A SIMPLE CORE ORIENTATION TECHNIQUE

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ABSTRACT

A simple and inexpensive clay imprint core orienting device has been developed by Dr. R. D. Call. It has a minimum of moving parts, is durable and easily used by drillers, and adds only 15 minutes to a core run. Conventional wire-line drilling and a drill hole inclined 30° to 60° from the horizontal plane are required. The device will not operate in a vertical hole. The orientor is an eccentrically weighted downhole device which can be constructed in a mine shop from an old inner core barrel and lead. Modeling clay is packed in the core lifter case, which is screwed on the downhole end of the orientor.

A clay imprint of the bottom of the hole is taken after each coring run. This imprint is matched to the top of the succeeding core run, the drill core is pieced together, and a reference line representing the drill hole is scribed on each core. Fracture attitudes are measured relative to the reference line and the core axis.

On recent drilling projects, tests for imprint reproducibility were conducted. The results of these tests show an average variation of ±3° in location of the scribed reference line between imprints. Comparisons of surface mapping data with oriented core data are good. It is rare that the entire length of drill core in intensely fractured zones can be oriented because it is impossible to piece the core together. However, if a triple tube set-up is used, a modification in the scribing procedure can result in a good statistical sampling of the fracture population. Attitudes of major structures have been oriented with this technique.

INTRODUCTION

Geotechnical studies for mine design require a knowledge of rock fabric, as well as general geology. Adits or drill holes must be planned for subsurface investigation if sufficient information cannot be obtained by surface mapping. Even if surface mapping were possible, there is no assurance that fracturing at the surface (the sampled population) would correspond to that at depth (the target population).

Stability analysis for ultimate mine designs requires knowledge of the rock substance and rock fabric beyond the ore boundaries. Oriented drill core provides a means of obtaining this knowledge.

When drilling geotechnical holes for slope design, it is preferable to drill an angle hole to maximize intercepting structural fractures in the critical orientation dipping into the pit. If the direction and plunge of an inclined hole are obtained by a conventional drill hole survey, which side of the core is up is the only additional information needed to orient core.

In 1970, a clay imprint orientor was used on the Tazadit Pit Slope Study in Mauritania (1). This device used an Eastman multi-shop to determine the top of the core. Subsequently, the device described below was developed; it has been used on a number of projects, and has proven to be operational.

ORIENTOR PROCEDURE

The orientor is an eccentrically weighted, downhole device, which consists of a 1 m length of inner core barrel half full of lead (Figure 1). Drilling fluid in the drill pipe surrounds the orientor during the operation and acts as a liquid bearing. In an inclined hole, the eccentricity produced by the weighted bottom of the orientor always causes it to rotate to the same position as it is dropped down the drill pipe. A line etched on the side of the orientor opposite the weighted side will be in the same direction as the drill hole and will represent the top of the hole. Conventional wire-line drilling and a drill hole inclined 30° to 60° from the horizontal plane are used. The device will not operate in a vertical hole.

Modeling clay is packed in the core lifter case, which is screwed on the downhole end of the orientor. The clay-packed lifter case is used for imprinting the bottom of the drill hole before each core run. Prior to imprinting, the drill string is raised about 6 in. (15 cm). The orientor is dropped inside the drill pipe and allowed to free-fall through a full mud column. When the orientor reaches the bit, the mud pump is engaged to hold the orientor in place at the bottom of the hole. In deep holes, it may be necessary to engage the mud pump and to pump the orientor to the bottom of the

