ACCURATE ORIENTATION OF THIN SECTIONS*

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INTRODUCTION

With the advent of petrofabric analysis has come the necessity for accurate measurement and recording of the orientations of thin sections with respect to geographic directions, or structures in the rocks, or both. Oriented sections have been used in Europe extensively since 1925, and are being more and more used in America, but, as far as the writer is aware, there is no apparatus in use for determining orientation accurately. It is commonly approximated by using combinations of protractor, straight edges, and reference lines on paper or cardboard. Such crude methods often give errors of 10° to 15° and the writer knows of one instance in which an uncertainty of that order of magnitude in the orientation of his thin sections caused an author to waver between two opposed interpretations in a regional problem. If he had known the orientation within 2°, the interpretation would probably have been definite.

The apparatus illustrated and described below was devised by the writer for the purpose of orienting hand specimens accurately in the laboratory and measuring the orientations of joints, s-planes, and lineations, and marking planes of thin sections. The model described was the first one built and is necessarily a little awkward for some of the measurements. However, it does give a rapid measurement of the orientation of any plane or lineation in a rock more accurately than similar measurements can be made in the field. It is, therefore, deemed advisable to publish a description at this time with the hope that the apparatus will prove of immediate usefulness to the workers in fabric analysis, and that improvements in design that are sure to come will be made more quickly as a result of suggestions from these workers.

DESCRIPTION OF APPARATUS

The apparatus consists of two separate pieces: 1. Table for holding a hand specimen. (Fig. 1, I.) 2. Measuring device. (Fig. 1, II.)

Table. The table for mounting hand specimens is very simple. It consists of a brass plate (Fig. 1, I, *A*), three inches square and one-fourth inch thick, mounted in the middle of a brass plate that is six inches square and one-half inch thick, *D*, by means of an ordinary ball and socket joint, *B*, like those used on tripods. The top of the upper plate is made

into a grid by cutting grooves one-fourth inch apart and one-sixteenth inch deep in it. This is a very effective method of holding the molding clay which, in turn, holds the specimen.

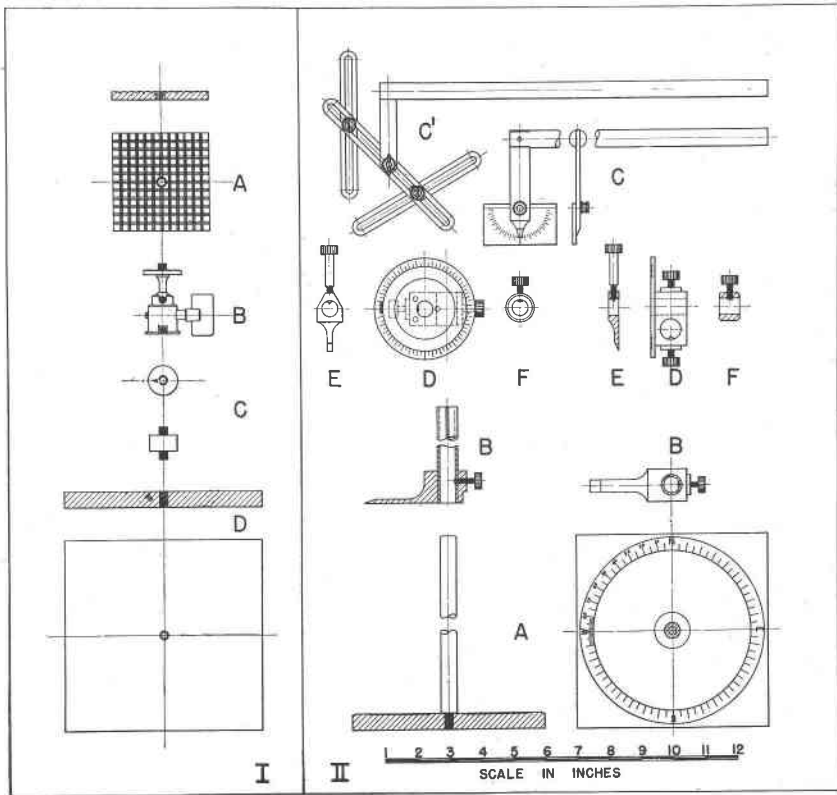The *measuring device* consists essentially of three parts:

Fig. 1—Detail drawing of the orienting apparatus.
I—Mounting table.
II—Measuring device.

