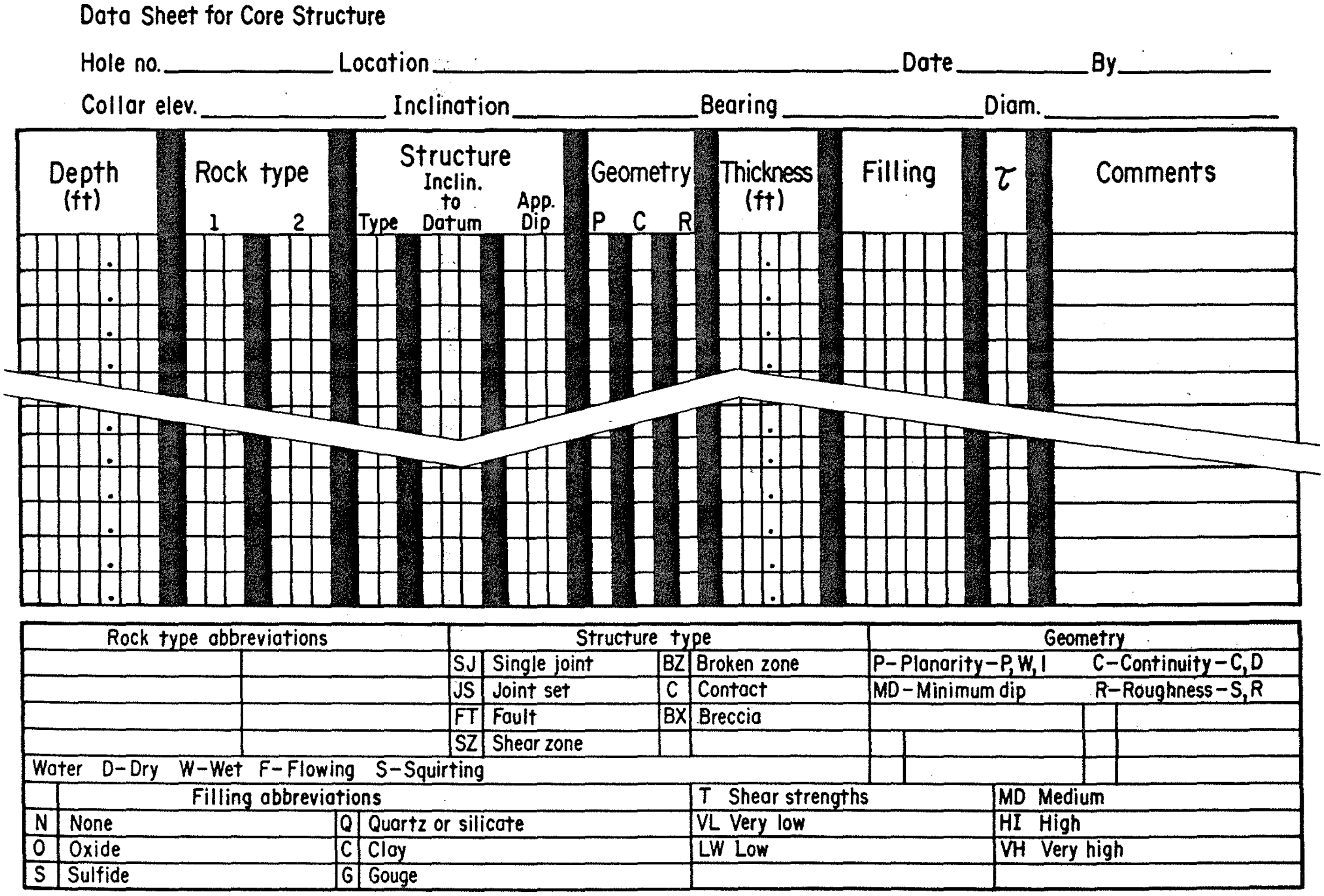
During the logging process, it is important that the person doing the logging has enough room to lay out at least 30 m of core. The logging area should also be well-lighted.

As the core is logged, samples for petrography and mineralogy should be collected. These samples should include typical as well as atypical occurrences of the rock units.

Fracture Characterization

Several holes should be drilled to obtain oriented drill core for use in measuring joint dips, strikes, and spacings. These holes will aid in projecting the results from mapped exposures and in detecting structural changes with depth. Holes should be oriented to intersect the greatest number of structures. The number of holes depends on equipment, personnel availability, and complexity of geology. Fig. 6 shows a general format for logging oriented core.

