“Drill Core Problems”

By Professor Alfred C. Lane, of Tufts College
(Until recently State Geologist of Michigan)

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The article begins:

Introduction

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DRILL CORE PROBLEMS

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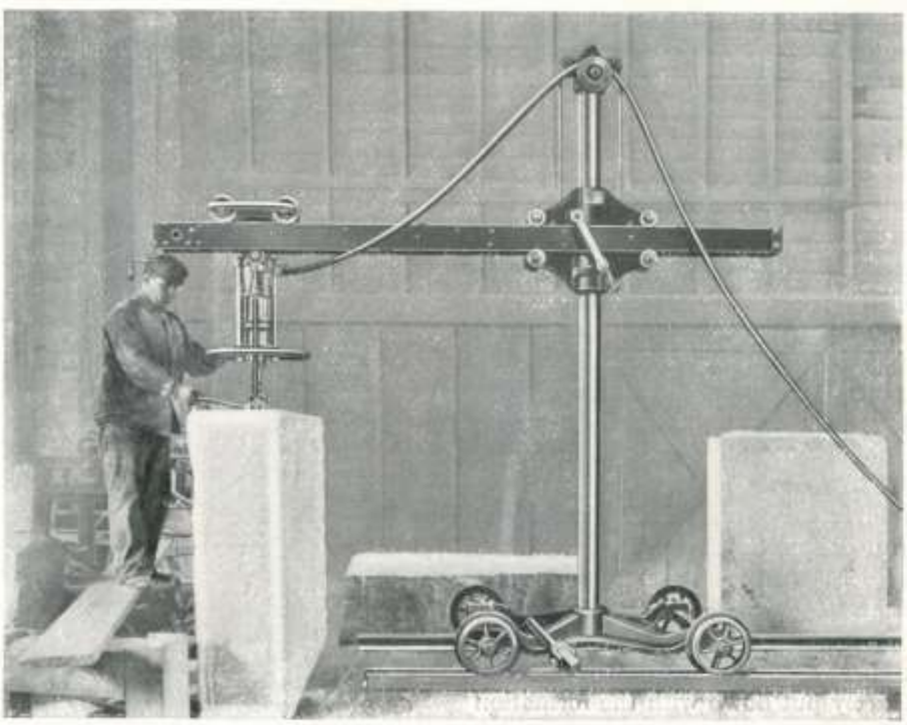
INTRODUCTION

The result of diamond drilling, which is the modern method of mineral exploration, is a series of cores or cylinders of rock. These cores are marked with bands or with lines. Some of these are due merely to the irregular wear of the drill. Others represent the bedding of successive layers of sedimentary rock. Exactly similar bands may represent the flow lines of lavas. Others may represent slaty cleavage, or other bandings due to pressure and shearing. Often these are small veins filled with calcite or other vein material.

The ends of these cylinders may be turned into a cup shape, or broken short off, or irregular. But very often they follow bedding or jointing or some line of weakness. If not, a sharp tap with a hammer will often break the core across, along some such plane.

The general tendency is to drill holes as nearly as possible at right angles to the bedding or that direction in which the rock parts most easily. There is more than one reason for this. For one thing, a greater thickness of strata is tested by a given length of hole. For another thing, the pieces of core are likely then to break off more nearly square across and move easily and smoothly up the core barrel (the tube in which they are contained) as the drill works its way into the rock. If they break obliquely they are likely to wedge and jam and get broken and ground into "sludge." It is always the object to get as much core as possible from the drill. Yet even with fair rock, from 1,000 feet drilled there is



Sullivan "D-28" Crane Surfacer, Barclay Brothers, Barre, Vermont

[1] Until recently State Geologist of Michigan.

often only 500 to 700 feet of core. If the cost per foot drilled is $2.50, the cost of the core will run from $3 to $4. It is, therefore, important to make as much as possible out of the core and the various lines and bands crossing it, whether they represent the bedding or represent displacements which may affect the record. The proper interpretation of these lines and bands is not always an easy matter. In the first place, the hole itself is liable to vary in direction. In the second place, generally speaking, we do not know the position of the core. A line or plane cutting it cuts it at an angle which can be measured. But in what direction that angle is from the core is usually not known. Little attention has been given to the marketing of core so as to know its exact position, — to know, for instance, the lowest side of the core taken from an inclined hole, though it is not impossible to do this.