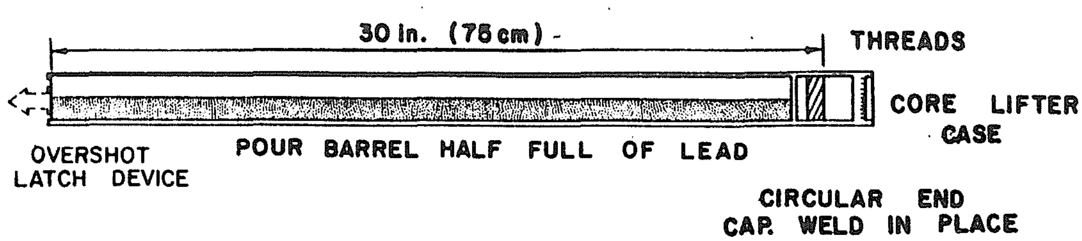


Figure 1: Clay Core Orientor

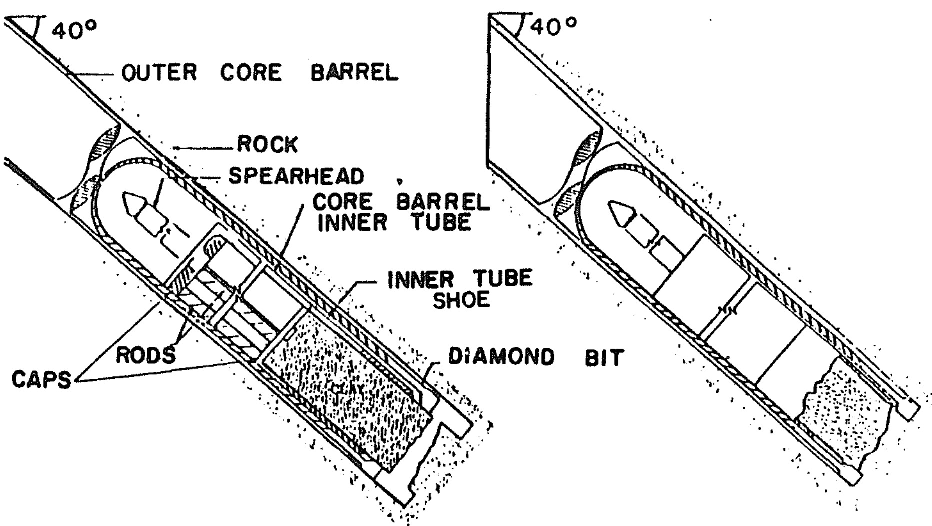


Figure 2: Imprinting Core Stub

hole. The drill string is lowered, without rotation, to take the imprint (Figure 2), and the overshot is then used to retrieve the orientor. The core lifter case containing the clay imprint of the bottom of the hole is unscrewed and then laid in the tray with the top of the core run next to the imprint. The imprint is matched to the top of the core run, the core pieces are fitted together, and a reference line, which represents the hole orientation, is scribed on the core. This reference line is an extension of the etched line on the unweighted side of the orientor.

As the drill core is logged, angles are measured for each structural feature present. A drill-hole survey provides the orientation of the drill hole and, thus, the orientation of the reference line on the core for various depth intervals. This survey is interpolated to specific depths in order to calculate the true orientations of each structural feature.

It is rare that the entire length of the drill core in intensely fractured zones can be oriented because it is impossible to piece the core together. However, if an attempt to imprint is made for every run, a good statistical sample of the fracturing can usually be obtained. In massive rock, it may not be necessary to imprint every run if the core can be reliably pieced together from one run to the next.

Triple tube or split tube core barrels greatly decrease the disturbance of the core and should be used if possible.

Reproducibility of the Orientor

On a recent quartz monzonite drilling project, two tests for imprint reproducibility were conducted. Test 1 was a 58° inclined hole, drilled to a depth of 97 ft. The orienting device was dropped six times. The first drop was considered the initial imprint, from which the variation in rotation of the five succeeding drops could be measured. Test 2 was a 52° inclined hole drilled to a depth of 513 ft. Table 1 summarizes the reproducibility of imprinting.

From the results of these two tests, it is apparent that the orientor averages about ±3° variation in location of the scribed reference line between imprints.

Table 1

Number of Drops	Test 1 Hole Depth = 97 ft Variation from First Dump	Test 2 Hole Depth = 513 ft Variation from First Dump
1	0.0°	0.0°
2	+3.0°	+1.1°
3	-2.2°	+2.1°
4	-1.1°	+5.3°
5	-2.2°	+1.1°
6	-4.3°	-4.8°

\+ = clockwise rotation of orientor
\- = counterclockwise rotation of orientor

MEASURING AND RECORDING FRACTURE DATA

Orientations of fractures in the drill core are measured relative to the core axis and the reference line, using a plexiglas goniometer (Figure 3). The measurements made with the goniometer are converted to dip direction and dip of the fractures by vector mathematics and the drill hole survey data.

A standard data sheet, prepared in key-punching format, is used to record the goniometer measurements (Figure 4). For each fracture, the following are recorded:

