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DRY POLISHING OF OPAQUE MINERALS

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ABSTRACT

The process of polishing opaque minerals is restudied with the hope of speeding up the process without undue loss of quality. It is found that the physical character and structure of a lap have a marked effect, both in grinding and polishing. The composition and structure of laps found satisfactory are presented. Determinations are given of the rate of removal of material during the various stages of grinding and polishing. Various types of mechanical heads are described, the method of charging laps is discussed in detail, and the complete process of mounting and polishing is outlined, together with illustrations of the various types of polish.

INTRODUCTION

The literature dealing with the study of ore minerals contains several excellent descriptions of various methods for polishing opaque minerals (1). These methods differ greatly in the character and relief of the surface which they produce, the freedom of that surface from pits and scratches, the time required to attain that surface, the type and size of abrasive used, and the type of mounting necessary. Cloth-lap polishing was introduced by the metallurgists and long considered satisfactory by them because, in general, they dealt with material which either showed relatively small variation in relief, or whose texture was such that differences in relief were not accentuated by polishing. The cloth lap, or buff, is still widely used in polishing glass, stone, plastics, metals, and those mineral surfaces where variation in hardness or texture will not produce excessive relief. Although this method produces much pitting, plucking and scratching, as well as obscuring the contact relationships between minerals of different hardness, it still is used in many laboratories because the necessary equipment is simple, the materials inexpensive, and the technique easy to acquire. The other extreme in polishing is represented by the high quality polish attained on a metal lap, such as the lead lap. The surface produced by this method is practically free from relief and under proper conditions is relatively free from scratches and pits. However, practically everyone agrees that the use of this method is an art which can only be acquired by a long and tedious apprenticeship. Moreover, the method is inherently slow, requires very precise sizing of the abrasive, critical control of the character and degree of lubrication, and close supervision by the operator. Although the method gives unequalled results under favorable conditions, the time required for a polish suitable for ordinary work is too great to justify the use of this method in routine work.

Dry polishing was investigated with the hope of obtaining a satisfactory polished surface more quickly than by the lead-lap method, and a surface of much less relief and more definition than that produced by cloth polishing. In the course of the investigation much was learned regarding the mechanism of polishing, and several rather radical departures from standard practice were successfully tried. Although any method will continually undergo some changes, the general procedure outlined in the following pages has been in use now for over three years in our laboratories, and the specific procedure has given excellent results during the last year.

Theory of Polishing

The principles involved in the development of a polished surface have been much discussed in the literature since such surfaces play a vital role in many fields. Some investigators consider that polishing consists of two processes, i.e., a removal of material by pitting or cutting, and a smoothing of the remaining surface by flowage of the material from high points to low points on that surface. Others consider that the process of polishing consists entirely in the removal of material, first by pits and then by cutting scratches successively smaller in width until they become sub-microscopic and consequently invisible at the ordinary magnifications.

The metallurgists have been strong advocates of the plastic deformation theory as the cause of the final polish. This is understandable since metals yield by flow much more readily than do most of the relatively brittle minerals. Moreover, it has been established that some of the polished surfaces achieved by cloth polishing are in reality films of metal oxide smeared over scratched metal. In fact, oxidation may be so rapid during polishing of metals that it is necessary to carry on the final polishing under benzene (2).

The geologist, on the other hand, who sees in a polished surface many delicate intergrowths and textures, finds it very difficult to believe that there has been any notable displacement of material. Recently this controversy has been revived through the publications of Bowden and Hughes (3). Investigations carried on in our laboratory left little doubt but that, with some methods of polishing at least, there is displacement of surface material. With other methods of polishing a different character of surface seems to be developed. Details of this investigation are presented in a separate paper.

The polishing process ideally consists of the cutting away of material by very sharp points. The perfect lap surface would be one on which these points—as represented by the corners of the abrasive—are all firmly held in one plane so that they would be in a position of maximum cutting efficiency, and at such a height that they would remove a uniform depth of cut at each operation. Moreover, they should be replaced as rapidly as they become worn or broken. The choice of an abrasive must be governed by several considerations. Its efficiency as a polishing agent is determined by its melting point rather than its hardness (2). However, the shape of the grains and their cleavability have an important bearing on the effective, useful life of any abrasive.

Anyone who examines a polishing cloth under the binocular microscope can immediately see why it makes such a rapidly cutting medium when treated with the proper amount of abrasive. The threads are so spaced that the grains of abrasive drop in between them and are held in position for cutting. If the cloth is strong enough, the abrasive grain cannot roll or move but is forced to stay in that position. Usually the cloth is backed by a hard surface so that the abrasive cannot be pressed into that surface and must rest on it and thereby remain available for cutting. The cloth lap, however, is also noted for the amount of relief which it produces. This is probably due to two factors. First, the bending of the cloth as it passes from hard to soft mineral and secondly, to the loose ends of the cloth fibers which become charged with abrasive and whip around on the surface. In the writers' experience this second fact is the more important one in producing relief. The chief asset of the cloth-lap method is its speed and this is due to the efficient method of maintaining abrasive in contact with the surface to be cut.

