talline mass of that composition and specific gravity, was also made by fusing 2PbS and As_2S_3 at a moderate temperature.

The name "revoredite" proposed by Amstutz, Ramdohr, and de las Casas appears untenable for the very reason that these authors propose for its acceptance. "The name Revoredite . . . was proposed . . . in case that a crystalline sample should be found, or that by some method, it might be possible to attribute a crystalline structure to this so far amorphous mineral." If crystalline phases do appear, they will simply be orpiment or one or more of the series of sartorite-dufrenoysite-jordanite.

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MINERAL SEPARATION WITH ASYMMETRIC VIBRATORS

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Introduction

Geochemical studies often require the separation of gram amounts of pure minerals from rocks. Hand picking is usually out of the question and one resorts to such well-known techniques as heavy liquid separation with bromoform, tetrabromoethane, or methylene iodide (Fairbairn, this journal, 1955), magnetic separation, (*ibid.* and Gaudin and Spedden, 1943; McAndrew, 1957; Rosenblum, 1958; Rubinstein *et al.*, 1958) or to laboratory adaptation of industrial beneficiation processes like flotation or the Wilfley table. Many other techniques are used for particular problems: sieving, panning, various arrangements for elutriation with air or water, not to mention the old trick of shaking grains on a sheet of paper to recover flakes of mica.

While separating minerals for geologic age determination, we have evolved a number of special ways to facilitate the recovery of various minerals, particularly zircon, biotite and muscovite. Several of our devices are based on the industrially well-known principle of asymmetric vibration.

The Asymmetric Vibrator

When a particle is placed on a smooth horizontal plane and the plane is made to vibrate horizontally or vertically, the particle will either slide to and fro or hop up and down, but will remain essentially on the same spot. However, if the plane is made to vibrate sinusoidally in any other direction, the grain will take off and march in a series of hops in the direction of the smallest angle between the plane and the direction of the vibration. We illustrate this motion, as nearly as it can be illustrated, in Fig. 1. An electromagnet (in practice a dismantled filter choke) supplies the energy for the vibration. The rate of advance depends on the length of the hops made by the particles. This is a function of the amplitude of vibration, which in turn is determined by the voltage impressed on the magnet. In this way, a rheostat or a variable transformer serves as a continuous control of the rate of feed. Sixty-cycle alternating current produces a vibration frequency of 120 cycles/sec. because the magnet gives two mechanical strokes for each cycle received. With a half-wave rectifier in the circuit, the second stroke for each cycle can be eliminated and a mechanical vibration of 60 cycles /sec. produced. As a rule one tries to drive these vibrators at about the resonant frequency of the system, but we have found that this requirement is not too stringent. The resonant frequency is, of course, adjustable

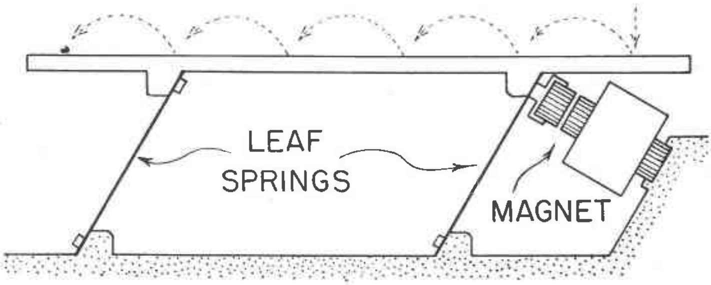

Fig. 1. The asymmetric vibrator and the motion of a particle upon it.

by controlling the strength of the blade springs that support the vibrating plate.

The angle of these springs with the plane is usually about 60°, and the drive is perpendicular to them, giving an angle of 30° between the plane and the direction of vibration. Again, this angle is not critical; we have used angles from 10° to 45° on vibrators for various purposes.

The linear hopping motion can be turned into a circle (or, more accurately, a spiral) by making the plate circular and mounting it on three or four inclined leaf springs radially arranged in positions symmetrical about the center of the plate. The magnet is mounted in the center, driving in the vertical direction. Industrial mechanical parts feeders use this modification of the asymmetric vibration principle. In mineralogy, small models of these parts feeders have been adapted to various tasks of picking and sorting.

FEEDERS

Even though the pure end product of a mineral separation may be only a gram or less, one may have to feed tens of kilos of a powder through a device to obtain the final result. In most applications, this feed should be uniform and have a continuously adjustable rate. Industrial feeders based on the asymmetric vibration principle are widely used for such diverse applications as loading coal and salting potato chips. Small industrial feeders are available (one make is illustrated by Fairbairn, 1955) and are useful for feeding Wilfley tables, flotation cells, disc-type magnetic separators, and sieving machines. However, they are too large for feeding the paramagnetic ("Isodynamic") separator or the mica separator described further on.