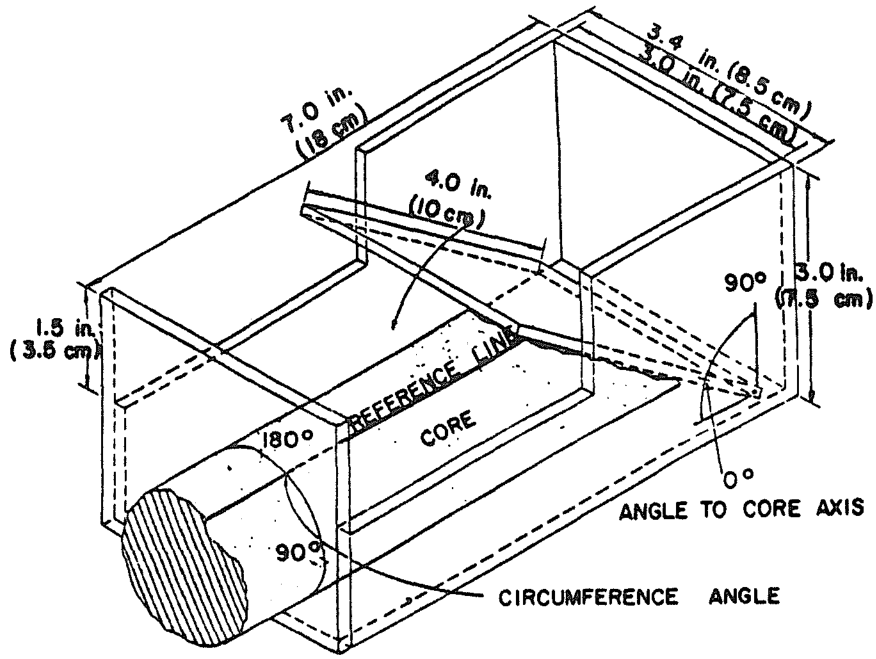


Figure 3: Plexiglas Core Orienting Goniometer

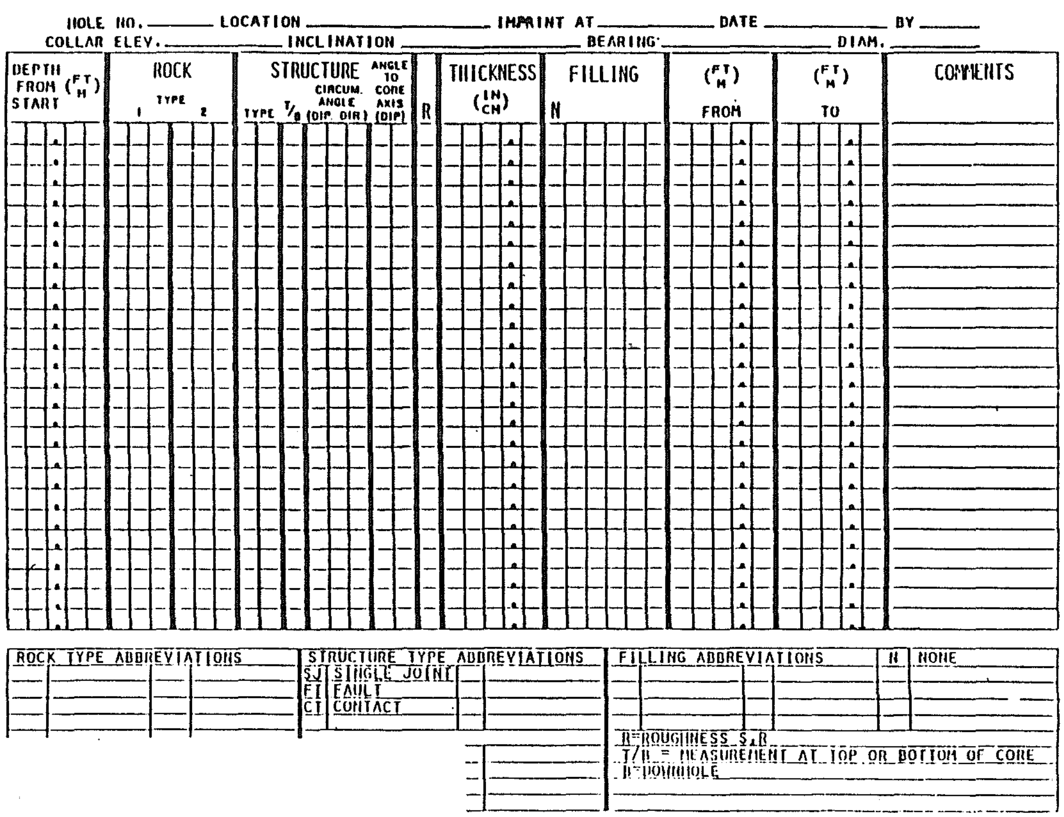


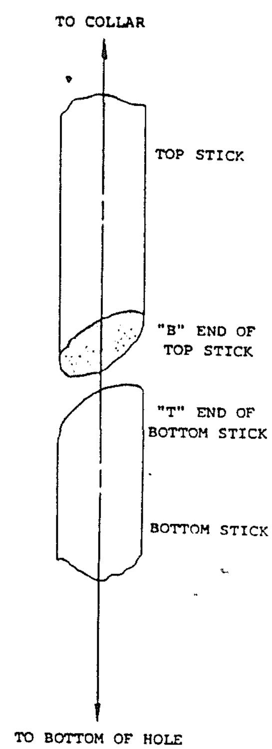
Figure 4: Data Sheet for Oriented Core

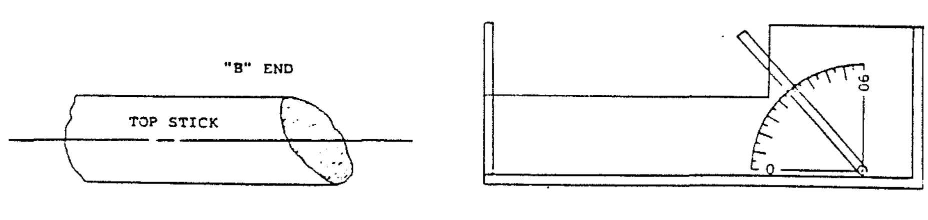
Depth from Start of Drill Run. The distance from the top of the drill run to the point where the reference line intercepts the fracture.

Rock Type. A three-character alphanumeric code to describe the rock type, such as SCH for schist.

Structure Type. A two-character code identification of the genetic nature of the fracture, such as SJ for single joint.

Bottom (or Top). "B" if the goniometer measurement is taken from the bottom of the top core stick, or "T" if the measurement is taken from the top of the bottom core stick. Either side of a fracture surface can be measured, but it is better to measure the bottom, or "B" end, of the top core stick (Figure 5).





NOTE: THIS MEASUREMENT WOULD HAVE A "B" DESIGNATION

Figure 5: "B" or "T" Designations for Recording Data

Circumference Angle (β). An angle measurement of the dip direction relative to the reference line.

Angle to Core Axis (α). An angle measurement that is the complement of the dip angle relative to the core axis.

Roughness. An alphanumeric character that qualitatively describes the nature of the fracture surface: "S" = smooth; "R" = rough surface.

Thickness. Width of the measured fracture opening.

Filling. Six columns for acknowledging the presence of fracture-filling materials.

From - To. Depth from collar to top and bottom of core run.

VECTOR AND STEREOGRAPHIC PROJECTION SOLUTIONS TO DETERMINE FRACTURE ORIENTATION

The following sections present both vector and stereographic projection solutions to determine the true fracture orientations from the fracture measurements which have been measured relative to the core axis.

Determination of Dip Direction and Dip by Vector Solution

The input orientation data are

1) angle to core axis (α),
2) circumference angle (β),
3) bearing of drill hole (B), and
4) plunge of drill hole (P).