On a lead-lap surface the abrasive is either held in position for cutting by being embedded in the lead, or else it rolls on the surface and gouges by pitting, rather than cuts by scratching. The hardness of the lead in the lap is important. If the resistance to embedding offered by the lead is not sufficiently great, the hard surface of the mineral will push the abrasive down into the lead thereby nullifying its cutting action. If the lead is too hard, the abrasive will not be sufficiently embedded and consequently will scratch. The quality of bonding between the abrasive and the lap is also related to the physical properties of the metal, of which hardness is one characteristic. Various investigators have attempted to control this bonding and the hardness of the lap surface by using other materials such as tin, copper, pitch, or various plastics. If the mineral surface is too soft, it will be deeply scratched, if it is too hard, the tendency will be to avoid any cutting. Effects of this principle are well known to anyone who has tried to polish native silver or chromite on a lead lap.

Another critical feature in any polishing process is the lubricant. The reason for lubricating is largely to keep down the heat produced at the point of contact between the abrasive and the surface, and to assist in removing the products of polishing. Local temperatures may be of the order of 600° C. or more, under conditions of boundary lubrication with a mineral oil (4). During grinding, or the coarser stages of polishing, when the rate of the removal of material from the surface is particularly rapid, the lubricant may perform a useful function.* During the final stages, when the amount of material removed is very small and the abrasive is relatively small in diameter, the presence of a film of lubricant which tends to float the polishing surface over the lap surface and to prevent proper cutting action, may become decidedly detrimental. In fact, one reaches a stage where the presence of any lubricant defeats polishing. It is for this reason that the control of the lubricant is so critical during the final stages of polishing on a lead lap.

The two major functions of lubrication, namely dispersal of heat and waste products, can be achieved by methods other than by the use of a liquid. Picture a cutting surface consisting of a series of points which project above the level of that surface. Spaced between these points is a set of "skids" which will control the depth of cutting of the points and yet leave no contact between most of the cutting surface and the surface which is being cut. The heat developed by the cutting action can be dispersed through the layer of air separating the two surfaces. The products of cutting, which must of necessity be smaller than the points producing the cuts, can likewise drop into the spaces between the "skids" and be removed from the surface of action.

The ideal lap surface then would consist of a series of hard smooth points or skids between which is a softer material to hold the abrasive or spaces in which the abrasive can be fixed. There are a number of different materials which have this general type of structure.

Certain types of papers and other materials made from wood pulp, such as pressboard, celotex and some kinds of wallboard consist of a mass

* Measurements made in our laboratory indicate that the rate of removal of material from a section 1.5 inches in diameter, is of the following order of magnitude; grinding on a bronze lap removes about .001 inch per minute, fine grinding on a wooden, celotex or lead lap, about .0005 inches in 10 minutes, and polishing on a celotex lap removes .00005 inches per hour. These rates of course fluctuate with the size and composition of the specimen as well as with the general lap conditions.

of interwoven wood fibers with a matrix of softer and much finer grained material. This is not true of all papers, many of which have been sized by the addition of clay or other bonding material which has filled the pores. The character of a material and its suitability as a polishing medium are readily determined by a binocular examination. The desirable structure is a criss-crossed matte of fibers which act as skids, and a matrix soft enough to hold the abrasive. It is essential to avoid a structure in which fibers have a tendency to lift free at the ends, since this develops excessive relief.

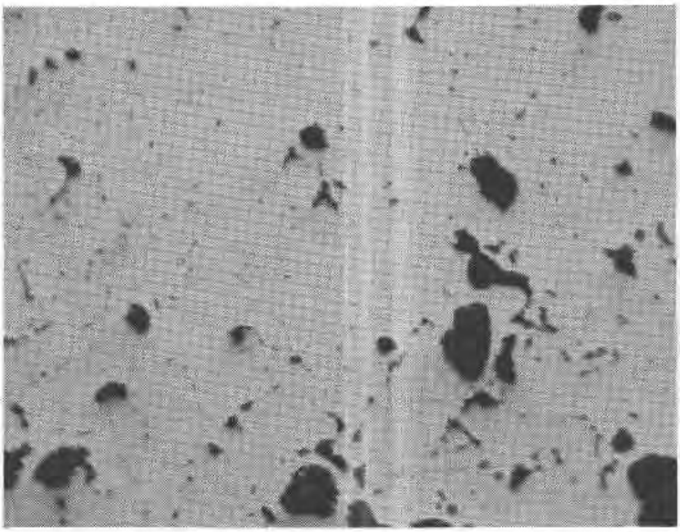

FIG. 1. Bronze lead lap. White is harder bronze, dark gray and black areas are lead impregnated with abrasive. Mag. 48 diameters.

