MINERAL DETERMINATION BY MEANS OF PUNCHED CARDS

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To the beginner in mineralogy the determination of minerals is a difficult and perplexing problem. He is taught how to make certain observations and determinations such as luster, hardness, specific gravity, and streak, but only through experience can he integrate these observations in a manner that will enable him to quickly determine the unknown mineral. To aid in such identification, determinative tables have been devised and published separately or appended to text books of elementary mineralogy.

The chief difficulty of all such tables is that the various properties must be considered in a prescribed order. For example, a common sequence is luster, hardness, cleavage, specific gravity. If the outstanding property is a high specific gravity, it can not be used until the mineral is classified first by several other less distinctive and perhaps less reliable properties.

In an effort to overcome this shortcoming of the ordinary determinative table, Donnay* in 1938 devised a set of cards or "grids" for the determination of 450 nonopaque minerals. To quote from Donnay's paper, " . . . a grid is a sheet of cardboard, about 7 by 3 inches on which 45 vertical columns of 10 figures each (0–9) are printed, the columns being numbered from 1 to 45 along the bottom edge of the card. Every one of the 450 figures stands for a mineral that can be looked up in the index." Each card, of which there are approximately 250, represents a property and in it holes are punched in the appropriate places representing all the minerals having that property. For example, there are cards for hardness greater than 1, greater than 1½, greater than 2, etc., and others for hardness less than 1, less than 1½, less than 2, etc. There are similar cards for specific gravity, cleavage, color, crystal system, crystal habit, optical properties, chemical elements, and others. Suppose the properties of a mineral have been determined as: white, H. greater than 5 but less than 7, G. greater than 2.5 but less than 2.9, tetragonal crystals, and no distinct cleavage. The seven cards representing white, H.>5, H.<7, G.>2.5, G.<2.9, tetragonal, and no distinct cleavage would be located in the pack, withdrawn, and placed over each other. If only one hole is common to all the cards, it represents the unknown mineral, the name of which can be looked up in the index. If more than

* Donnay, J. D. H., A small set of grids for the determination of non-opaque minerals: *Am. Mineral.*, **23,** 91–100 (1938).

one hole is common to all the cards, additional cards representing other properties must be withdrawn and placed over the others.

The new type of punched cards described below differs from Donnay's in many respects but notably in that each card represents a mineral and not a property. Thus as many minerals may be considered as one wishes to add cards. The cards† are $7\frac{1}{2}$ inches by $3\frac{1}{4}$ inches and have 76 $\frac{1}{8}$-inch holes punched around the border—28 holes at the top, 30 at the bottom, and 9 at each side (Fig. 1). Each hole, the same hole on all the cards, has been assigned a property, the name of which is printed adjacent to it.

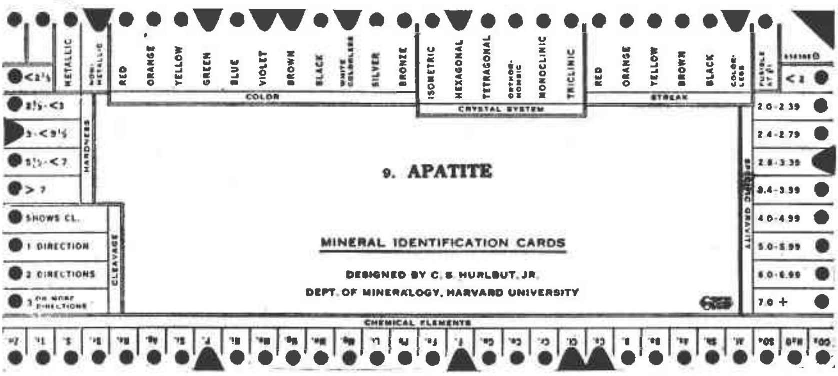

FIG. 1. Mineral identification card of apatite.

The properties and the divisions of them are:

Luster
- Metallic
- Nonmetallic

Color
- Red
- Orange
- Yellow
- Green
- Blue
- Violet
- Brown
- Black
- White or colorless
- Silver
- Bronze

Crystal System
- Isometric
- Tetragonal
- Hexagonal
- Orthorhombic
- Monoclinic
- Triclinic

Streak
- Red
- Orange
- Yellow
- Brown
- Black
- Colorless

Specific Gravity
- Less than 2
- 2.0–2.39
- 2.4–2.79
- 2.8–3.39
- 3.4–3.99
- 4.0–4.99

† The cards, sold under the name of "Keysort," are manufactured by the McBee Company, Athens, Ohio.

5.0–5.99
6.0–6.99
7.0 and greater

Hardness

Less than $2\frac{1}{2}$
$2\frac{1}{2}$ to less than 3
3 to less than $5\frac{1}{2}$
$5\frac{1}{2}$ to less than 7
7 and greater

Cleavage

Show cleavage
One direction
Two directions
Three or more directions

Fusibility

Fusible at 1

In addition, 27 of the commonest elements as well as CO_2, SO_4, and H_2O are represented by the holes at the bottom of the card.

The card representing any given mineral has had V-shaped notches punched in such a way that the holes representing the properties of that mineral are opened to the edge. As an example, consider the apatite card shown in Fig. 1. Notches are punched for: *nonmetallic;* the various colors that it might show—*green, violet, brown, colorless; hexagonal,* crystal system; *colorless* streak; specific gravity *2.8–3.39;* hardness *3–5½*; chemical elements *Ca*, *Cl*, *F*, and *P*. In the sets thus far made there are 150 cards representing 150 of the commonest minerals, those usually considered in an elementary course in mineralogy. The number of cards could be increased easily if one wished to consider a larger number of minerals.