For those holes that are not oriented, certain information should be noted: (1) fracture angle to core axis (dip), (2) filling type between fractures, and (3) shear strength along fracture surfaces. The dip mea-


Data Sheet for Core Structure

Hole no.________ Location________ Date________ By________

Collar elev.________ Inclination________ Bearing________ Diam.________

Depth (ft)	Rock type 1	Rock type 2	Structure Type	Structure Inclin. to Datum	Structure App. Dip	Geometry P	Geometry C	Geometry R	Thickness (ft)	Filling	τ	Comments

Rock type abbreviations		Structure type				Geometry	
		SJ	Single joint	BZ	Broken zone	P-Planarity-P, W, I	C-Continuity-C, D
		JS	Joint set	C	Contact	MD-Minimum dip	R-Roughness-S, R
		FT	Fault	BX	Breccia		
		SZ	Shear zone				

Water D-Dry W-Wet F-Flowing S-Squirting

Filling abbreviations				T Shear strengths	MD Medium
N	None	Q	Quartz or silicate	VL Very low	HI High
O	Oxide	C	Clay	LW Low	VH Very high
S	Sulfide	G	Gouge		

Fig. 6. Example data collection form for oriented core.

surements can be recorded in terms of the number of fractures per dip interval. Possible dip intervals are:

0-30
30-45
45-60
60-75
75-90

The percent of joints of a given shear strength within a drill interval should be measured. The following categories of shear strength are recommended: (1) very low—smooth joint and/or gouge filled, broken during coring; (2) low—has asperities, contains minimal fill, broken during coring; (3) medium—fracture easily broken by twisting with hand; (4) strong—takes great effort to break by twisting, or cannot be broken in this way, but has strength less than rock substance strength; and (5) very strong—fracture strength equal to or greater than rock substance strength. Although these measurements have no direct input to a stability analysis, they can be used to define zones of fracture characteristics throughout the deposit.

Samples for Rock Testing from Drill Core

For compressive and elastic properties (Young's modulus and Poisson's ratio), samples of core 2.5 times the core diameter are required. For small-scale direct shear and tensile strength, core samples 50.8 mm (2 in.) in length are required. When faults with appreciable gouge are encountered, a sample of gouge should be collected for shear testing. A piece of gouge 50.8 mm (2 in.) long would be best, but if this would affect the assay, a remolded test could be run on the gouge remaining after core splitting. Otherwise, all samples must be collected prior to splitting.

For each engineering rock type (different alteration phases would be considered different rock types), the number of samples listed in Table 2 is desirable. If the total footage of a rock type to be drilled is known (or a good estimate is available), then the number of core samples required can be divided by the depth to determine how frequently a sample should be collected. The first specimen should be collected at a random distance in the first interval. The following samples

Table 2. Number of Samples Per Rock Type

	No. Samples collected per hole per rock type	No. Samples tested per rock type	Length
Uniaxial compression w/ E & γ	3	24	2.5 x diam
Triaxial compression	3	24	2.5 x diam
Tension	6	48	~ 2 in.*
Shear	2	16	~ 2 in.
Fault gouge	As Encountered	As Encountered	~ 2 in.

* Metric equivalent: 1 in. x 25.4 = mm.

should then be collected at every interval from that starting point. This is called a random start series sampling method. If the coring at the sampling point is too broken (note this condition), then collect the nearest sample from above or below the originally planned location. If the rock sampling point is not representative, e.g., a dike, an additional sample of the major rock type should be set aside.

For cases where the amount of each rock type is unknown, collection of samples every 30.5 m (100 ft) down the hole should be sufficient.

By sampling each hole in this fashion, a collection of samples will be built up from which samples can be taken for the testing program. At each sample location a specimen whose length is 50.8 mm (2 in.) greater than 2.5 times the diameter should be collected.

Rock Hardness (Uniaxial Compressive Strength)

To evaluate relative variations within a deposit and to enable comparisons and discussions with other engineers, an estimate of the rock hardness or uniaxial compressive strength is required. Table 3 proposes one method for classifying soils (fault gouge) and rock hardness. This table is the result of work by Deere (1968), Terzaghi and Peck (1967), Jennings and Robertson (1969), and Piteau (1970). The system proposed in this table has the advantage of requiring only normal field equipment.

Another method for estimating the compressive strength is the point load test. The result of a point load test run on a core section is multiplied by the appropriate correction factor (Bieniawski, 1975) to estimate the uniaxial compressive strength. Because this system will only accommodate intact rock, a classification is still required for broken zones and soil or fault gouge.

Assays

Except in cases where small drill core (EX or smaller) is used, the core should be split in half for assay. Studies by Krige (1966) and Hazen and Berkenkotter (1962) have shown that the variance between mean assays of split core vs. total core has little effect on composited results. Because of geologic structure, it is often difficult to split core evenly down its longitudinal axis. In these cases, it may be necessary to saw cut the core. The splitting process leaves core for relogging at some future time when new or additional geologic information is needed. The saved split core can also be used for additional assaying. One technique that has proved useful is to saw cut the core three-quarters through and split the remainder. This provides the geologist with both a smooth and rough surface for logging.