A suitable structure can also be developed in certain types of alloys where a hard constituent forms the skids and a softer material the bonding agent for the abrasive. The best material of this type found to date is a bronze lead, a photograph of which is shown in Fig. 1. This material is prepared as follows:

To a given amount of government bronze while in the ladle, there is added approximately 14 per cent, by weight, of lead and 1 per cent of nickel. The material is then cast and machined in the usual fashion. This type of lap avoids the plucking, pulling and pitting characteristic of many other types of grinding laps.

A comparison of this concept with that held for bearing metals is both interesting and instructive. According to Bassett (5) it is essential that any satisfactory bearing metal be composed of a hard constituent supported or embedded in a softer matrix. Bassett also holds that the hard constituent stands in relief above the soft matrix and carries the load, whereas the lubricant is held in the hollows formed by the soft constituent. Kyropolous (2) disagrees with this last concept and has demonstrated that in a satisfactory bearing metal, the soft constituent possesses a much greater thermal expansion, so that in use, it expands above the elevation of the harder constituent and actually carries the load. When cooled it contracts so that its elevation is lower than the harder constituent. If this phenomenon occurs to an important extent in a binary grinding lap, its effect will be to push the abrasive grains above the level of the harder constituent and thus enhance their cutting action. Moreover, the structural characteristics of such a binary mixture strongly counteract any tendency towards drag or gripping which is the cause of much plucking and pitting when pure metal laps, such as copper, are used for grinding.

The applications of the principle discussed above, to grinding and polishing as practiced in our laboratories, are elaborated in the following pages.

Preparation of Specimen for Polishing

Experience has shown that the gentler the treatment of the surface to be polished, throughout the preparation stages, the less difficulty will be encountered from pitting and breaking during the final polishing.

The chip to be polished is cut from the specimen with a Felker DiMet diamond saw. The edges are slightly rounded and after drying, the specimen is mounted in a circular bakelite mount. The present method of mounting has not been materially changed from that described by Murdoch (6). The specimen is numbered as follows:

> The symbol and number are stamped on a strip of aluminum, or copper, about one quarter inch wide and one inch long. The ends of the strip are then bent at right angles and the strip stuck with rubber cement to the end of the piston which has a central shoulder 0.8 inch in diameter and 0.065 inch high. The piston and label are then inserted into the mold containing the sample and powdered bakelite. The number is thus mounted on the bottom side of the specimen, in a circular depression one sixteenth of an inch below the rim.

Impregnation of Specimen.

Immediately upon removal of the mounted specimen from the molding press, the hot, rough surface of the ore specimen is given a liberal coating of bakelite varnish No. B-V 1115, to a depth of about $\frac{1}{8}$ of an inch. It is not essential for the success of the impregnation that the specimen be hot but it is believed that a better bonding is attained when the specimen has been preheated. The mounted specimen is then placed coated side up on a small vacuum plate [Fig. 2], the plate covered with a small glass jar and a vacuum created by water passing through an ordinary air aspirator. The bakelite varnish immediately begins to froth and the vacuum treatment is continued as long as the frothing lasts. This usually requires about one and one half minutes at which time the vacuum in the jar is equivalent to about 4 cm. of mercury. At this time the bakelite froth collapses and forms a thin film over the surface of the specimen. Air is then permitted to enter the jar, the specimen removed, the surplus bakelite wiped off with absorbent paper and the specimen placed on a hot plate maintained at a temperature of between 120 and 140° C. for a period of at least 12 hours, after which it is ready to grind.

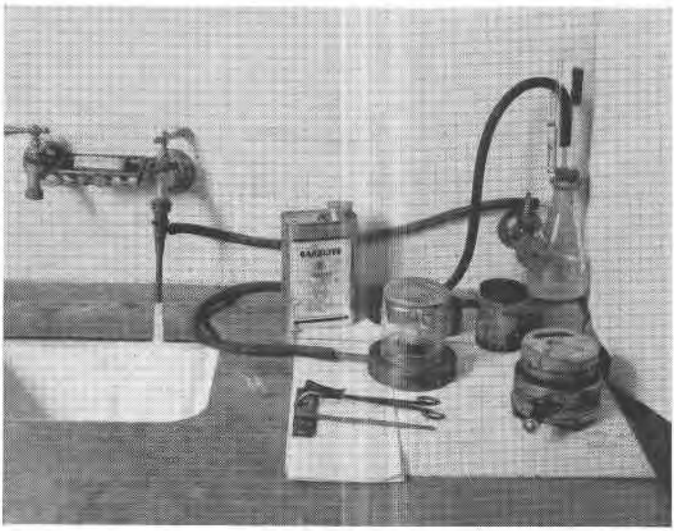

FIG. 2. Bakelite vacuum impregnation apparatus.