For some of these applications a very slow feed is desired, almost a grain at a time, and we have developed a special feeder for the purpose. This device consists of a small 24-volt D. C. relay with the points soldered in the open position and an aluminum cradle bolted to the relay anchor. A bent glass hopper-funnel is attached to the cradle by small coil springs (Fig. 2). When the relay is energized with low-voltage 60-cycle alternating current from a rheostat or a small variable transformer, the funnel vibrates at a frequency of 120 cycles/sec. with amplitude proportional to the voltage. With a half-wave selenium rectifier in the circuit, the vibration will have a frequency of 60 cycles/sec., which may be advantageous for materials that tend to "hang up" at the higher frequency. A hopper with a volume of about 10–20 cc. and an orifice about 3 mm. in diameter will feed 40-mesh (0.4 mm.) material very nicely with 10–30 volts AC on the coil. Smaller orifices are advantageous for slow feeding of finer powders.

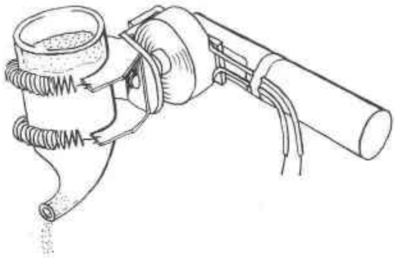

FIG. 2. Slow power feeder made with a d-c relay and a glass hopper-funnel. For clarity, only the essential parts of the relay are shown. The hopper holds about 25 cc.

An ordinary laboratory funnel can be used to feed the small vibrating hopper. There is no limit on the size of this larger funnel, as long as the funnel orifice is drawn down to a size that will not interfere with the motion of the powder in the hopper. This arrangement permits slow, continuous feeding of the Isodynamic separator overnight, for example.

PARAMAGNETIC SEPARATION

The "Isodynamic" separators widely used in geochemical laboratories sort paramagnetic minerals by their magnetic susceptibility. Ferromagnetic particles seek the nearest pole, but a paramagnetic grain in a divergent magnetic field will seek the region of highest magnetic flux concentration between the poles. If the resultant force is now balanced against the force of gravity, separations can be made between minerals of different magnetic susceptibilities.

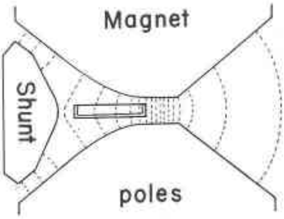

FIG. 3. Schematic transverse section through the magnetic field of a paramagnetic separator. The sample passes down the trough which is placed in the region of widest uniform divergence of flux line density.

A divergent magnetic field is produced between suitably shaped pole pieces (Fig. 3) and the divergence can be further increased by a properly shaped magnetic shunt. The commercially available paramagnetic separators introduce the particles into the region of greatest field divergence by sliding them along a longitudinally vibrating inclined plane. The slope of this plane is also adjustable at right angles to its inclination.

The more strongly paramagnetic grains are pulled up into the higher magnetic field as they slide and a septum prevents them from falling back into the main stream as they leave the magnet. Apart from the noise that these vibrators make, the system has the obvious disadvantage of continuous contact between the grains and the plane they slide on. The resulting differential effects of friction and mutual interaction of the grains tend to reduce the sensitivity of separation in many instances.

These difficulties can be overcome with the asymmetric vibrator. Fig. 4 shows a commercial paramagnetic separator modified with an asymmetrically vibrating trough to transport the grains through the magnetic field. The grains hop along the trough and are acted upon by the field while they are in the air, without much regard to their shape, size, or surface texture. Mutual grain interaction is also minimized by the hopping motion. As illustrated, the paramagnetic separator is usually operated in the horizontal position. However, for special separations involving differences in grain size or shape, there may be advantages in using either positive or negative inclination.

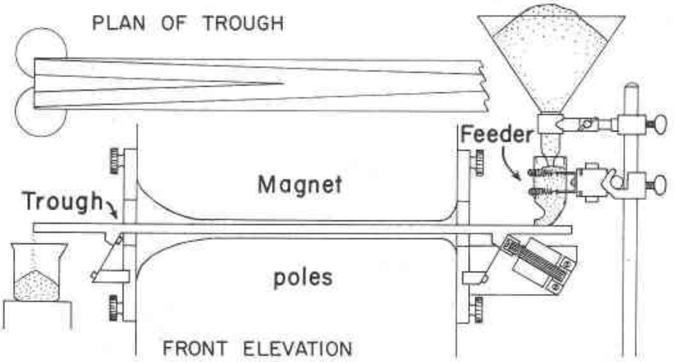

FIG. 4. Asymmetrically vibrating trough with the slow powder feeder (See Fig. 3) mounted on an "Isodynamic" separator.