(a) A brass plate (Fig. 1, II, *A*), with a graduated circle from the center of which rises a one-half inch brass rod twelve inches long, normal to the plate. The four sides of the plate are marked *N*, *E*, *S*, and *W*, and the four quadrants are numbered independently.

(b) A brass tube, *B*, turns on the rod and there is a pointer brazed to it so that the two turn together. A set screw opposite the pointer can be tightened so that the tube and pointer are clamped in a given position. This pointer gives the strike readings. There is a groove in the outside

of the tube into which a screw of a right angle clamp, D, fits so that the clamp maintains a fixed relation to the tube and pointer. Through the other (a horizontal) hole of the clamp passes:

(c) A one-half inch brass rod, C, twelve inches long. To one end of the rod is fastened, by means of a three inch bar normal to the rod, a brass plate that is one and one-half by two inches and one-eighth inch thick. A set screw in the right angle clamp holds the rod (and plate) in any desired position. The rod is grooved and a pointer on a screw collar, E, rides the rod in such a position that it is always normal to the measuring plate. A vertical graduated circle is brazed to the clamp, D, with its zero point at the top so that the pointer, E, reads 0 when the measuring plate is horizontal. These readings obviously give the dips. A movable collar F, on the rod and opposite from the pointer keeps the rod from slipping through the clamp while it is being turned.

The end of the bar that holds the measuring plate serves as a pointer for the graduated semi-circle on the latter. When this pointer indicates zero the long edge of the plate is horizontal and is parallel to the rod that carries it, and hence to the pointer on B. Therefore, the readings on the circles of D and A give the dip and strike, respectively, for the plate. C may be replaced by a similar rod on which three slotted thin brass bars, C', take the place of the plate. The bars may be moved in the plane of the plate and are oriented in the same manner. They are for marking the plane of a thin section on a hand specimen, or for determining the orientation of an *s*-plane.

PROCEDURE

The apparatus can be used for the following:

1. To orient a hand specimen for laboratory study.

2. To measure the orientation of a plane surface other than the one marked (e.g., a joint plane).

3. To measure the direction and angle of plunge of a lineation.

4. To mark a plane in a given position.

5. To measure the orientation of an *s*-plane or other plane that does not form a flat surface on the specimen.

1. The first step in marking or measuring a plane or lineation on a hand specimen is to orient the specimen. A specimen oriented in the field will necessarily have a more or less plane surface with arrows marked on it representing the dip and strike. To re-orient such a specimen in the laboratory it is only necessary to set the measuring plate at the proper dip and strike, mount the specimen on the table, and bring the marked surface parallel to the plate, with the strike arrow on the

specimen parallel to the long edge of the plate (Fig. 2). This is accomplished as follows:

(a) Turn the pointer on *B* so that it reads the strike and clamp it tightly.

(b) Turn the rod holding the measuring plate until the pointer on the vertical circle reads the proper dip. Clamp. In the example illustrated in Fig. 2 the face on the specimen strikes *N* 69° *E* and dips 27° *SE*.
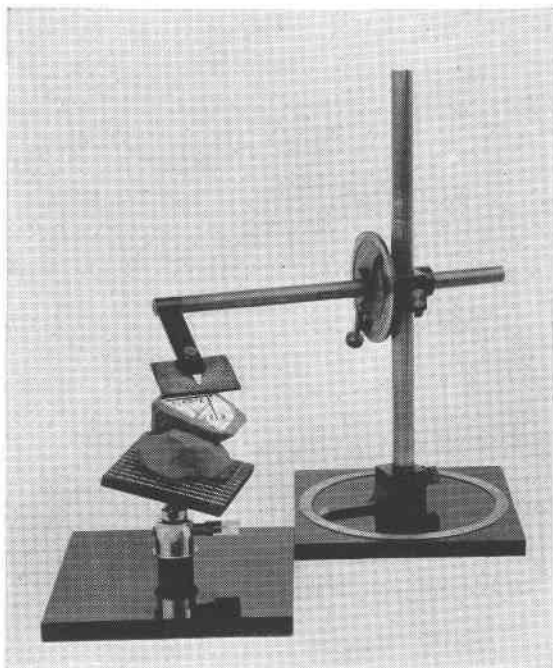

Fig. 2—Method of re-orienting a hand specimen in the laboratory.

