NOTES AND NEWS

MEASURING LINEAR STRUCTURES ON STEEP-DIPPING SURFACES

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Ingerson[1] has recently described an "Apparatus for Direct Measurement of Linear Structures." In the course of this article he correctly states the method of obtaining by means of the meridian stereographic net the bearing (B) and pitch (P) of the lineation from (1) the dip (D) and strike (S) of the *s*-surface plus (2) the protractor angle (A) in the *s*-plane between its strike and the direction of lineation. He dislikes this procedure for a number of reasons, one of which is that "it does not give final measurements for comparison in the field."

The writer has recently described a new projection protractor[2] which takes the place of the ordinary protractor commonly carried by the field geologist. This new instrument is only about half again as large as the common 5-inch semi-circular protractor. By using the new stabilized tracing paper many stereographic problems including the one described by Ingerson can be solved above the semi-net of this protractor, and this is easily done right in the field.

As pointed out by Ingerson the problem of measuring linear structures in the field is not difficult as long as these lie in planes which do not dip steeply. If one meets many cases involving fairly high dips, it would be desirable to have the Ingerson apparatus, though this must be quite expensive. For those who cannot afford this, or for whom the problem is only an occasional one, the net solution approximately as given by Ingerson or the special protractor solutions described below may be of interest. The problem used is the same one stated by Ingerson, where $D=70°$ NE., $S=$ N. 56 W., and $A=69°$ (down to the NW.), and the projection is from the lower hemisphere.

[1] *Am. Mineral.*, **27**, 721–725 (1942).

[2] *Jour. Geol.*, **49**, 292–323, 419–442 (1941). Reprint, protractor, and paper are available from the Univ. of Chicago Bookstore.

Stereonet Solution.[3] Place the projection protractor above a piece of $\frac{1}{4}''$ thick plywood on which rests a piece of white paper (or paint the plywood white).[4] Place a piece of stabilized tracing paper above the semi-net and insert a fine needle[5] through it and the center of the net C[6] into the plywood. Plywood and paper need be only slightly larger than the semi-net, but it is perhaps better to have the tracing paper slightly larger than the full net.

Draw a short arrow tick on the tracing paper above the north end of the polar diameter of the net and label it N. Rotate the paper so that N lies above N. 56° W. Place a dot at point L along meridian 20° (out from center along equator) and 69° from N. Rotate the tracing paper until L lies above the polar diameter, when it is read that $LC = 29° -$ and N lies 14° west of the polar diameter.

This method thus requires the location of one tick and one point together with two rotations. Really only one rotation is necessary, since the initial tick (N) may be drawn at N. 56° W. The visualization of this particular problem is clearer if the S pole of the net is taken as the one near the center of the projection protractor, rather than the reverse as is done above. L is then established when the N tick on the tracing paper lies above N. 56° E. of the net; this condition fits Ingerson's Fig. 1. LC is then read when N is above N. 14° E.

[3] A stereonet solution (upper hemisphere projection) is described in H. W. Fairbairn: Structural Petrology of Deformed Rocks (1942), pp. 106, 125.

[4] Or make a positive cut film copy of a complete net (as suggested by Ingerson and Tuttle in the following paper) and cement its emulsion side to a $\frac{1}{8}$-inch thick piece of white celluloid.

[5] For convenience in carrying, my friend F. Paba has suggested that the needle may be mounted in the cap of a small metal box such as is supplied with extra leads for a mechanical pencil. First insert its eye end in a blob of soft glass; then cement this in the metal cap with plastic wood, sealing wax, or plaster of Paris.

[6] Symbols are as in Fig. 2 on p. 296 of *Jour. Geol.*, **49**, 296 (1941), with N (north pole) just below the center of the projection protractor.