The length of core to be assayed varies according to geologic breaks, high-grade zones, weights sample bags can carry, or drill-run intervals. Assay intervals usually run between 1.5 and 3 m. The key point to remember is that assay intervals can always be composited but cannot be broken down. The minerals assayed depend on the type of deposit (Waterman and Hazen, 1968).

In preparing the split core for assays, it is usually crushed, then split into quarters, of which one is ground and used for assaying. The remaining crushed rock should be saved for a metallurgist to perform Bond Work Index, flotation, and other metallurgical tests. This crushed material should be around 6.4 mm (¼ in.). With the crushed rejects, the metallurgist can

Table 3. Relationship Between Hardness or Consistency and Unconfined Compressive Strength[‡]

Hardness	Consistency	Field identification	Approximate range of unconfined compressive strength, psi[§]
		Soils and fault gouge	
S1[*]	Very soft soil	Easily penetrated several millimeters (inches)[§] by fist	<3.5
S2	Soft soil	Easily penetrated several millimeters (inches) by thumb	3.5–7
S3	Firm soil	Can be penetrated several millimeters (inches) by thumb with moderate effort	7–14
S4	Stiff soil	Readily indented by thumb but penetrated only with great effort	14–28
S5	Very stiff soil	Readily indented by thumbnail	28–56
S6	Hard soil	Indented with difficulty by thumbnail	>56
		Rock	
R0	Extremely soft rock	Indented by thumbnail	28–100
R1[†]	Very soft rock	Crumbles under firm blows with point of geologic pick; can be peeled by a pocket knife	100–1000
R2	Soft rock	Can be peeled by a pocket knife with difficulty; shallow indentations made by firm blow of geological pick	1000–4000
R3	Average rock	Cannot be scraped or peeled with a pocket knife; specimen can be fractured with single firm blow of hammer end of geological pick	4000–8000
R4	Hard rock	Specimen required more than one blow with hammer end of pick to fracture it	8000–16 000
R5	Very hard rock	Specimen required many blows of hammer end of geological pick to fracture it	16 000–32 000
R6	Extremely hard rock	Specimen can only be chipped with geological pick	> 32 000

[*] S1 to S6 (Terzaghi and Peck, 1967).
[†] R1 to R5 (Deere, 1968; and Jennings and Robertson, 1969).
[‡] Modified by Piteau, 1970.
[§] Metric equivalents: 1 in. x 25.4 = mm; 1 psi x 6.894 757 = kPa.

run a flotation test for all known ore conditions that will define the variability of the metallurgical nature of the ore. Bulk samples may still be used for pilot plant testing. Only one or two ore types will usually be represented in the bulk samples. Therefore, the variability of metallurgical characteristics of the ore will not be determined.

Core Storage

All core and assay rejects should be saved at least until mine planning is well along. The storage facility should protect the core, especially core in cardboard boxes, from the elements. Saving core is much less expensive than redrilling. When, if ever, the core is to be discarded, a skeleton of core should be retained. Skeletonizing usually consists of saving a 50.8- to 101.6-mm (2- to 4-in.) piece for every 0.6 m (2 ft) of core.

Data Collection for Noncoring Drill Methods

Noncoring drill methods generally have the advantage of lower costs than coring drill methods. Consequently, when core is not required, a noncoring drill method is preferable. Noncoring drill methods are commonly used for: (1) geophysical logging, (2) obtaining samples for assay and metallurgical testing, (3) defining ore contacts in extensive sedimentary deposits, (4) drilling through thick sections of overburden, and (5) hydrological testing. For holes used in geophysical logging or hydrological testing, there are minimum diameters and limitations on casing. Specific requirements should be supplied by the geophysicist or hydrologist who will conduct the testing.

Chips from a noncoring drill hole can be used for identifying general rock types. One of the better methods is to collect samples every 1.5 to 3 m and to glue a portion of the chips onto a board. This will ease making differentiations between rock units. After about 50 to 60 m, the intermixing of chips may make logging more difficult.

Final Comments

The preceding chapter briefly discussed determination of drill pattern and spacing, types of drilling methods, and required data collection. At first it may appear that a great deal of expensive data collection must be conducted; however, the cost of core drilling alone is the most expensive part of the program, $25 to $70 per meter. Conversely, all the data collection would usually be under $10 per meter. Because of the costs involved in driving an exploration shaft or adit, as much information should be determined from the drill core as possible.

The geologist responsible for development drilling should collect data not only for his purposes, but also for those of the rock mechanics engineer, the miner, and the metallurgist. Consequently, prior to or during the initial period of the drilling program, the geologist should meet with these people to determine what information they will need. Without this interaction, a lot of money could be spent to obtain an inadequate estimate of just tonnage and grade.

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