Very fine powders (−200) may form clumps when transported in this way. We have successfully separated small quantities of such fine materials by constructing a special trough with high side walls, closed ends, and built-in sloping bottom, and passing the material through the field submerged in a liquid. The hopping motion is damped by the liquid, but the small particles are kept free of each other. One cannot simply state the lower limit of particle size that can be conveniently handled that way. In general, materials of higher density can be handled in finer fractions.

THE MICA SEPARATOR

We have already mentioned the simple procedure for separating mica from other, rounder grains that tend to roll off an inclined plane, leaving the flat grains behind. One may separate a number of minerals in this way, depending on the differences in cleavages.

Our most successful mica separator is an aluminum plate about 10 inches wide, about 12 inches long, and $\frac{1}{4}$ inch thick, mounted on the base on a commercial vibrating feeder. The plate is mounted at a slant of about 15° to one side (Fig. 5) and is made to vibrate asymmetrically along its length. The powder is fed to the plate with one of the small shaking feeders we have discussed (Fig. 2). When the amplitude of vibration is adjusted just right for the grain size of the powder, the flattest grains will march lengthwise across the plate and fall off the far end, while the rounder grains bounce and roll down the slope. Troughs around the plate collect the product in a continuous spectrum from the roundest to the flattest and cuts may be made wherever desired. The procedure is rather wasteful, for the thicker books of mica will bounce and roll along with the quartz and feldspar grains. However, such difficult separations as biotite-chlorite, for example, are feasible with this vibrator.

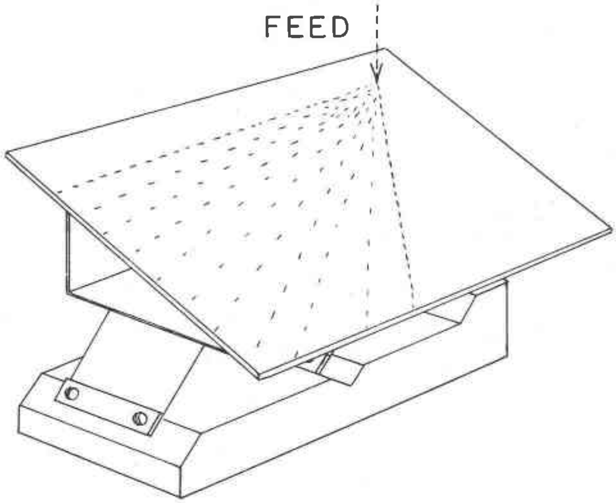

FIG. 5. The inclined-plane mica separator. The smooth aluminum table measures 11×13 inches and slopes 15°. It is mounted on the base of a commercial vibrating feeder.

Fairly close sizing tends to increase the efficiency of the separation. The best separation is obtained in the range minus 40 plus 100 mesh.

Working drawings of these devices are available from the authors.

ACKNOWLEDGMENTS

The work outlined in this note is admittedly a side line. We have experimented with these devices from time to time for several years, and many individuals have helped us with valuable suggestions. It is difficult to recall them all by name. We are grateful to M. R. Forrer and M. H. Maeschler of the Institute of Physics, University of Strasbourg, and to Profs. F. Houtermans and E. Niggli of the University of Bern. Faul acknowledges the support of the U. S. Educational Commission for France (Fulbright program) during the early mineral separation experiments in Strasbourg. The assistance of the Syntron Company, Homer City, Pa., and the W. Flämrich Co., Recklinghausen, Germany, is also acknowledged.

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PECTOLITE IN MICA PERIDOTITE, WOODSON COUNTY, KANSAS*

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Pectolite has been identified by optical and *x*-ray diffraction techniques as a major constituent in the groundmass of one facies of the Hills Pond peridotite, section 32, T. 26 S., R. 15 E., Woodson County, Kansas. The occurrence of pectolite as a major component of the groundmass of a facies of peridotite seemingly is unique. Pectolite has been recognized as a secondary mineral in cavities and seams in mafic eruptive rocks as at Weehawken and Patterson, New Jersey, and as a minor component in syenitic rocks as at Hot Springs, Arkansas and in the Kola Peninsula, U.S.S.R. (Dana and Ford, 1932, p. 567). Some pectolite has been found

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