The results are shown in figures 7 and 8. Because of the small number of observations, contouring and shading of the diagrams were not attempted. The orientation is not nearly so pronounced as for the feldspars, but the *c* axes do seem to fall very largely in a horizontal band. In other words, the short prismatic augite crystals tend to be roughly parallel to the tabular feldspars.

TRANSFER OF GRAINS FROM ONE LIQUID TO ANOTHER*

F. C. CALKINS, *U. S. Geological Survey.*

INTRODUCTION

In the course of the potash investigations of the U. S. Geological Survey, several thousand samples of drill cuttings from saline deposits have been examined by the immersion method. The first mount of the powder representing a sample is ordinarily made with an oil whose refractive index is near that of halite (1.544), because in such a medium the halite, which is the chief constituent of most samples, is "flattened out," so that the other constituents are clearly visible. The appearance of the common minerals under these conditions becomes familiar with practice, and they are usually recognized at sight in the initial mount. When a mineral that is not thus easily recognized occurs, it can, as a rule, be identified with certainty and with economy of both labor and material by means of the procedure that forms the subject of the present article. This procedure consists essentially of transferring individual grains from the initial immersion medium to one or more other liquids—usually to other immersion media with whose refractive indices the indices of the grain are compared. The grains are washed in xylol prior to accurate measurement of indices or to microchemical tests. It is hoped that this technique may occasionally be useful to other persons who study mixtures of minerals or artificial compounds by the immersion method.

INSTRUMENTS USED

All of the instruments depicted in Fig. 1 may be employed in transferring grains, and they will be considered here with reference

* Published by permission of the Director, U. S. Geological Survey. The author is indebted to R. K. Bailey, A. H. Koschmann, J. C. Reed, and A. C. Spencer for friendly criticism and advice.

to that purpose only, though some of them are also suitable for handling liquids in microchemical operations.

The instruments are designed for use under the microscope, and each is most comfortably held like a teaspoon in the fingers, which rest on the edge of the stage. As the inclination of the handle is then about 30°, the flat sole which terminates each of the instruments except the mounted needle is inclined 30° to the axis of the handle, so that it can be held essentially parallel to the stage when in use. The tip of each tool is placed near the axis, where it is easily guided and does not touch the table when the tool is laid down.

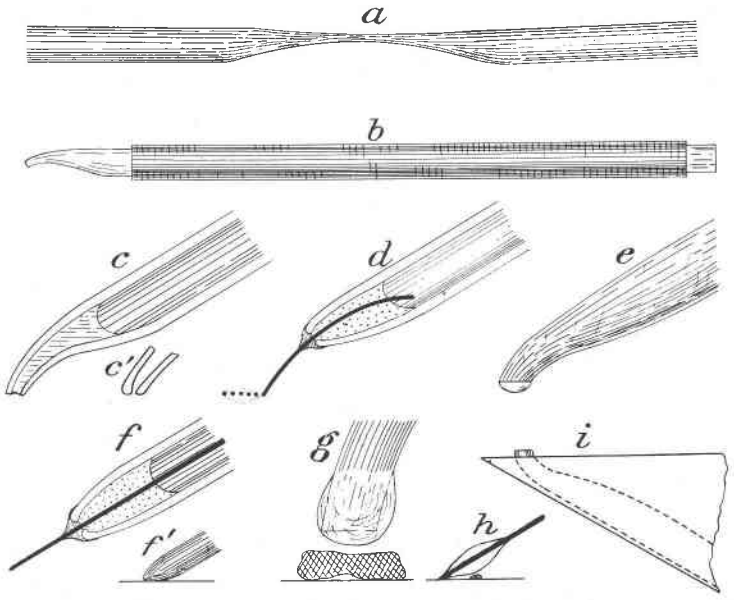

FIG. 1. *a*, Tube drawn out after heating unsymmetrically, ×2/3; *b*, Pipette with rubber sleeve, ×2/3; *c*, Section of "droplet-maker," ×4/3; *c'*, Tip of "drinker," ×4/3; *d*, Section to illustrate grain-lifter and crotchet; dotted lines represent eye of crotchet holding a lens of liquid; stippling represents hard balsam and darker shading "liquid solder"; *e*, Truncated rod, with charge of liquid on sole, ×4/3; *f*, Mounted needle, ×4/3; *f'*, Tip of same, ×10; *g*, Foot of grain-lifter, charged with soft balsam and poised over a grain, ×50; *h*, Needle dipped in balsam, ×5; *i*, Tip-guage in use, ×2/3.