Specimens which are unusually fragile or porous may be given an impregnation treatment prior to mounting. The cut and trimmed specimen is first thoroughly washed with bakelite-thinner or with banana oil and is then placed in a container under about $\frac{1}{4}$ inch of bakelite varnish. The vacuum is then applied in the usual manner until the varnish froths vigorously. Air is then admitted, the specimen removed and placed on a piece of paper on the hot plate and heating continues until the bakelite is thoroughly hardened. The time for this treatment varies greatly depending on the porosity and thickness of the specimen and the thickness of the bakelite coat. The maximum time is required for the hardening of impregnated pellets of mineral products prepared after the procedure described by the Lake Shore staff (7). This drying time ranges between a minimum of about 12 hours to a maximum of 5 days, but it must be continued until the bakelite is thoroughly hardened or else the benefits of the procedure are nullified.

Pre-mounting impregnation of specimens has the additional advantage that the film of bakelite acts as a strong enveloping bond to prevent the specimen from disintegrating during mounting or during the subsequent polishing procedure. Consequently its use is recommended for friable specimens although they may have very low porosity. During the grinding and polishing process it sometimes is necessary to remove a layer of the mineral thicker than the depth of impregnation to get below the deep pits, i.e. those deeper than 0.01 inch. In such cases it is advisable to re-impregnate the specimen. The cold-mount specimen is first washed with bakelite-thinner and then given a fairly thin coating of bakelite so as to cover the ore sample and its margins, and the specimen is then placed under vacuum and treated in the same manner as a newly mounted specimen.

Measurement of Removal of Material

In studying any grinding or polishing methods it is desirable to know the rate of removal of material from the mineral surface. Ordinary micrometric methods are not satisfactory particularly during polishing, when the rate of removal is very slow.

The following method provides a convenient means of accurately measuring the amount of removal between any stages.

A piece of 250-mesh Tyler screen is soldered onto a piece of tin and then cut in quarter-inch strips at an angle of approximately 14 degrees to the mesh line. The cut surface is carefully filed until there is no distortion of the wire. The diameter of this wire is about 1.6 thousandths and the opening between wires is 2.4 thousandths of an inch. A strip of this mounted screen is bent to a right angle and placed vertical beside the specimen in the mold and both mounted together.

During grinding and polishing the appearance of this strip at any time is similar to Fig. 3, where the rounded areas are the upright wires and the elongated areas are transverse sections of the other wires inclined 14 degrees to the plane of the section. As the surface is cut down, the absolute position of the rounded sections shifts slightly and that of the elongated sections very substantially with respect to the rounded sections. The nature of these changes are shown in Fig. 4, and the mathematical relations are as follows:

$$\sin\alpha = \frac{X}{T+t} \qquad \therefore \quad X = \sin\alpha\,(T+t) \quad \text{and} \quad \cos\alpha = \frac{R}{X}$$

$$\therefore \quad R = \cos\alpha \cdot X = \cos\alpha \cdot \sin\alpha(T+t) = \frac{(T+t)}{L} \cdot W \cdot \cos\alpha$$

or

$$R = \frac{(T+t)w}{L} \cdot \cos\alpha.$$

Where W is a diameter of wire as measured on photograph, either as small axis of projection of inclined wire or diameter of upright wire.
L is length of long axis of inclined wire as measured on photograph.
T is travel of inclined wire as measured on photograph.
t is travel of upright wire as measured on photograph.
w is actual diameter of wire (for 250 mesh screen w is 0.0016 inch).
α is angle of inclination of wire to surface of section.
R is thickness of material removed from polishing surface.

For accurate measurements of the removal of material, a photograph is taken at the beginning of the polishing process and another at the desired interval, the photographic conditions remaining constant. The first negative is projected through an enlarger and the position of the wire sections traced on a sheet of paper. The second negative is then projected, the paper moved until the rounded sections coincide and the new position of the elongate sections marked. The value for R, the amount of material removed, is then obtained from the above equation. For less precise work the change in position of any particular elongated section can be measured with respect to any rounded section on the assumption that the shift in position of the rounded section is not material. In general, the travel of the point of an elongated section from opposite one wire to opposite the next, represents a removal of about one thousandth of an inch.

Grinding

After the specimen has been mounted and impregnated it is necessary to remove the rough edges before it enters the next stage. The top and bottom edges of the cylindrical mount are rounded off on an old bronze lap using 400 carborundum abrasive and a copious supply of water. The face of the specimen is not touched on the lap, otherwise it will be deeply pitted by the action of this abrasive.

The coarse grinding is next done on a bronze lap using water as a lubricant and 800 crushed corundum as an abrasive. Specimens are held in the low pressure mechanical head (see Fig. 5). Grinding is continued on this lap until the front and back sides of the specimen are parallel, and until the face of the sample has a uniform matte surface. The pits that go to make this matte surface should be uniform in diameter and depth. The ordinary specimen requires about 5 minutes on this lap to produce a surface satisfactory for the next step.