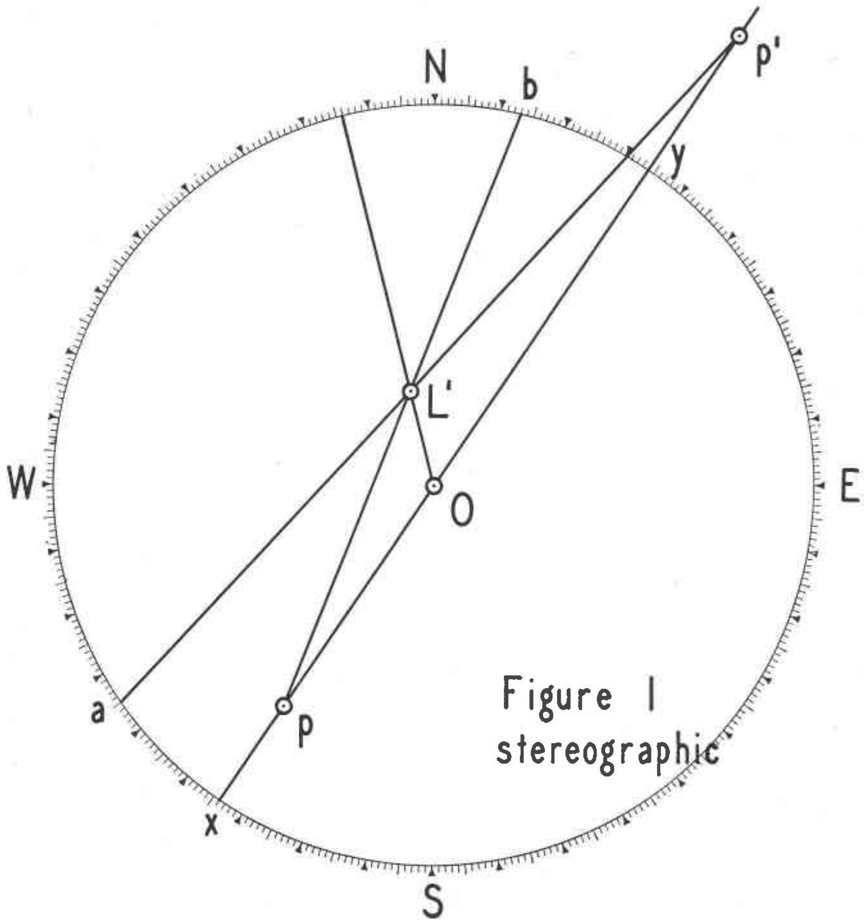

FIG. 1.

Alternative Stereographic Solution. Figure 1. Draw the diameter xy in the dip direction. With the top scale of the projection protractor along this, its zero-point at O, establish antipodal points p and p' such that $Op = D$ and $Op' = (180 - D) = 110°$, the latter in the dip direction. Locate a and b on the protractor circle out from x and y by $(90 - A) = 21°$. Draw pb and $p'a$ their intersection[7] giving L'. Then the angle of pitch $P = (90 - OL') = 61° +$ (read along the top scale of the projection protractor) and a radius through OL' gives the required bearing $B =$ N. 14° W.

[7] Explanation of this method appears in Fisher, D. J., *op. cit.*, footnote 16.