The circumference angle (β) would be the dip direction, if the hole were vertical and the top of the hole were north when the bottom end (B) of the core is inserted into the measuring box. If the top end (T) has been inserted, the circumference angle (β) must be subtracted from 360° before the conversions. The angle to the core axis (α) would be the complement of the fracture dip if the hole were vertical.

1) Conversion to lower hemisphere pole:

For bottom reading, $S = 180° + \beta$
For top reading, $S = 360° - \beta$
$D = 90° - \alpha$

2) Calculation of directional cosines:

$$X = \cos S \sin D$$
$$Y = \sin S \sin D$$
$$Z = \cos D$$

NOTE: The top of the hole is +X, east +Y, and down +Z.

3) Axis rotation for hole inclination:

$$\phi = 90° - \text{plunge of hole}$$
$$X' = X \cos \phi + Z \sin \phi$$
$$Y' = Y$$
$$Z' = Z \cos \phi - X \sin \phi$$

4) Axis rotation for bearing of hole (Θ):

$$X'' = X' \cos \Theta - Y' \sin \Theta$$
$$Y'' = Y' \cos \Theta + X' \sin \Theta,$$
$$Z'' = Z'$$

5) Conversion to dip direction and dip:

$$A = \left|\text{Tan}^{-1} \left(\frac{Y''}{X''}\right)\right|$$

$Y'' > 0$ and $X'' \geq 0$ DDR = A + 180
$Y'' \geq 0$ $X'' \leq 0$ DDR = 360 - A
$Y'' \leq 0$ $X'' \geq 0$ DDR = 180 - A
$Y'' < 0$ $X'' \leq 0$ DDR = A

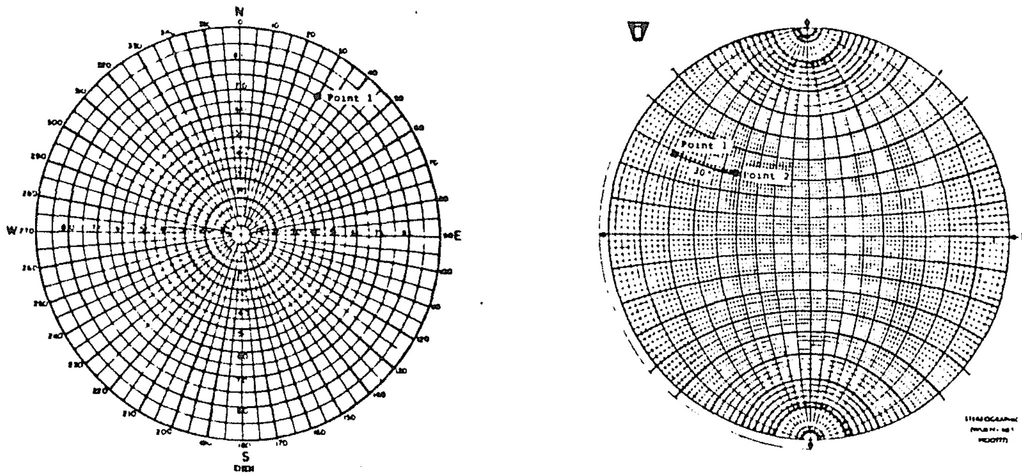
$$\text{Dip} = \cos^{-1} Z''$$

Determination of Dip Direction and Dip by Stereographic Projection

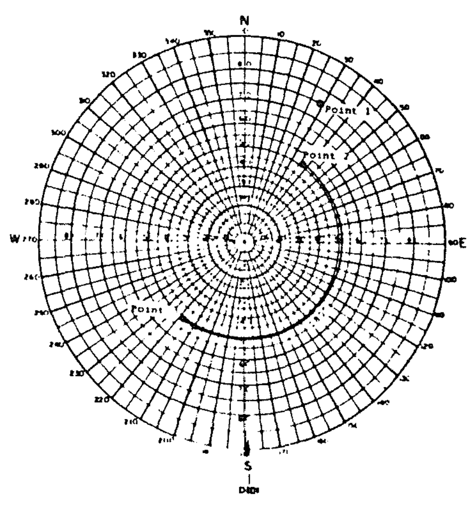
The lower hemisphere equal angle net can be used to determine the fracture orientation. The usual procedure is to use a transparent overlay for plotting fracture poles. Figure 6 is an example of the four steps that are to be followed in determining the dip direction and dip from the recorded oriented core data.

CASE STUDY

A geotechnical study was undertaken on a large porphyry copper operation in Northern British Columbia (1979). This operation is one of the largest operating copper pits in Canada, with ultimate dimensions on the order of 8000 ft x 4000 ft x 1200 ft. The stability study required the mapping of all exposed bench faces within the mine area (Figure 7). A drill program for evaluating the ore/waste contact that would be encountered on the north wall of the pit below the 720 ft level was initiated in March, 1980. The area



Equal Angle Net



Equal Angle Net

STEREOGRAPHIC SOLUTION

STEP 1 a) For a bottom reading, plot circumference angle (ß) and dip angle (90° - α) on polar equal angle net (Point 1). For a top reading, the circumference angle = 180° - ß

b) Lable 180° as "Drill Hole North" (DHN).

STEP 2 a) Using the overlay created in Step 1 and a Wulff equatorial net, line up DHN with Wulff net east.

b) Rotate Point 1 to the east along a small circle an amount equal to 90° - Plunge of hole. (Mark Point 2 on overlay.)