Mechanical Polishing Equipment.

All of the mechanical grinding and polishing equipment in our laboratories has the same type of mechanism for driving the laps. The mechanical heads which hold the specimens differ radically and deserve a brief explanation.

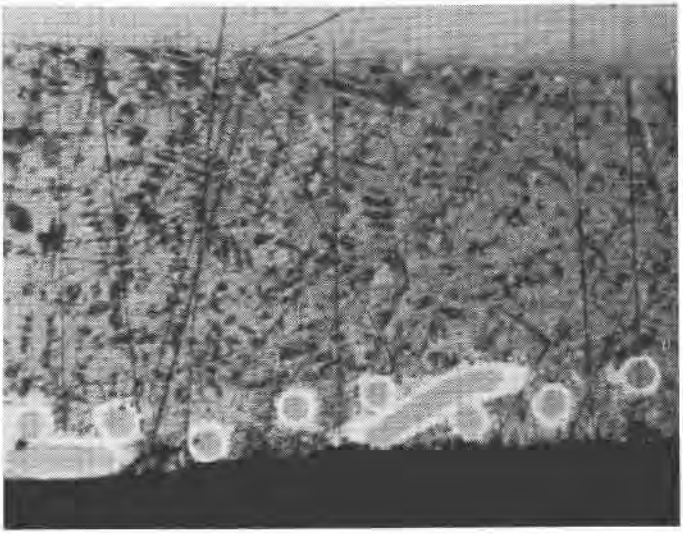

FIG. 3. Polished cross-section of measuring screen. Circular and elongated gray areas with white rim are wires. Mag. 48 diameters.

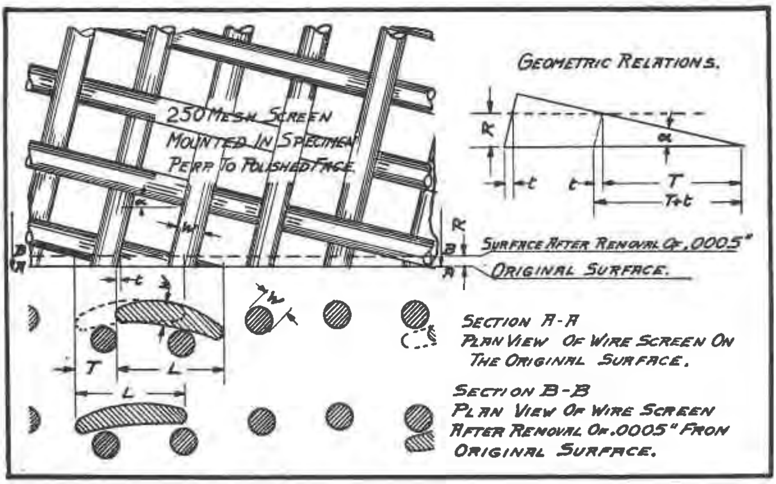

FIG. 4. Diagrammatic section of measuring screen.

The laps, 12 inches in diameter, are screwed on a spindle running in the standard bearings of a Ford model *T* front wheel. On the lower end of this spindle is a compound four groove pulley. Each lap is driven by a standard $\frac{1}{4}$ H.P.A.C. motor which likewise has a four diameter pulley mounted on its shaft. The drive is by a V-belt which runs over an idler pulley kept tight by a spring—see the drive mechanism of a separate machine in the left background of Fig. 5.

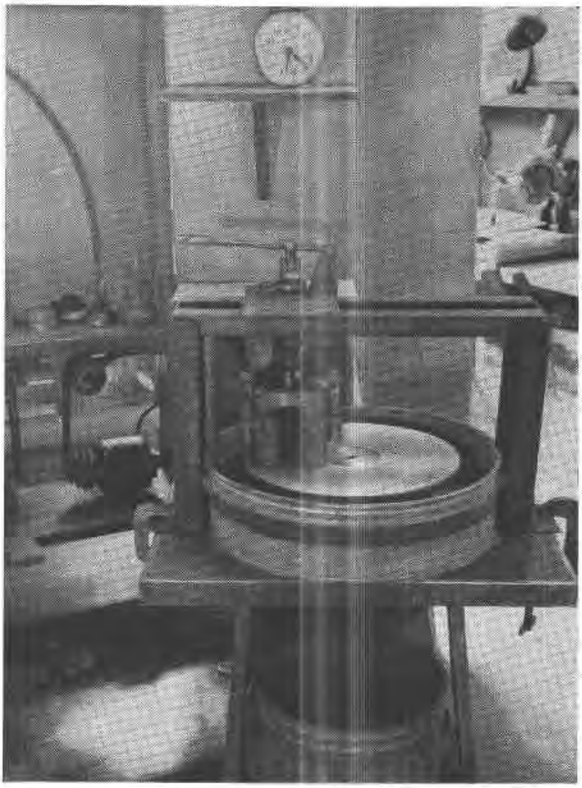

FIG. 5. Low pressure mechanical grinding and polishing equipment.