Two pipettes (Figs. 1-*a* to 1-*c'*) may be made from a piece of glass tubing 25 mm. long and between 6 and 8 mm. in diameter, with walls at least 1 mm. thick. The tube is rotated in the fingers

while the middle of it is heated in a Bunsen flame until thoroughly soft. The rotation is then arrested, the heating continued for a few seconds longer, the tube withdrawn, and its ends pulled straight away from each other. The drawn-out portion, having been softened more on the under than the upper side, will have an asymmetric profile, of the character shown in Fig. 1-*a* but longer and more slender.

The two halves are separated, and one of them is fashioned as follows: The position of the sole is chosen at a point where the diameter is about 1½ mm. The knee is formed by gently heating the glass until it softens and bends under its own weight; the superfluous glass is then broken away on a scratch made with a file near the destined position of the sole. The sole is ground free-hand on fine sand-paper, at an angle of 30° with the axis, which is checked with a simple gauge made by folding an equilateral triangle of thin cardboard on a medial line (Fig. 1-*i*). The completed instrument is shown in Figs. 1-*b* and 1-*c*. The other half of the tube is made into a second pipette, which is like the first except that the diameter of the orifice is reduced to about ½ mm., by cautiously heating it before the sole is ground (Fig. 1-*c'*). The pipette with the larger orifice will be distinguished as the "droplet-maker,"[1] the small-mouthed one as the "drinker," because of the purposes for which they are to be used.

The form of pipette thus made is believed to be somewhat novel in form and mode of use. It is charged (Fig. 1-*c*) by capillary force when the tip is immersed in a liquid; the barrel should be inclined at least 30° while this is done. If the orifice is then brought in contact with a clean slide and raised, a droplet of the liquid will be left on the glass; and by repeated contacts a series of droplets, each a very little smaller than the preceding, may be deposited until the pipette is nearly empty. Neither suction nor blowing is employed; the pipette is charged by contact with the liquid and discharged by contact with the slide, and it may appropriately be called a *contact pipette*. It is convenient for holding xylol, which is frequently used in the procedure to be described, because it yields many droplets from a single charge.

The tool employed for picking up grains will be called the grain-lifter (Figs. 1-*d* and 1-*g*). Its handle is made by drawing out a tube

[1] "Droplet" seems a better term than "drop" for a bead of liquid too small to be formed by dropping from any pipette that is commonly used.

as in Fig. 1-*a*, cutting away the slender part, and fire-polishing the orifice. The tip is a short piece of moderately stiff wire. This may be made by annealing a small needle and cutting off the point; but steel "music wire" is more convenient though not always readily obtained in the small gauges required. A No. 10 or 12 needle, or No. 2 "music wire," which is about 0.27 mm. thick, is suitable for seizing most grains; but lifters with larger and smaller tips may occasionally be useful. To join the tip and handle, a few fragments of cooked balsam are dropped into the tube and melted in its taper end, the wire is inserted, and the balsam allowed to set. The wire is then bent to the proper curve and cut off about 5 mm. from the handle, and a sole is ground on its end with a carborundum whetstone. The wire is held with great tenacity by the balsam, and lateral play at the joint may be prevented by covering it with "liquid solder" or a clear cellulose cement.

The droplet of oil in which a captured grain is re-immersed for comparison of indices can be deposited from the rod attached to the usual type of oil-bottle, but its volume can be better controlled if this rod is used for charging a crotchet[2] (Fig. 1-*d*) or a truncated rod (Fig. 1-*e*), with which the oil is placed on the slide. The construction and properties of these instruments may be worth stating even if they are dispensed with in the procedure here described.

The eye of the crotchet has the form of a screw-eye with the joint slightly open instead of being closed as in a true loop. The crotchet used for the present purpose should have an inner diameter between 1 mm. and 1.5 mm., the gap at the joint should be about 0.3 mm. wide, and the wire of which it is made should have a diameter of about 0.35 mm. (26 or 28 gauge B. & S.). The crotchet is fashioned by looping the wire around a stout darning needle, pulling it snug, cutting it inside the crossing, and bending up the shank. Various metals may be used. A crotchet of brass or "nickel silver" wire should be cemented into the handle as in Fig. 1-*d*; nickel-chromium wire may be either cemented or fused in, care being taken to heat as little of it as possible; platinum or platin-iridium—which is better because stiffer—should be fused in.

The crotchet is charged by bringing it in contact with the liquid

[2] "Crotchet" is English for "Häkchen," the word used by H. Behrens (Anleitung zur mikrochemischen Analyse, 1895, p. 20) to designate an instrument not figured nor fully described but presumably the same in essentials as the one described here.

hanging at the end of the rod from the oil-bottle and drawing it aside. It will then hold a convex lens of liquid. When this lens touches a slide, it instantly breaks, and nearly all the liquid is deposited. When a loop is similarly handled, the lens is not broken, and much of the liquid is retained. The crotchet, therefore, wastes less liquid and is more easily cleaned than a loop. It is sufficiently freed from oil if gently wiped and twice rinsed with xylol.