(c) Mount the specimen on the table and place the table base against that of the measuring device in such a position that the specimen is brought as near to the plate as possible. Adjust the specimen in the clay so that the marked surface comes somewhere near parallel to the plate.

(d) Loosen the universal joint and adjust the table until the two surfaces are practically parallel. Re-clamp the universal joint.

(e) Adjust the height of the plate (without changing the orientation) so that it just touches the rock.

(f) Loosen the universal joint again and complete the orientation by turning the table slightly and moving the base of the table, if necessary. Be sure that the strike line on the specimen is parallel to the long edge of the plate.

2. To measure the orientation of another plane surface on a specimen after it has been oriented the following steps are taken:

(a) Move the mounting table to such a position that the face to be measured strikes approximately toward the upright rod of the measuring device.

(b) Release the tube and pointer (Fig. 1, II, *B*), and turn them until the measuring plate approaches the specimen.

(c) Release the rod, *C*, on which the measuring plate is fixed and turn it until the plate comes approximately parallel to the surface to be measured.

(d) Complete the measurement by moving the base of the mounting table slightly and/or adjusting the measuring plate.

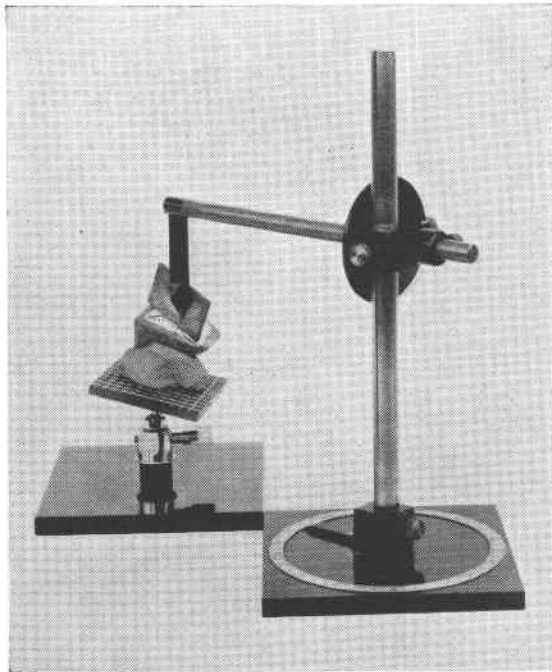(e) Read the dip and strike on the vertical and horizontal circles respectively.

FIG. 3—Measurement of the direction and angle of plunge
of a lineation (25° *S* 47° *E*).

3. Measurement of a lineation.

(a) Direct measurement (Fig. 3); when the lineation lies in a plane surface:

(1) Fasten the dip plate so that it is vertical; i.e., so that the pointer, E, reads 90°.

(2) Move the mounting table so that the lineation plunges approximately toward the upright rod.

(3) Release the tube and its pointer and turn the measuring device until the measuring plate is directly over the lineation. It may be necessary to move the mounting table slightly.

(4) Loosen the plate itself so that it swings about its pivot and turn it until the lower edge of the plate is approximately parallel to the surface and hence to the lineation.

(5) Lower the plate until it just touches the specimen and make minor adjustments of the plate and/or mounting table until the edge of the plate and the lineation are as nearly parallel as possible.

(6) Read the direction of plunge on the graduated circle of the base, and the angle of plunge on the graduated semi-circle on the measuring plate. The lineation of the illustrative example, Fig. 3, plunges 25° S 47° E.

If the lineation is not in a plane surface on the specimen the edge of the plate cannot be placed in contact with it. However, it can be placed more or less parallel to the lineation by manipulations similar to those described above. The degree of parallelism depends upon how well the lineation is developed and exposed. The plate touches the specimen at the lowest corner only.

(b) Graphic solution; convenient only when the lineation lies in the marked surface. If a specimen has just been oriented and the plate is still parallel to the surface it may be easier to make a graphic solution of the direction and angle of plunge of a lineation in that surface as follows:

(1) Free the measuring plate and turn it about the pivot until the long edge is parallel to the lineation. The angle indicated on the plate gives the deviation of the lineation from the strike. If the geographic coordinates are desired a graphic solution must be made. The simplest one, for fabric analysis, is made by using the Schmidt net:

(2) The projection of the plane surface is drawn on a piece of tracing paper placed over the Schmidt net. This is done by turning the paper until the point on the periphery that represents the north end of the strike line is at the north pole of the net and then drawing the great circle that is as many degrees from the periphery as the angle of dip.