*Low Pressure Head.**

The low pressure mechanical head (Fig. 5) has four specimen holders. Each holder has a piston operating against a coil spring or weight, inside a closely fitted cylinder. On the outside of this cylinder there is a sliding

* Assembly drawings of any of this equipment are available on request from either author.

sleeve, clamped by a wing-nut bolt and band at the top, whose inside diameter is slightly greater than the mounted specimen. These sleeves are adjusted to a height of about one sixteenth of an inch above the lap. The entire head can be lifted by the upper lever when it is necessary to remove the specimens, and the pressure on the specimens adjusted by the amount the head is lowered onto the springs after the pistons come in contact with the specimens, or by the amount of weight, ranging from one-half to three pounds, placed on each piston. The elevation of the entire head is controlled by the adjusting collar on the main shaft.

The head is not mechanically driven but turns owing to the friction between the specimens and the lap. The speed of the head is controllable

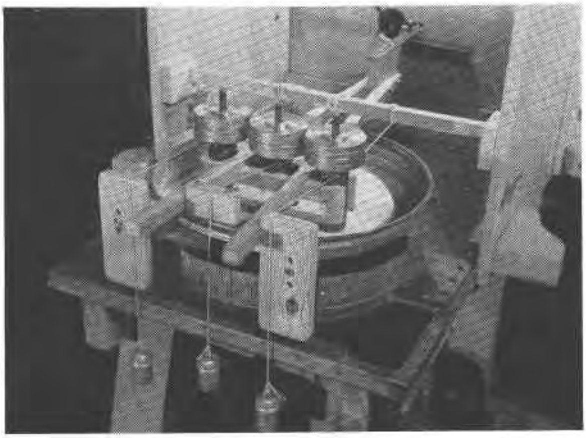

FIG. 6. High pressure mechanical polishing equipment.

by adjusting the length of the two governor arms which press against a brake band on the main shaft, but in practice this adjustment is rarely changed. This unit gives three motions; the lap is driven by the motor, the entire head spins by lap friction, and each specimen is turned within its own sleeve by friction. Since the pressure on the specimen, ranging from one-half to three pounds per specimen, is applied perpendicular to the bottom surface of the specimen, and since, if the specimen tries to tip, all of this pressure is concentrated on the opposite edge in opposition to the tipping action, the grinding action results in the development of parallel top and bottom surfaces. It is desirable to achieve this as soon as possible in all mechanical polishing.

High Pressure Head.

The high pressure head was developed to obtain a mechanical motion as comparable as possible to that found most satisfactory in hand polishing and to permit as great a variation as necessary in the speed and pressure during polishing.

Each specimen holder follows an elliptical path from the edge of the lap toward the central part and back again. This is achieved by having the entire head driven by an eccentric, seen in the background of Fig. 6. The specimen which rotates freely inside its sleeve holder is pressed on by a piston weighted by one or more lead weights. A loop of cord passes once around the piston and is also weighted. As the piston and head are driven back and forth, the cord turns the piston through 90° and the weighted specimen likewise turns. These heads are simple to construct, give a very effective polishing action, and will operate with little attention over long periods. While the use of a mechanical head is not essential in polishing, it not only saves much time but also gives more consistent results.

Semi-Polishing

Up to this point the treatment of all specimens is essentially the same. Beginning at this stage, the methods and time required to prepare the specimen for a final polish vary greatly with different types of material. Consequently three different procedures have been adopted. The choice between these is based largely on experience.

Celotex Lap Method.

For the majority of specimens the next step of grinding or semi-polishing is usually carried out on a worn celotex lap. The rough side of the lap is first washed with a few drops of kerosene and wiped dry with a clean cloth. It is then lightly smeared with a small amount of a paste composed of Dynamo oil and No. 800 crushed corundum. This paste is applied lightly with a cloth swab and the lap is then re-wiped with a clean cloth until it is almost dry. It should have a slight oily reflection which can be tested for by touching the lap lightly with a finger and observing the oily film left on the finger. All of this is carried out while the lap is running. Specimens are ground on this lap using the low pressure head, until no further improvement is noticed in the specimen. Ordinarily this requires from 5 to 10 minutes but may be longer depending on the specimen.

The term celotex as used in this paper refers to celotex panel board which is softer than the commercial grade of hard board and has not been oil tempered. Equally satisfactory material is also sold under the trade name "masonite."

Wooden Lap Method.

Specimens of certain minerals characterized by brittleness or good cleavage, particularly from certain localities, show an undue amount of plucking and pitting, which cannot be removed by additional grinding, when polished on the celotex lap. Experience has shown that these minerals may sometimes be greatly improved by using a wooden lap. The type which we have adopted is made of ordinary ¼ inch ply wood and is cut and fastened onto the base in the same fashion as the celotex lap. The procedure for cleaning and treating this lap with abrasive is identical to that described above for the celotex lap. We do not understand why this lap avoids the plucking and pitting of other types, but experience has shown that it will produce results where all others fail completely.