In using the cards for determination, they are stacked together evenly with the clipped corners at the upper right. A slender metal rod is then pushed through the hole in the cards representing the property to be considered. The first separation can be made according to any property, but it is usually convenient to make it on the basis of luster (metallic or nonmetallic), for this immediately eliminates a large number of minerals. For submetallic minerals, both metallic and nonmetallic are punched.

If apatite is the unknown mineral and its properties have been determined by the student, the rod is put in the hole "nonmetallic." By raising the rod all the cards punched for nonmetallic drop out of the pack and the apatite card would be among them. The next separation might be on the basis of color. If the apatite is brown, the needle is inserted in the "brown" hole and all the cards representing minerals that may be of this color are separated from the others. Thus it would be found that 37 minerals of the 150 are nonmetallic and may be brown. Another separation on the basis of hardness (H. greater than 3 to less than $5\frac{1}{2}$) leaves 16 cards, among which is the one representing the unknown mineral. A further separation on the basis of specific gravity (G. 2.8–3.39) leaves only 3 cards—collophanite, fluorite, and apatite. If the apatite were in crystals, a last separation on the basis of hexagonal crystal system would leave *apatite* as the only mineral satisfying all the requirements.

It may happen that the easily observed properties will not isolate a card but two or three cards are left. In such a case it is easy for the student to look up the minerals in question and make an additional test to positively identify his mineral.

After a determination has been made, it is unnecessary to return the cards to any given place in the pack for, stacked together in any order, they are ready for use again.

In teaching, this method of mineral identification has an advantage over ordinary tables, for when the card for a given mineral is isolated, the student has before him more than a name. By observing the notches he can see the ranges within which the hardness and specific gravity fall and can note the colors, the crystal system, cleavage, and the chemical elements. More important than these would be the notes made on the card by the student pointing out tests that can be used to distinguish between similar appearing minerals.

The two holes at the extreme left at the top of the cards have not been used. Thus, if the student wishes to make use of other properties, they can be assigned to these holes and the notches made with scissors. The number of minerals is by no means fixed. The 150 included is about the maximum number studied in most elementary courses of mineralogy. If certain instructors wish to include others, this can easily be done by notching unpunched cards at the appropriate places and writing the mineral names at the center. Five blank cards are included with each set for this purpose.

Unlike Donnay's grids which consider 450 nonopaque minerals, this set of punched cards* is designed for the student of elementary mineralogy and takes into account only those properties most easily determined. With these limited properties it would undoubtedly be impractical to consider more than 250 minerals. However, the method would lend itself to a much more comprehensive adaptation. Larger cards with double rows of holes are available and on them it would be possible to include such additional data as refractive indices, 2V, extinction angle, dimensions of the unit cell, and *d* spacings as obtained from *x*-ray powder photographs. In fact after seeing the set of 150 small cards, Mr. E. E. Fairbanks obtained some larger cards and punched a few sets for use in the determination of the opaque minerals.†

This type of punched card for mineral identification has several advantages over determinative tables: (1) The properties can be consid-

* The set of 150 cards can be purchased from Ward's Natural Science Establishment, Inc., Rochester, N. Y.

† Fairbanks, Ernest E., The punched card identification of ore minerals: *Econ. Geology*, **41,** 761–768 (1946).

ered in any order; (2) all the cards representing minerals containing a given element or belonging to a given crystal system can be quickly separated and studied as a group; (3) there is ample room for making notes on both the face and back of the card for future reference; (4) the number of minerals considered is flexible. More cards can be added if necessary or cards representing minerals not studied in a given course can be removed, thus simplifying the determinative procedure.

The greatest advantage these punched cards have over Donnay's grids is that the separation by properties is easily and quickly made and it is unnecessary to thumb through the pack looking for the card representing a given property. Moreover, after a determination is made, the cards can be stacked together in any order and without refiling are ready for use again.

FIRE HAZARD WITH C. D. WEST'S HIGH REFRACTIVE INDEX LIQUIDS*

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Twelve years after C. D. West[1] proposed the use of yellow phosphorus-sulfur-methylene iodide solutions, there have been few published data concerning their actual use. Recently, a discussion by Bruun and Barth[2] emphasized the stability of these liquids, with special reference to the refractive index, over a period of five years.

West very properly mentions that, "the liquids are stored in glass-stoppered bottles which are kept in a covered metal container, the latter to reduce fire hazard and to exclude light which has an adverse effect. In the present experiments, a half inch layer of water was kept over the liquids." It might be thought that such precautions would ensure safety; yet, under these very conditions, there is still a very serious danger of fire from this treacherous preparation.

A set of six liquids, prepared a year ago, was contained in 35 ml. glass bottles, each with ground-in glass applicator rod, and ground-in glass cap. The liquid was covered with about an inch of water. Finally, the six bottles were placed in a galvanized iron box, with a fairly close-fitting lid.

At intervals of several months throughout the year, the liquids were inspected and found to remain clear and apparently unaltered. What was not noted, however, was the gradual evaporation of the water layer in some of the bottles. Concerning this water layer, West observes, "The stability of the liquids on storage without a water layer has not been de-

* Published with permission of the Director, U. S. Geological Survey.

[1] West, C. D., Immersion liquids of high refractive index: *Am. Mineral.*, **21**, 245–249 (1936).

[2] Bruun, Brynjolf, and Barth, Tom. F. W., Stability on storage of the high refractive index liquids of C. D. West: *Am. Mineral.*, **32**, 92–93 (1947).