(3) The projection of the lineation is then represented by a point on this great circle as many degree from the north, or south, pole of the net as the lineation deviates from the strike.

(4) To determine the direction of plunge of the lineation turn the tracing paper back to the zero position and draw the radius that passes through the point representing the projection of the lineation. The point where this radius strikes the periphery of the net gives the direction of plunge.

(5) To obtain the angle of plunge turn the tracing paper until the projection of the lineation is on the equator of the net. The number of degrees that it lies from the periphery of the net then gives the angle of plunge.

4. To mark the plane of a desired thin section (Fig. 4):

(a) Substitute the arm carrying the slotted bars, *C'*, for the one carrying the plate, *C*.

(b) Set the pointers for the desired dip and strike, as in 1.

(c) Move the mounting table, keeping constant orientation, until the specimen comes within the three bars. It may be necessary to adjust the height or length of *C'*.

Fig. 4—Measuring and marking the plane of a thin section. The apparatus has been turned 180° from its position in Figs. 2 and 3 in order to show the marking arms to better advantage. Plane of thin section, *N* 67° *W* 89° *NE*.

(d) Adjust the bars until they fit the specimen as closely as possible and mark the trace of the plane with a sharp pencil, using the bars as straight edges. Fig. 4 shows the apparatus set up for marking the plane of a thin section. See Fig. 5 for a graphic representation of the data for this specimen.

(e) Remove the specimen and complete the trace of the plane by drawing a line across the bottom of the specimen, using a flexible straight edge, and then mark the trace all the way around with a heavy line in India ink.

If it is desired to mark a thin section plane with respect to some structure in the rock, the simplest procedure is to make a graphic solution to obtain the geographic coordinates of the desired plane and then proceed as outlined above.

5. To measure the orientation of a plane that does not form a flat surface on the specimen:

(a) Move the mounting table until the plane to be measured strikes, as nearly as can be told, toward the upright rod of the measuring device.

(b) Release the tube and pointer, *B*, and turn the measuring device until the arms of *C'* can be placed around the specimen. Release the rod carrying the arms and turn them until their plane approximately coincides with the one that is being measured.
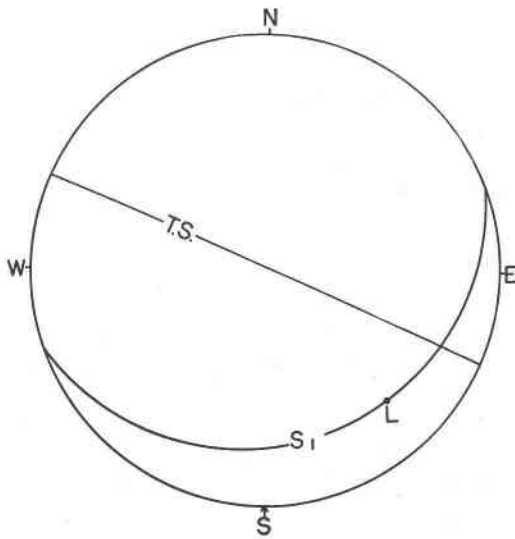

Fig. 5—Graphic representation on an equal area projection of the data measured for the illustrative specimen in Figs. 2, 3, and 4.

(c) Shift the table base and/or rod carrying the arms until they can be fitted to the plane to be measured on two or three sides of the specimen.

(d) Read the dip and strike of the plane on the vertical and horizontal circles, respectively.

Figures 2–4 show the apparatus set up for various measurements, as indicated in the legends and Fig. 5 shows the data plotted on a Schmidt net.

Improved measuring device.—The second model constructed is a decided improvement over the original one. Its description is included as a supplement to, rather than replacing, that of the original, because the latter is so much easier to make. Many shops are not equipped to construct the improved model, but its ease of operation more than justifies the extra effort required to build it, if it is at all possible.

Figure 6, I shows the improved model set up to orient a specimen; Fig. 6, II is a detail drawing of the parts that are essentially different from those of the first model. There are three important changes:

(1) Keys and keyways replace the slots and pointed screws that hold the pointer, *E*, of the original model and the right angle clamp and attached vertical circle, *D*, in constant relation to the rod, *C*, and the tube of *B*, respectively (see Fig. 1, II, and Fig. 6, II). This arrangement makes it impossible to get a wrong reading with either of the pointers.