Lead Lap Method.

The use of the lead lap in grinding is recommended for certain types of specimens typified by a fine grained distribution of brittle sulphides enclosed in talcose, or clayey matrix, in quartz. Some of the epithermal silver gold ores and some mill products, particularly where sericite forms an important part gangue, are best treated by this method. With specimens of this type the celotex lap seems either to pluck out the sulphide grain or else cut it down rapidly and cover it with a coating of grinding debris. It is a curious behavior not in accordance with the usual characteristics of the celotex lap. The lead lap used is 12 inches in diameter and has 1/16 inch concentric grooves spaced at ¼ inch intervals. The lap is dressed for grinding in identically the same manner as a celotex lap, but the specimens are polished with a weight of about 3 pounds to the specimen and are not rotated any more than is absolutely essential. The lead lap turns at about 500 r.p.m. Cutting on this lap is much slower than on the other laps and specimens which require this treatment are usually run for a total of 30 minutes or more.

Summary.

The fine-grinding or semi-polished stage is the most critical one in the preparation of a polished surface. No hard or fast rules can be laid down for the behavior of any mineral, as the grain size, mineral association and texture are variables whose total range is greater than that of mineralogical differences. Moreover, there may be a wide variation in the behavior during polishing of what appears to be similar ore from different localities. Past and current experience must be the guide as to which method of grinding will prove most satisfactory. However, it must be emphasized that time cannot be saved at this stage because the amount of material removed during the final polishing is so small that pits left during fine grinding are not removed during any reasonable period of final polishing. Flat, shallow pits can be polished out but deep pits must be ground out at this stage.

Final Polishing

The final polish on all types of specimens is done on a celotex lap using an abrasive which is composed of approximately two parts of tin oxide to one part talc, and held on the lap by a celluloid cement. This abrasive mixture is composed of 8 grams of cellulose acetate, 25 grams of tin oxide (putty powder), 15 grams of talc and sufficient acetone to fill a 250 cc. flask. The mixture is kept tightly stoppered. Graphite may be substituted for talc by using a mixture containing one part graphite to seven parts tin oxide. The surface of the polishing lap is prepared as follows:

If the lap has been running it is first cleaned, using acetone and a stiff bristled brush to remove any debris, grease or other material which may have accumulated on the lap surface. Next, while the lap is still turning it is scrubbed fairly roughly with a steel-bristled hand brush, or scraped with the sharpened edge of a straightened steel plate to flatten the surface, and then acetone is squirted on and the lap wiped with a cloth. The lap is then stopped, the abrasive mixture is thoroughly shaken, and about 5 cubic centimeters are poured onto the lap and spread over the entire surface of the lap with a dry hair-bristled brush, using a circular motion. For effective polishing the surface of the lap should be covered with a series of low, round-edged ridges of the abrasive mixture. To achieve this, brushing must not be continued after the abrasive becomes fairly sticky, as otherwise it will give sharp high ridges. A lap prepared in this manner gives a gentle but slow polishing action. For rougher action, the lap is first wetted with acetone, about 10 cc. of abrasive are added and worked with the brush until the abrasive is nearly dry. This gives sharp, higher ridges which cut much more rapidly. After the lap has been dressed it is permitted to run for about 5 minutes to thoroughly dry out the mixture. It normally requires about 8 minutes to re-dress the lap which then will polish, without further attention, for an hour at the normal rate of action, and much longer at a somewhat reduced rate of cutting. Specimens are run on the lap using the high pressure head with a pressure of about 6 pounds per specimen, but varied with the specimen. Whenever a lap is re-started it is wise to add first a few drops of dynamo oil and then dry the lap with a clean cloth. The purpose of this is to remove any debris which may have accumulated on the lap surface. The time required for this final polish varies between 10 minutes and an hour, or sometimes more, depending on the perfection of polish desired and the nature of the specimen.

During the polishing the specimens are periodically removed, washed with xylene, dried with absorbent paper and examined under the microscope to determine the progress of the polishing. It should be emphasized, however, that these laps require no alteration when running and that prolonged polishing will do no harm and may often greatly improve a surface. Mechanically these polishing units are practically fool-proof and the specimen cannot tip or jump off the lap. We commonly start a machine and let it run several hours without any attention, while working in another laboratory.

Laps prepared in the foregoing manner cut and polish at a rapid rate, as judged by the changes seen under the microscope. The actual rate of removal of material is of the order of .00005 inches per hour.