STEP 3 a) Using the polar net, align DHN with the bearing of the hole.

b) Rotate Point 2 180°.

c) Read Dip direction and dip of fracture (Point 3).

EXAMPLE: Bearing of hole = 179°
Hole plunge = 60°

Circumference angle (ß) = 30°
Angle to core axis (α) = 15°
Bottom reading

SOLUTION:
Dip direction = 217°
Dip = 51°

Figure 6: Stereographic Solution

involved was at ultimate limit above the 720 level, and it was at this point that the findings of the geotechnical study were to be implemented. The majority of the proposed drill holes were to be inclined between 50° and 57° and dip into the pit area. A core orienting technique, where discontinuity information could be obtained through the orientation of the drill core was applied.

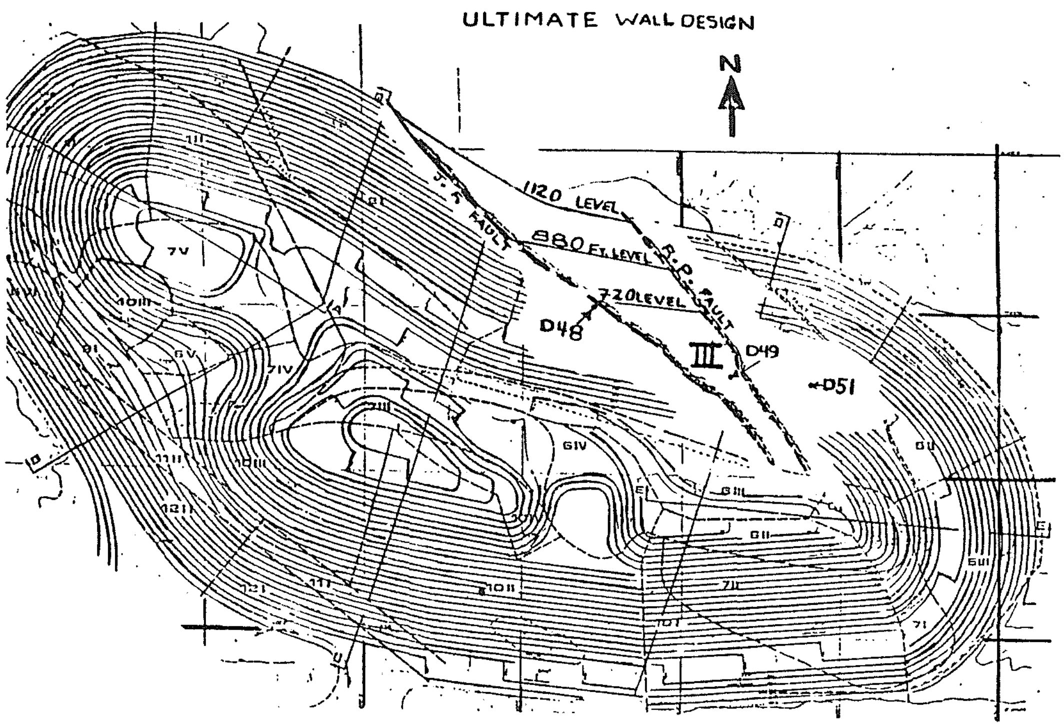


Figure 7: Planned Final Pit

Various orienting techniques were analyzed (Table 1); most proved to be too technically involved and/or greatly impeded the normal drill rate. The device designed by Dr. Call was employed for the following reasons:

1) it was the least expensive method of orientation (10 percent increase in drill cost at mine site);
2) it was technically simple (procedure was conducted by drillers);
3) it was accurate (the ±3° deviation per drop was verified at the mine site through back/fore orienting the core); and
4) it had a minimal effect on drill rate (10 percent slower at mine site).

Procedure

The procedure followed was that outlined by Dr. Call, where the orienting device was dropped approximately every 10 ft. A modification of the method was that a reference line was drawn along the entire length of the retrieved core, with the only restriction being that the line be parallel to the core axis. It was found that an edge of the splits from the triple tube barrel facilitated drawing of the line. The core stub, whose impression had been taken, was additionally referenced with an extension from the unweighted scribe line from the clay pot orientor.

Therefore, the tub has two parallel scribe lines, and the deviation from the true scribe is recorded on the goniometer, the true scribe being the line corresponding to the inclination of the drill hole.

This recorded deviation is then applied to all oriented data obtained for that particular core run.

Three diamond drill holes, D48, D49, and D51, a total of 2486 ft, were drilled simultaneously with the clay pot orienting technique. The drill core was NQ-3 size with triple tube wireline procedures employed throughout.

A typical drill hole, D48, gave the following information:

1) 65 percent of core was oriented 530/815 ft;
2) 993 structures were noted;
3) RQD was less than 60 percent; and
4) geology was that of a fresh andesite.