The truncated rod, whose sole should be about 2.5 mm. broad, is made from soft Pyrex rodding in the same manner as the pipette, but its sole is fire-polished. It is charged and discharged like the crotchet, but retains more of the liquid. The oil remaining on the tip can be quickly and almost completely removed by wiping, but the glass is electrified by friction and attracts fibers, which may cause annoyance by being deposited with the oil.

A mounted needle for moving grains about is shown in Fig. 1-*f*. It is mounted like the grain-lifter, but the tubing from which the handle is made is rotated throughout the heating process, to get a symmetrical taper. The point of the needle, which should be a fine one, is rounded off (Fig. 1-*f'*) so that it will not catch in scratches on the slides.

The handles of all the tools may be sheathed with rubber tubing (Fig. 1-*b*), but this is not advisable unless the handle is less than 7 mm. thick. The grain-lifter, crotchet, and needle may optionally be mounted in wooden handles. A neat handle can be made by cutting off both ends of a pen-holder; the metal tip is inserted in a hole made in the smaller end with a mounted coarse needle and the joint is covered with cement.

Procedure

If the mount is covered, the cover-glass must of course be removed, which may be done either by pushing it aside with a needle, but the immersion medium is likely to be so much disturbed by this operation that it may not be possible to find the desired grain afterward. This trouble is avoided when covers are dispensed with, which may often be done without disadvantage. The grain, unless it is rather large, is first isolated, a space being cleared with the mounted needle and the grain drawn into it with the same tool.

The sole of a grain-lifter, whose diameter should be greater, or not much less, than that of the desired grain, must now be covered with a substance to which the grain will adhere while be-

ing lifted out of the oil but from which it can readily be freed. Soft balsam is the material that I first found to fulfill these requirements and that I have chiefly used. The form assumed by the balsam which adheres to a lifter whose tip has been dipped in it is shown in Fig. 1-*g*: much of it is under the sole, where it can readily be pressed against the upper surface of the grain, whereas that taken up by a needle (Fig. 1-*h*) pulls away from the point and is obviously less effective. A material that now seems preferable to balsam is vaseline. The use of vaseline was suggested to me by Mr. A. H. Koschmann of the U. S. Geological Survey, who experimented with it at the suggestion of Professor A. N. Winchell but did not obtain satisfactory results because he used a needle, necessarily carrying a relatively large quantity of vaseline, and because he did not hit upon a way to remove the vaseline from the captured grain. The grain-lifter need carry only a minute quantity of the grease, with which the sole is coated by dabbing it against a thin layer smeared on a slide. A third adhesive recently found effective is mucin, applied to the sole by lightly touching it to the tongue. This practise is rather uncleanly, and grains adhere a little less readily to mucin than to vaseline. Mucin, on the other hand, offers a definite advantage when a grain is to be picked out of a liquid that contains a large proportion of monochlornaphthalene or methylene iodide, for both of these compounds, which are constituents of many oils of high refractive index, dissolve vaseline and balsam with great rapidity but do not noticeably attack mucin.

The sole of the lifter, coated with the chosen adhesive, is immersed in the oil, poised close above the grain, brought gently down upon it, and rather quickly raised. After a little practise, one seldom fails to pick up at the first attempt any compact grain as much as 0.1 mm. in average diameter.

So much of the adhering oil can be drained from the grain, by bringing it a few times in contact with the dry part of the slide, that the remnant will not seriously vitiate a rough comparison of its refractive indices with the index of another oil, a droplet of which is placed on a slide by means of a crotchet or a rod. Usually the grain can be rubbed off the lifter into this oil, and picked out of it by means of the same lifter without putting more adhesive on the sole. One or two immersions thus made may suffice to identify the mineral, but if a more accurate determination of an index, or a microchemical test, is to be attempted, the grain, after being

drained as before, is washed in xylol, which may conveniently be done as follows:

A droplet of xylol is deposited on a clean slide by means of the pipette called the "droplet-maker." The tip of the grain-lifter, with the grain adhering to it, is immersed in the solvent and agitated until the grain is detached. The droplet of xylol, carrying oil and perhaps vaseline or balsam in solution, is then promptly taken up by means of the "drinker," which should be kept in contact with the slide while it is pushed into the droplet, moved around the grain, and drawn a little aside; it is then raised, and drained by touching the tip with absorbent paper.[3] The small quantity of xylol remaining on the slide soon evaporates, but an oily residue is usually visible after the first washing, and the washing should, as a rule, be repeated once or twice. Comparison of the refractive indices of the grain with that of xylol—about 1.494—is often useful, and if the mineral is thought to be one whose average index is near that figure it should be transferred immediately from the initial medium to xylol.

[3] "Disposable tissues," such as Kleenex, are useful for this purpose and for wiping liquids from instruments and slides.