If the core is crossed by lines of bedding, and we know from surface observations, what the direction of that bedding is, we can then tell how the core stands, and with that information can definitely determine the direction of other lines that cross it.

It is customary, as we have said, to put down holes at right angles to the dip, and often diamond drill holes are arranged in a series, so as to make a section across the formation. There is another advantage, beside the two above mentioned, in doing this, that errors are of less importance. The errors in thickness of a hole supposed to be put at right angles to the formation, but really deviating as much as 15° therefrom are but one-thirtieth and a deviation of one-third as much will have but one-ninth the error.

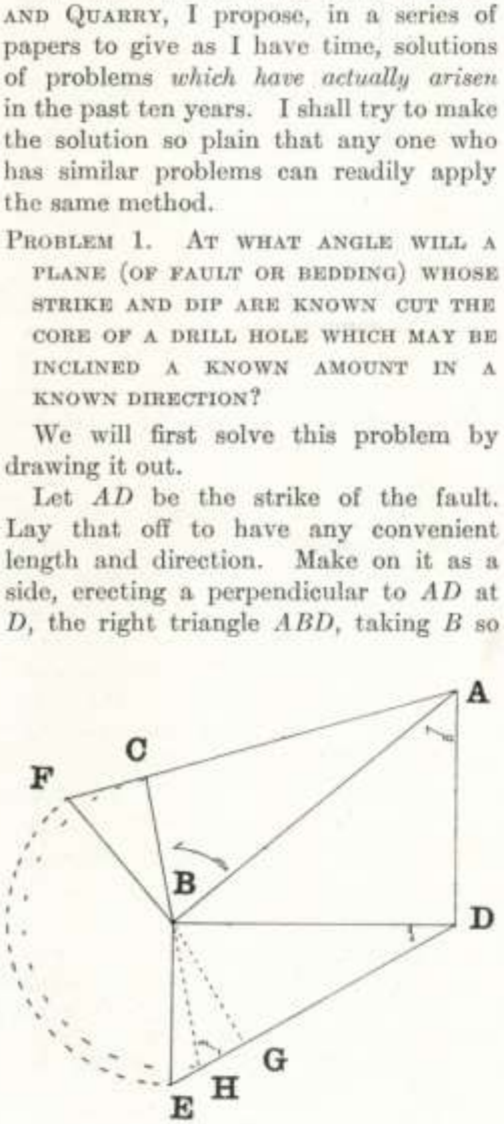
But occasionally, through unforseen quirks in the formation, holes are far from perpendicular to the formation to be tested. Of course, holes are sometimes deliberately put down with the formation to prove up the average quality of a chute, and put down vertical, even though the strata are highly inclined. In that case it is not always a simple job to compute just what the strike and dip of a formation are, even from a number of holes, though these are of vital importance, and there is a temptation to use approximate methods, beyond the limit of even approximate accuracy. I gave a discussion of a number of such problems that arise in my report on Isle Royale — Geological Survey of Michigan, Vol. VI, Part 1. 1899.

At the invitation of the editor of MINE AND QUARRY, I propose, in a series of papers to give as I have time, solutions of problems *which have actually arisen* in the past ten years. I shall try to make the solution so plain that any one who has similar problems can readily apply the same method.

PROBLEM 1. AT WHAT ANGLE WILL A PLANE (OF FAULT OR BEDDING) WHOSE STRIKE AND DIP ARE KNOWN CUT THE CORE OF A DRILL HOLE WHICH MAY BE INCLINED A KNOWN AMOUNT IN A KNOWN DIRECTION?

We will first solve this problem by drawing it out.

Let AD be the strike of the fault. Lay that off to have any convenient length and direction. Make on it as a side, erecting a perpendicular to AD at D, the right triangle ABD, taking B so



Drill Core Problem

that the angle DAB shall be equal to the difference in direction between the strike of the fault, and the direction of inclination of the hole. If, for instance, the hole is inclined 65° to N, 55° E, and the strike of the fault is N, 5° E, the angle DAB would be 50°.