(2) A keyed collar has been put in the side of the right angle clamp carrying the measuring arm, *C*, making it possible to vary the length of the arm without loosening a screw, or changing the orientation of the measuring plate or arms (see Fig. 6, II, *J*).

(3) The measuring arms and plate have been attached to the same rod so that no change of parts is necessary to orient a specimen or mark the plane of a thin section (see Fig. 6, I).

Marking of oriented sections.—It is important that the orientation of a thin section not only be measured and recorded accurately, but that it be marked on the thin section itself so that it can be oriented properly during the subsequent study and can be used by other workers, if occasion arises. If one knows the dip and strike of the plane of a thin section and knows which direction he is looking through it, then a single arrow fixes its orientation completely. However, it is very easy for a thin section to become inverted while it is being prepared, or even during mounting on a universal stage, so it is safer to have two directions marked on each section to obviate the possibility of inversion. The thin sections should be mounted so that one looks through them at the surfaces of the rock from which they are cut.
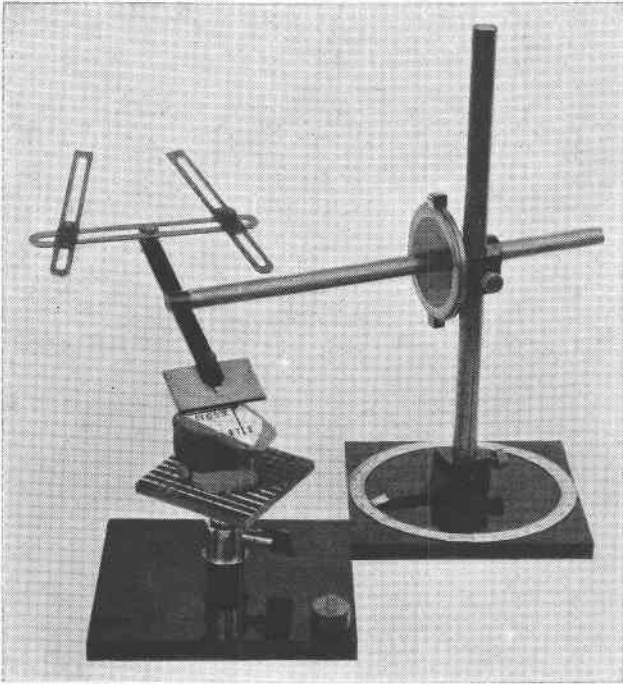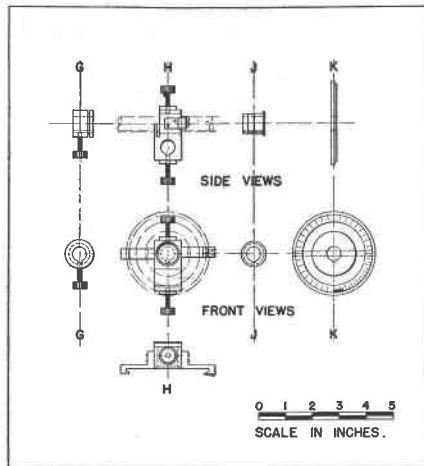
FIG. 6—I, improved model; II, detail drawing of the parts that are different from those of the original model.

If the positions of the fabric axes are known before the thin sections are cut it is customary to have the arrows parallel to the fabric axes. Sections cut normal to the *a*- or to the *b*-axis should have their arrows parallel to the *c*-axis, and to the length of the thin section, with the barbs toward the upper (positive) end of the *c*-axis. The other direction marked on the section normal to the *a*-axis is indicated by a short line without barbs, normal to the arrow, and on the side of $+b$. That on the section normal to *b* is toward $+a$. The arrow on the section normal to the *c*-axis should be parallel to the *a*-axis, with the barbs toward the front (positive) end, and with the auxiliary line on the side of $+b$. These orientations are based on the conception that the fabric axes are placed for study as the corresponding axes of a crystal would be. Such an orientation is convenient, but by no means essential. It is shorter to refer to thin sections by the names of the axes to which they are normal. Thus, the "*a* section," the "*bc* section," and "the section normal to the *a*-axis" are synonymous.