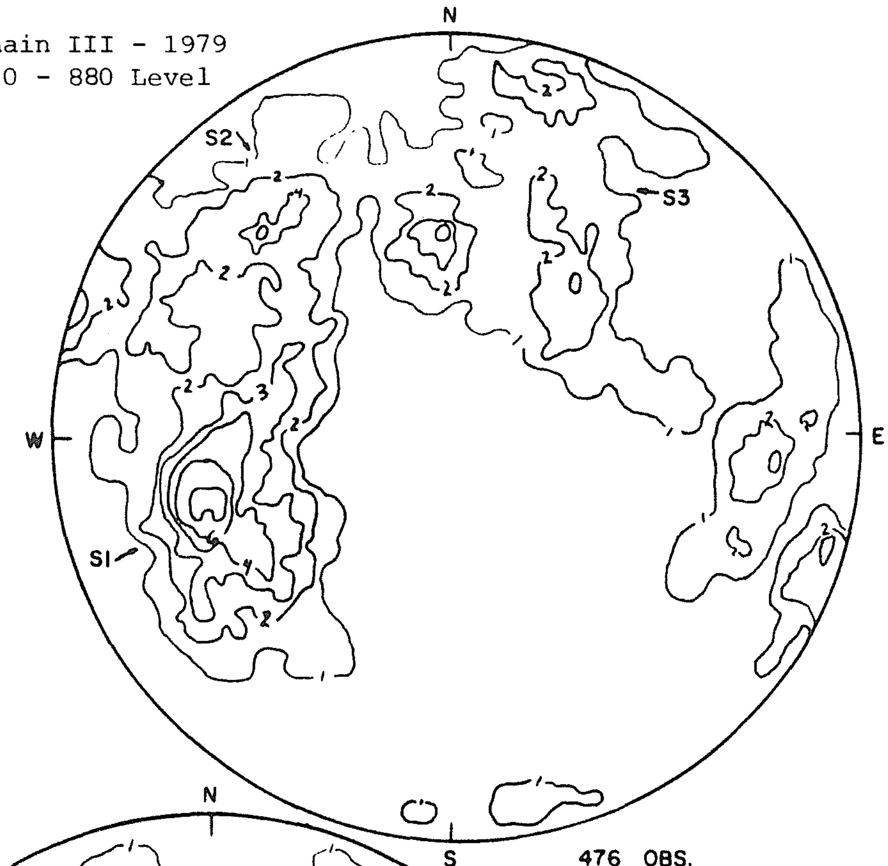
Drill rate was as follows: 63 ft of core per ten hour shift were drilled and oriented, with one hour out of ten employed for orienting. Normal operations would yield 70 ft/ton per ten hour shift

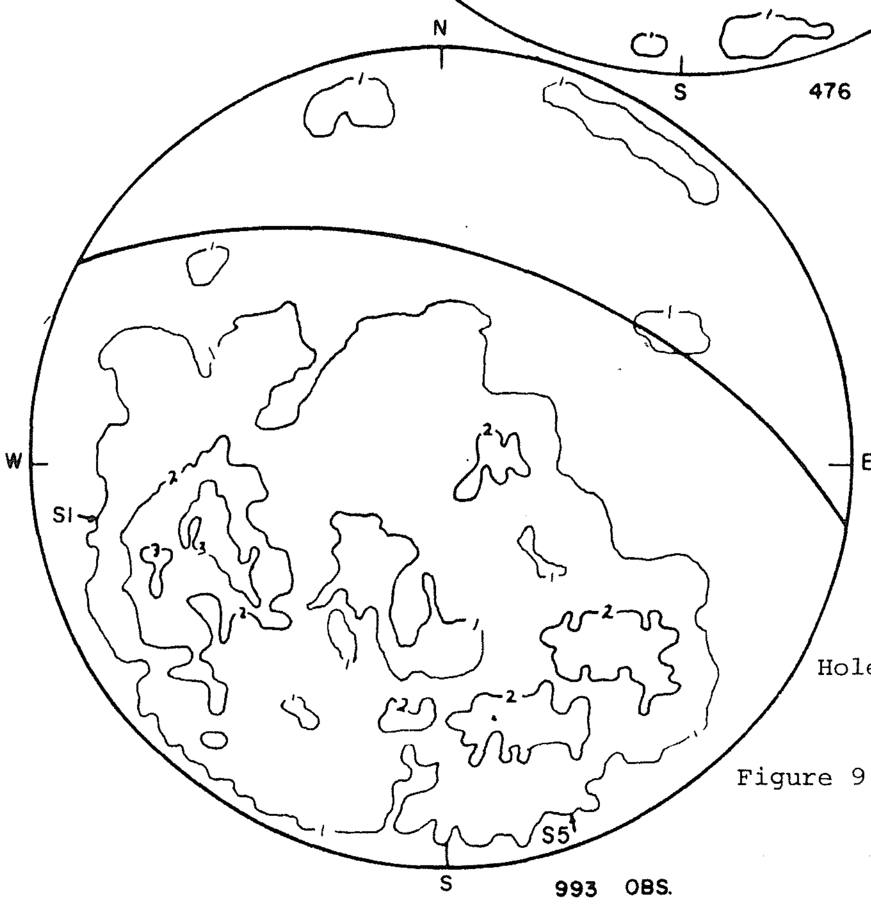
The geotechnical study of 1979 suggested that the location of D48 would fall in Domain III, which is separated from adjacent areas by the JF and RP faults (Figure 7). Domain III was designed using structural data obtained from mapping exposed bench faces; at the time of the 1979 report, this involved the area between 1102 and 880 ft level. Structural data representing the 1979 mapping and the oriented data for D48 are shown in Figures 8 and 9, respectively. The two stereo-nets revealed the strong S1 concentration, but, as expected, the oriented hole would result in a blind band that would neglect structures parallel to the trend of the drill hole. Therefore, S1, S2, and S3, which were present in Domain III, were absent in D48. Initially, that this concentration would not be detected with holes drilled parallel to the strike of S1 and S3 was obvious; however, because of poor continuity, they did not appear to dominate the stability of Domain III.

