SOME EASILY CONSTRUCTED MODELS FOR TEACHING OPTICAL MINERALOGY

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The study of optical mineralogy generally offers considerable difficulty to the average student of geology. Any method, therefore, which will enable the instructor to simplify the subject matter and enable the student to grasp the concepts involving three dimensions may be considered worthwhile.

A definite contribution to the simplification of teaching as well as learning the fundamentals of optical crystallography has been made by those who have suggested or described the numerous kinds of models which illustrate the various optical and crystallographic phenomena. At one extreme are those models so elaborate in their nature as to require great skill in construction. At the other extreme are models so simple in their makeup that they may be readily prepared by almost anyone. This paper deals with models of the latter group; and although these models are relatively simple in their construction, they have, nonetheless, proved very successful in teaching mineral optics, and have greatly aided those students who have experimented with them.

Most of the models described in the literature for representing the various relationships between optical and crystallographic properties consist of transparent glass, celluloid or plastic-like crystal forms within which the crystallographic axes and principal optical directions are represented by ruled lines, wires, or threads. Most of these are permanent and can be constructed with considerable accuracy. Any one model is somewhat restricted in its use; a different model must be prepared to represent each set of relationships. Such models do not, therefore, permit the flexibility required for demonstration and for student use as do the simple types described in this paper.

It is not intended here to consider models other than for biaxial crystals. If models for other optical types are desired, they can be prepared with little difficulty. It is hoped that the few examples given below will suggest to the reader ideas for making new models and simplifying or improving older ones.

Demonstration Models for Biaxial Crystals

Satisfactory models may be made of soft pine by cutting blocks of desired lengths from good quality 2 x 4 inch material. These blocks can be shaped into solid models with the crystal faces desired. For simplicity, models with only the three pinacoidal forms are illustrated here, but it will be found desirable to prepare some models with a prism form and perhaps with domes and bipyramids.

Orthorhombic models.—An orthorhombic model about 1¾ x 2⅝ x 4 inches is quite satisfactory, and when finished appears as in figure 1. The two rows of dots on each face represent small holes drilled directly toward the center of the model to

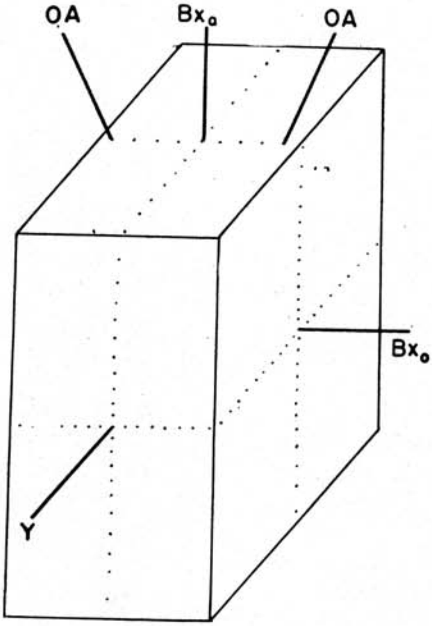

FIG. 1.

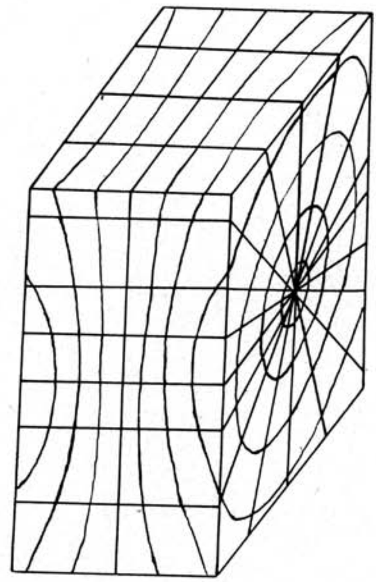

FIG. 2

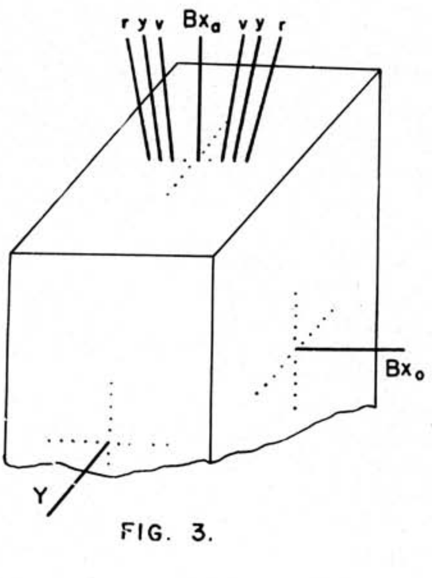

FIG. 3.