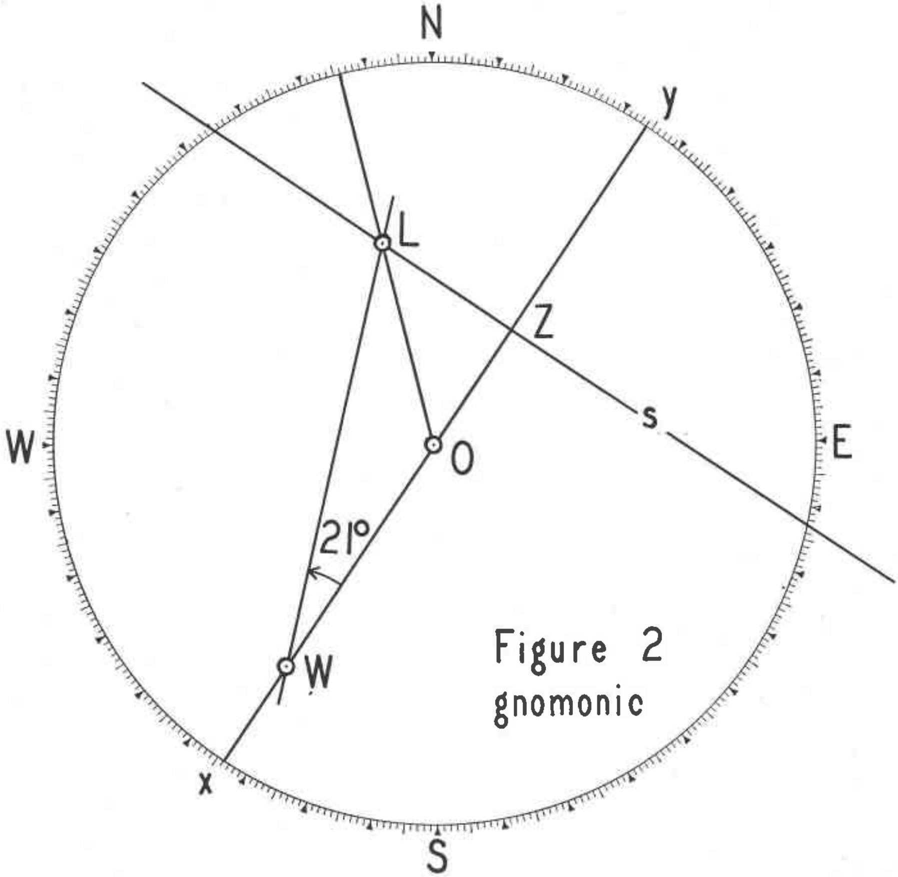

FIG. 2.

Gnomonic Solution. Figure 2. Draw the diameter xy in the dip direction. With the top scale of the projection protractor along this, its zero-point at O, establish W and Z such that $OW=D$ (measured in *stereographic* degrees) and $OZ=(90-D)=20°$ (measured in *gnomonic* degrees in the direction of the dip). With a straight edge (or field scale) along xy, erect a normal to it at Z by using the projection protractor in lieu of a small right angle triangle. This line represents the euthygraphic projection of the s-surface, and W is its angle point. At W lay off an angle of $(90-A)=21°=\angle ZWL$ which serves to establish L along line ZL. Then the angle of pitch $P=(90-OL)=61°+$ (read in gnomonic degrees along the top scale of the projection protractor) and a radius through OL gives the required bearing $B=$ N. 14° W.

Discussion

It is felt that the stereonet solution is definitely to be preferred to the alternative stereographic construction. However, the gnomonic solution, as is commonly the case, is considerably more accurate than the stereographic one; it also permits the easiest visualization of the problem, and so mistakes are less likely to occur.

If the geologist could go into the field knowing just what problems he would meet, for many cases he could take the necessary graphical solutions with him. Where the nature of his work is such that he expects to need to solve a certain equation many times, he does well to have with him the necessary graph or piece of apparatus to accomplish his purpose with a minimum consumption of time.

The advantage of projection solutions of problems involving angles between lines and planes is that they combine the clearness of descriptive geometry with the speed of the graphical solution. The user is not an automaton following a set routine; he is an artist visualizing what he is doing. Many problems can be done on a stereonet, and the small ones on positive film mentioned by Ingerson and Tuttle[8] are satisfactory for field use. Where the greater accuracy that is generally inherent in gnomonic solutions is desired, the gnomonic scale of the projection protractor is essential. Those stereographic problems requiring the use of small circles[9] cannot be done above a net, and are greatly facilitated by a stereoscale. For any one particular problem the stereonet or even the whole projection protractor may not offer the best solution, though the writer considers that it does in some cases, such as the two-tilt[10] and two-borehole problems. When one takes into consideration the large numbers of problems that can be solved with this one piece of equipment, it seems that it should be in the outfit of every field geologist, especially since it replaces an ordinary protractor, as well as a small right-angle triangle and a centimeter scale.

[8] See following paper.

[9] Fisher, D. Jerome, Drillhole problems in the stereographic projection: *Econ. Geol.*, **36**, 551–560 (1941).

[10] *Jour. Geol.*, **49**, 429 (1941).