A concentration, S5, was detected in D48, but not in the 1979 mapping (Figure 9). Further mapping of exposed benches at the 880 to 720 level resulted in the plot shown in Figure 10, which has the same concentrations as depicted in 1979, with the addition of S5. The conclusion was that the same concentrations can be expected to elevations of 128 ft, which is the bottom of D48.

The technique was further used on an exploration property in Northern British Columbia. The following observations were made:

Figure 8: Domain III - 1979
1120 - 880 Level





Plunge: 47°
Length: 814 ft
Hole Direction: 198

Figure 9: Orientations
from Hole 48

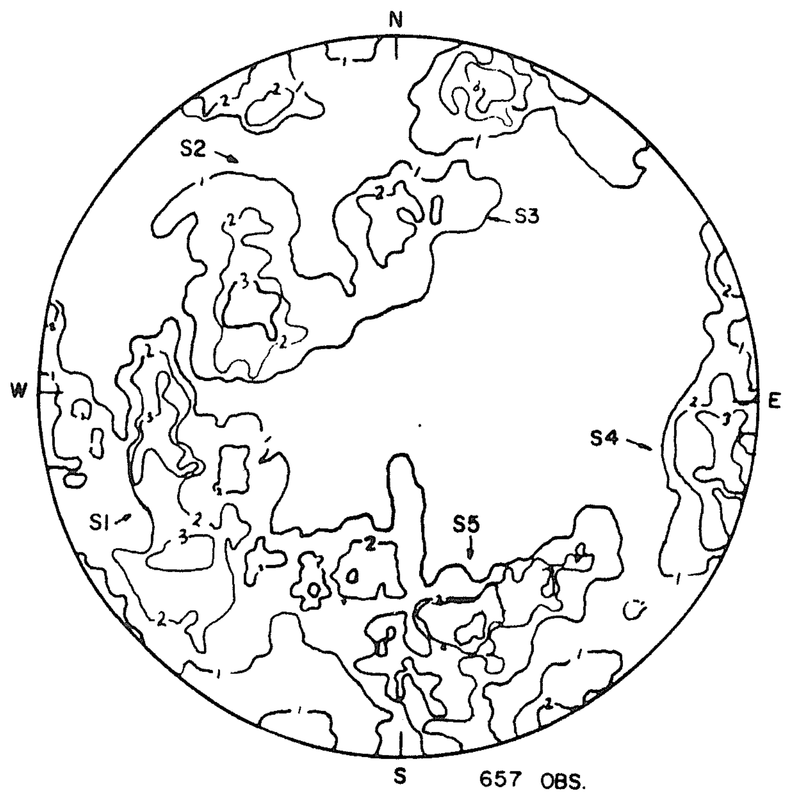


Figure 10: Orientations from 800 to 720 Level - Domain III

1) 75 percent of the core was oriented 221/300 meters;
2) RQD was 80 percent; and
3) geology was that of a feldspar porphyry.

Drill rates were as follows: 140 ft of core per ten hour shift were drilled and oriented. Normal operations would yield 200 ft per ten hour shift.

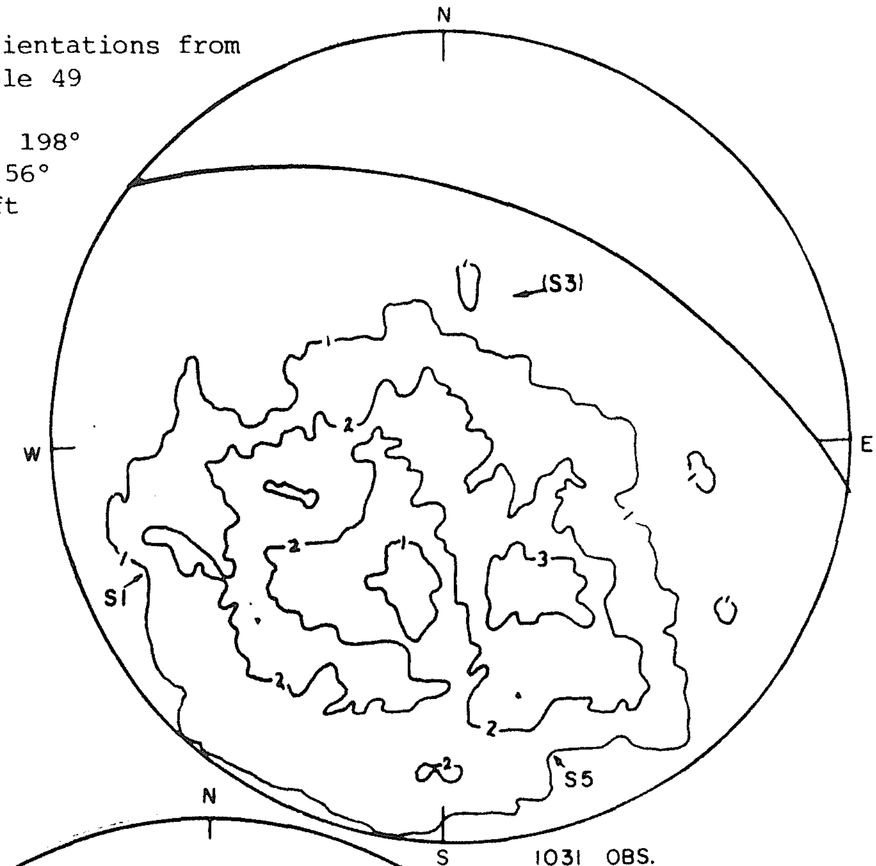
Due to the high drill rate in this type of rock, drill rates were impeded by 30 percent. The orientor, however, was dropped every 20 ft, and, due to the intact nature of the core, it could be back/fore oriented by matching up the impression stub (fore-running core) and the mirror-image stub (back-running core).