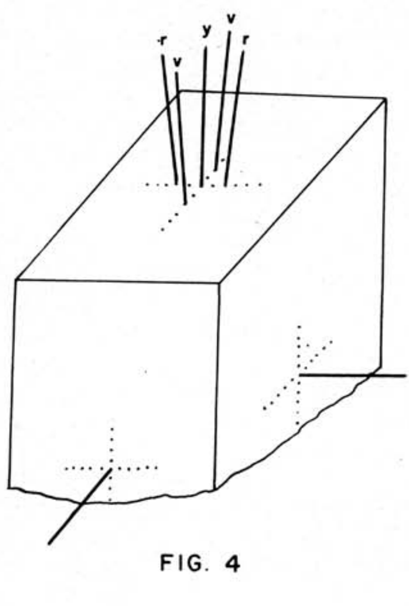

FIG. 4

a depth of about one-half inch. The points of intersection of the rows of holes lie at the centers of the pinacoids and the rows are parallel to the crystal axes. If round wooden sticks, about two inches long, are now inserted in the six holes at the intersections of the rows, the three principal optic directions X, Y, and Z may be represented in their proper positions parallel to the crystallographic axes. By inserting four more wooden sticks in the proper holes, the positions of the optic axes may be shown for a number of different optic angles. It is suggested that a relatively small number of holes be made to represent different optic angles. Holes spaced about 10° apart will be quite satisfactory.

To determine the spacing of holes, the following equation may be used:

$$D = \frac{\tan VT}{2}$$

where D is the distance from the center of the crystal face to the hole position desired, V is half the optic angle desired, and T is the thickness of the model measured perpendicular to the face to be drilled.

This model is suitable to demonstrate the unusual but instructive optical phenomenon of the lithiophyllite-triphylite series. In the most iron-poor variety the optic plane is parallel to (001) and the 2V about the b-axis is 65°. With an increase in iron, the optic angle decreases to zero and the mineral becomes uniaxial. As the iron content continues to increase, the optic plane becomes parallel to (100) and the optic angle about the b-axis increases to 90° and then begins to decrease about the c-axis until it again becomes zero and the mineral is uniaxial. With additional iron, the optic plane is believed to shift to a position parallel to (010) and the optic angle increases again about the c-axis.

Monoclinic models.—The monoclinic model as shown in figure 2 may be prepared with slightly greater difficulty. After preparing the desired crystal model, the center of the (010) face is located and radial lines drawn therefrom to the edges of the crystal face. These lines are continued across the faces in the zone of the b-axis parallel to the zone line. The radial lines might be spaced 10° or more apart. Next, concentric circles are drawn on (010), and their spacing is determined by the following equation:

$$r = \frac{\tan VT}{2}$$

where r is the radius of a given circle, V is half the optic angle desired and T is the thickness of the model measured perpendicular to (010). On the faces in the zone of the b-axis, hyperbolic curves are drawn. These can be roughly determined by computing their spacing along three of the parallel lines on each face and drawing smooth curves through these points. The spacings may be determined by use of the following formula:

$$S = \tan VM$$

where S is the distance measured right or left from the plane of symmetry, V is half the optic angle desired, and M is the distance from the parallel line to the b-axis measured on (010).

Where straight lines intersect curved lines, holes are drilled toward the center of the model to a depth of about half an inch. This model may be employed in much the same manner as the orthorhombic model. Extra sets of round sticks may be

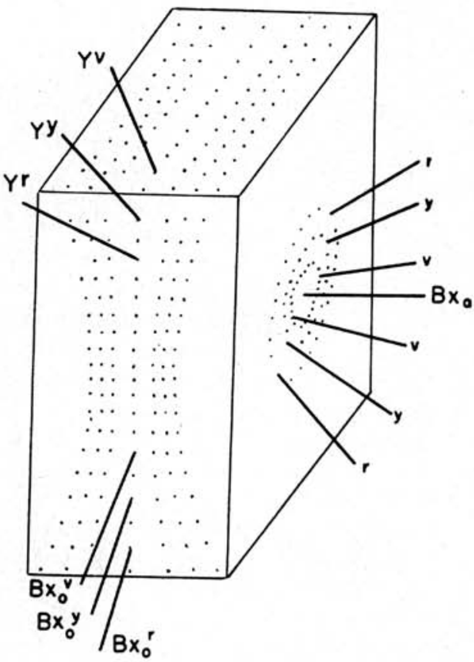

FIG. 5

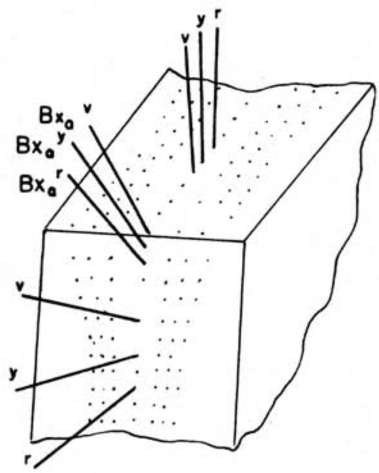

FIG. 6.

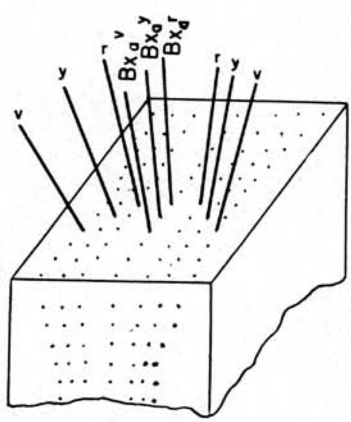

FIG. 7.