Now, on BD make a right triangle BDE, with BE perpendicular to BD, such that the angle BDE is the same as the dip of the fault, which is known. This known angle and the fact that BE is perpendicular to BD determines E. Draw BF perpendicular to BA and equal in length to BE. Draw BC, making an angle with AB representing the inclination of the drill hole. If we should cut out along the heavy lines of the figure, A to F to B to E to D to A, and fold down ABF around AB and DBE around BD until BE and BF met, we should have a little model of the situation. The line BC would represent the drill hole and the plane from AD to the combined point FE, the plane of the fault. A line BG perpendicular to DE, which will represent the direction of dip, will be perpendicular to the plane of the fault, when thus rotated, and the angle the plane of the fault and the signs of it crossing the core make with the core, will be the complement of the angle BC will then make with BG. But as BG is perpendicular to the plane of the fault, the triangle BGC in which GC is in the plane of the fault, will be a right triangle.

Thence we have the rest of the construction. Lay off (cutting DE extended, if necessary) $BH = BC$ and the triangle, BGH will be similar to the triangle BGC of the model. The angle GBH = angle GBC of model, and the angle BHG is the complement of it and the angle sought.

The solution obtained by a careful drawing is generally as accurate as there is any use for, since it can be made as accurate as observations of lines crossing a drill core. Similar drawings may be used to solve many other problems.

For instance: We may in similar fashion connect the true dip and strike with the dip as it appears on a quarry wall running in some direction.

A trigonometric solution in numbers may be obtained by solving a series of right triangles corresponding to those we have constructed.

1. Let $AD = 1$. Then BA = sec of the angle DAB, the known angle between the strike of the fault and the direction of inclination of the hole. Call it s. $BA = \sec s = 1.56$ in the particular case drawn where $s = 50°$.

2. $BD = \tan s$ similarly $= 1.192$.

3. $BE / BD = \tan BDE$. This angle is the dip of the fault. Call it d. Then $BE = \tan s \tan d$. In the case drawn $d = 30°$, $\tan d = .577$ and $BE = .688$.

4. $BG / BD = \sin EDB$. Therefore, from 2, $BG = \tan s \sin d$. As drawn $BG = .596$.

5. $BE = BF$ and so the angle at BAF may be found since by 3 and 1, $\tan BAF = BF / BA$. Then by 3 $BF = BE = \tan s \tan d$ and BA in the triangle $ABD = \sec s$; so $\tan BAF = \tan s \tan d / \sec s = \sin s \tan d$.

In the case before us $\sin s = \sin 50° = .766$ and $\tan d$ as in 3 is .577 and $\tan BAF = .442$. $BAF = 24°$ Call the angle $BAF = BAC\ a$, then $\tan a = \sin s \tan d$.

6. By a standard trigonometric formula any two sides of a triangle are as the sines of the opposite angles. It may readily be proved by dividing it (ACB for instance) in two right triangles by a perpendicular dropped from (C) the remaining angle to the other side. Hence $BC / BA = \sin BAF / \sin BCA$. But it was found by 1, that BA is sec s; this angle BAF (we call it a) was found by 5. $BCA = 180° - a -$ (inclination of hole ABC) (call this i). Therefore, since $\sin (180° - a - i) = \sin (a + i)$ $BC = \sec s \sin a / \sin (a + i)$. In this case draw $BC = 1.560 \times 0.405 / 1. = .632$.

7. Hence we have the angle sought, BHG, which is the complement of $GBH = GBC$; $\sin BHG = BG / BH = BG / BC =$ (by 4 and 6) $\tan s \sin d / \sec s \sin a / \sin (a + i) = \sin s \sin d \sin (a + i) / \sin a$, where a by 5 is $\tan^{-1} \sin s \tan d$. If the hole is not inclined $BC = BF$ and $BH = BE$. $i = 90°$ and BHG complement of 90°.

With a slide rule this series of triangles may be solved by one used to working it in a few minutes, as short a time as required to make a careful drawing.

In the case drawn $\sin BHG = (BG = .596) / (BC = .63) = .946$, therefore, angle $BHG = 70°$.