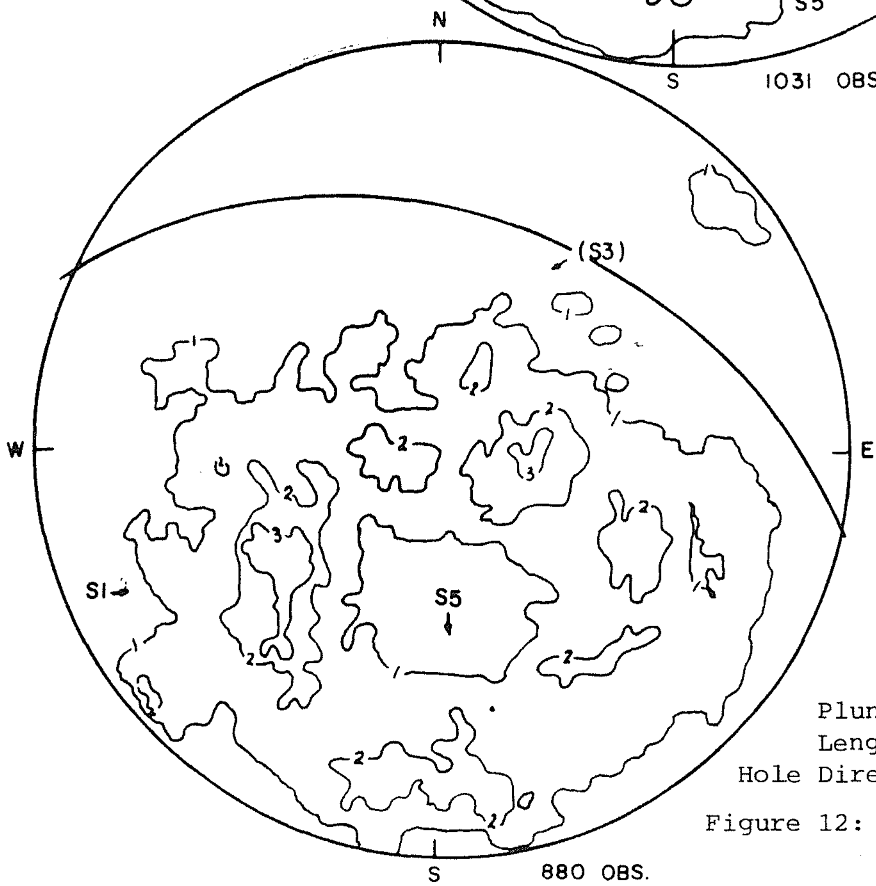
Salient Points

In addition to the blind band, a gap was evident in D48, D49, and D51. Upon closer examination, it became apparent that the gap had an orientation that reflected all discontinuities perpendicular to the core axis (orientations in Figures 9, 11, and 12). At the mine site, these perpendicular structures to the core were assumed to be due to the drilling procedure and not natural breaks, and, therefore, they were not measured. It was also found that recording Tropari readings at the bottom, middle, and top of the hole was sufficient.

Figure 11: Orientations from Hole 49

Hole Bearing: 198°
Inclination: 56°
Length: 791 ft





Plunge: 55°
Length: 870 ft
Hole Direction: 195

Figure 12: Orientations from Hole 51

Bits with the water courses on the inside helped drillers to know when the core orientor had reached its destination. This occurred because the orientor blocked passage of water through the bit annulus; as a consequence, water pressure increased.

The device was used by exploration geologists at Utah Ltd. to orient particular faults, enabling the geologists to obtain a better understanding of the genesis of the deposit.

Summary of Borehole Structural Logging Techniques

Method	Borehole Size	Principal of Operation	Restrictions	Cost
Paint Marker	no limit	gravity	Inclined hole, difficult to apply paint mark under water	Double (50% slower)
Craelius Core Orientor	wide range	mechanical profiling	inclined hole, requires expert on site	$2200/unit (buy) Slows drilling Can only obtain 8½ft core/10 ft run
Borehole Camera	60 mm	photography of borehole wall	restricted to clear water, low head	$5000/month (rent) (+$300/day/expert)
Borehole Television	63 mm	video of wall	water head is bad, require clear water	$70/day(rent) (+$300/day/expert)
Christensen	no limit	mechanical scribe plus photo of scribe superimposed on a compass	slow	$10,000/mo (rent) (double cost of drilling - 50% slower)

Costs are obtained from Roctest Stockholm, Sweden; CANMET; B.C. Hydro; Christensen, Salt Lake City, Utah; 1980 figures.

CONCLUSIONS

Drill core can be reliably and inexpensively oriented, using a clay imprint device. Tests have shown that fracture orientations can be accurately obtained from core drilled in an inclined drill hole, using conventional wire-line coring procedures. The orientor is simple, with a minimum of moving parts; mechanical failure is, therefore, nearly eliminated. The clay imprint on the bottom of the hole produces an imprint that can be reliably matched to the extracted drill core. Since the drill core must be fitted together in the core tray, some drill runs in intensely fractured rock cannot be oriented. However, in most holes, a sufficient number of fractures can be oriented to give a good statistical sample of the fracture population. Major structure, as well as rock fabric, can be oriented.

ACKNOWLEDGMENTS

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