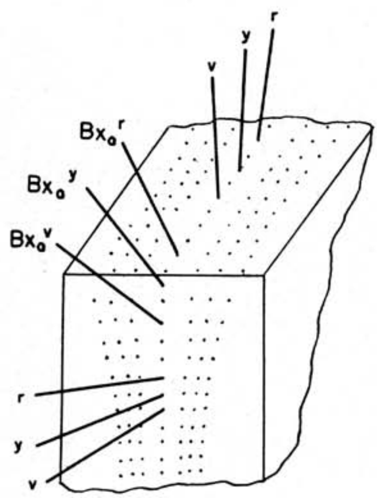

FIG. 8

used to show the positions of crystallographic a and c.

Triclinic models.—Triclinic models may be prepared by following essentially the same rules and with only slightly greater difficulty. It is suggested that only a few possible orientations be selected. Each set of holes for the directions X, Y, and Z must, in general, have an accompanying set of holes for optic axis positions.

Dispersion models.—A model like figure 1 or one like figure 3, in which a fewer number of closely spaced holes have been drilled, serves to illustrate the types of dispersion in orthorhombic crystals. Three sets of wooden sticks are used to represent the optic axes for different colors of light. One set is painted red, one yellow, and one violet. Figure 3 shows the model arrangement for dispersion of 2V with $r > v$. An arrangement like figure 4 illustrates crossed axial plane dispersion where the optic plane for red light is parallel to (100) and that for violet light is parallel to (010). The yellow stick in the position of the acute bisectrix indicates a uniaxial character for yellow light.

Figure 5 illustrates the monoclinic model for representing dispersion of 2V combined with dispersion of orientation. The principles of construction of this model are the same as those for figure 2. It is recommended, however, that there be a greater number of holes in each row and that the number of rows be reduced to seven. Figure 5 illustrates a condition in which $Bx_a = b$, crossed dispersion, and $r > v$. Figure 6 shows $Y = b$, inclined dispersion, and $r > v$. Figure 7 shows $Bx_o = b$, horizontal dispersion, and $r < v$. Figure 8 illustrates the type of relationship which exists in some minerals like epidote. If one optic axis only is observed in the interference figure, the dispersion appears $r > v$. If the other axis is observed, however, the dispersion appears reversed. Actually the dispersion of 2V is $r > v$. In figures 6 and 8 an extra hole is shown for the acute bisectrix for yellow light (Bx_a^y).

A model may also be constructed to illustrate several general examples of dispersion in triclinic crystals.

Permanent Reference Models

A very helpful set of models may be prepared for student study or reference work by employing the well-known Krantz pearwood models. After selecting the desired models, small holes are carefully drilled and long wire brads inserted to simulate the optic axes and the principal optic directions in each mineral represented. If desired, extra holes may be drilled and extra brads inserted to represent crystallographic axes as well. If the brads representing crystal axes are painted one color, those representing optic axes another color, and those representing the principal index directions a third color, each set will stand out more clearly. To produce a more finished model, the heads of the wire brads may be clipped and the rough ends filed smooth before painting.

Problem Models

Instructive problems and exercises may be undertaken by the student with the aid of inexpensive and easily acquired materials. Each student is provided with three small blocks, an inch or so long, cut from pieces of balsa wood, and roughly formed to represent the three pinacoids of the orthorhombic, monoclinic, and triclinic systems. Substitutes for balsa wood might include any soft material like cork or art gum. In addition the student should have a supply of straight pins with different colored heads. Different colors may be designated to represent the optic axes, crystal axes, and principal index directions. By inserting the round-headed pins into the balsa wood block an unlimited variety of problems may be worked out.

In order to reproduce a given optic angle, for example, the center of the model is held directly over the index mark of a small protractor placed on the table. By sighting down upon the protractor the pins are inserted to give the proper angle. The student should be instructed to insert all pins in such a fashion that if extended inward the pins would all intersect the model's center. Inserting pins at the proper angle may be facilitated by use of a simple type of protractor. From a point at the center of the long edge of a 3 x 5 inch filing card, draw a series of radial lines spaced at intervals of 5°. If each pin is aligned with the proper radial line of this protractor before it is inserted into the balsa wood, it will point directly to the center of the model and angles will be more correctly duplicated.

Just a few types of problems and exercises are suggested here. A list of optical data for a theoretical mineral might be given the student who is required to build up a model to illustrate as many of these data as possible. Again, the instructor might prepare a model and request the student to tabulate the optical data illustrated by this model. Starting with a given model, the student might be required to predict the type of interference figure which would be obtained for a specified orientation.

Even crude models prepared of common pins and pieces of pencil eraser may be employed to good advantage by the student in his microscopic work. A simple model of a biaxial crystal with the principal index directions and the optic axes may be used to help visualize the orientation of various grains under the microscope. It will enable the student to correlate the interference figure on a particular grain with the optical orientation of that grain. Simple models of this type will permit him to visualize more intelligently the relationship between extinction angle and grain orientation.