The sketches of Fig. 7 will make clear the suggested system for marking thin sections. The letters enclosed by parentheses are not marked on the actual thin sections; they are put on the sketches to indicate the directions of the arrows and lines for the different sections. If the positions of the axes are not known the dip and strike marked on a section fix its orientation. The actual marking may be with reference to fabric axes, prominent structures, or geographic coordinates. It makes no difference as long as the worker has enough data recorded so that he can relate all of these things to each other in the integration of his results.
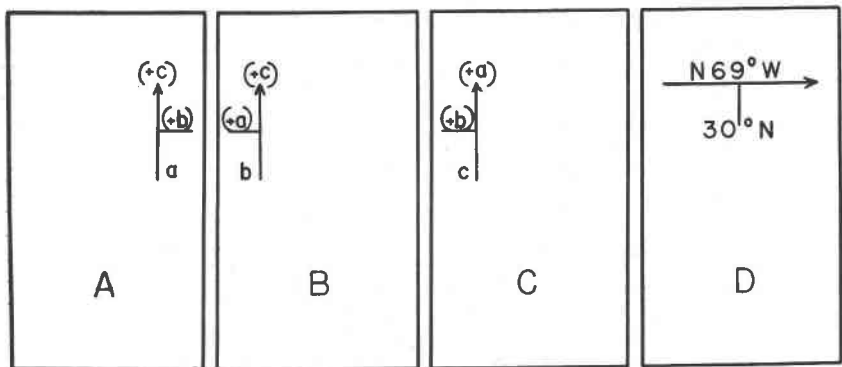

FIG. 7—Suggested method of marking thin sections. A, B, C, with respect to fabric axes. D, with respect to geographic coordinates. The letters in parentheses are not marked on the actual thin sections.

If one has a saw available so that the plane of the thin section may be smoothed off, the directions may be drawn directly on the surface for the thin section marker. If, however, the directions must be indicated on the rough specimen, the measuring device may be used to good advantage. A line may be drawn on the specimen in such a position that its points of intersection with the plane of the thin section determine the direction of the arrow on the thin section. Such a line should be drawn only on the part of the specimen through which it is desired to look at the finished thin section. Its orientation is fixed by measuring and recording the orientation of the plane that it determines. A different color of ink or pencil or different kind of line will distinguish this line from that of the thin section itself. The direction that the arrow is to point may be indicated by barbs on the line, and the auxiliary orienting line drawn on the proper side. It may be made a little more certain by marking the side of the specimen toward which the arrow is to point, ⊙, and the opposite side, ⊕. Figure 8 shows a specimen marked in this manner.
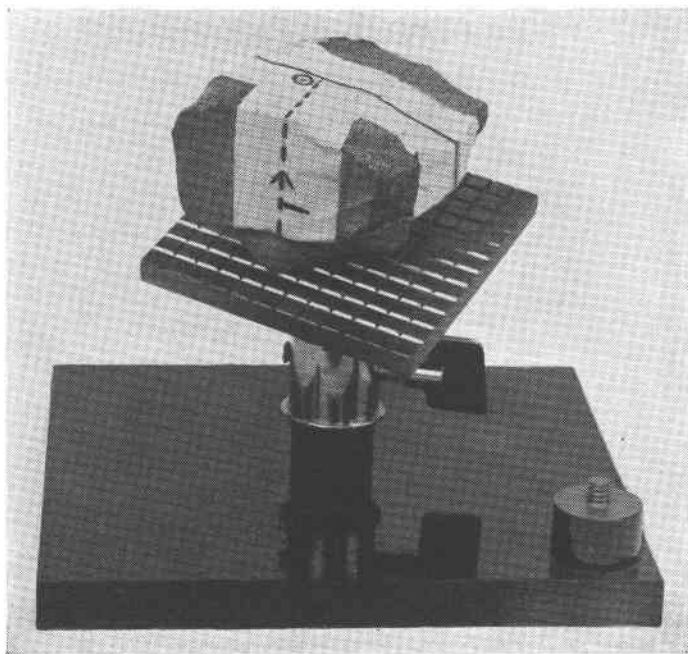

FIG. 8—Hand specimen marked in the suggested manner. The solid line is the plane of the thin section and the dashed line gives the direction of the arrow.

The actual sawing of a specimen along a given line is facilitated by having a machinist's flexible vise with spring-controlled "fingers" mounted in connection with a diamond, or carborundum, saw. Such a vise will hold an irregularly shaped specimen in any position. It is mounted so that it can be moved along two horizontal tracks that are at right angles to each other. The specimen is gripped in the vise with the plane of the desired thin section parallel to the plane of the saw and the vise is moved until the saw will cut the specimen at the desired place.