Although the foregoing description of the polishing process is given particularly with reference to the use of mechanical equipment, the

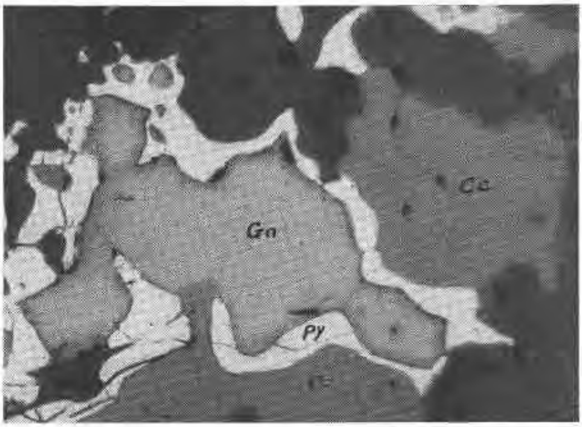

FIG. 7. Celotex polish. White, pyrite Py; light gray, galena Gn; medium gray, chalcocite Cc; darkest gray, bornite Bn. Mag. 150 diameters.

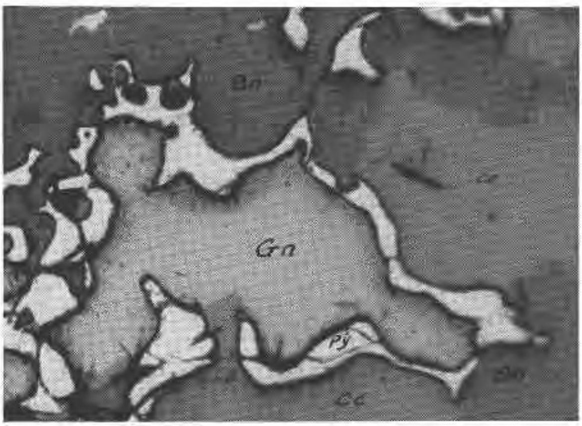

FIG. 8. Paper polish, same area as Fig. 7.

methods are wholly adaptable to hand work. The chief virtue of the mechanical equipment is to increase the number of specimens that can be handled at one time.

Figures 7, 8 and 9 give a comparative view of the same area when polished by the celotex, paper and cloth methods. It is interesting to note not only the difference in relief but also the greatly increased visibility of minerals and textures as the quality of the polish is improved. Figure 10,

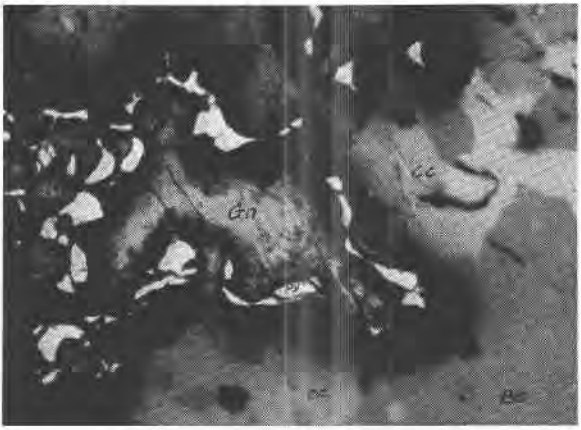

FIG. 9. Cloth lap polish, same area as Fig. 7.

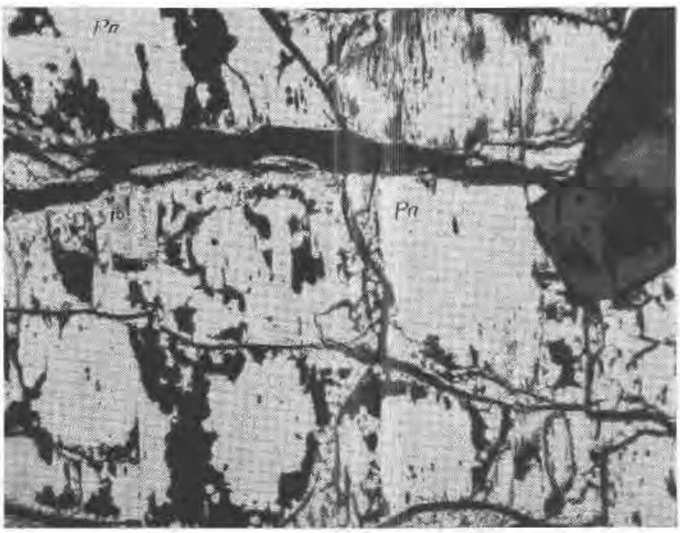

FIG. 10. Celotex polish. Pentlandite, white Pn; pyrrhotite, light gray Po; veined by silica, dark gray, and limonite in tiny veinlets. Mag. 55 diameters.

polished on celotex, shows an area of pyrrhotite and pentlandite veined by limonite and chalcedony stringers. Most of this detail can be seen only in a celotex or lead polish since the material is extremely friable and brittle.

Paper Lap Polishing

The use of the paper lap polish is justified where one is willing to sacrifice somewhat the quality of the polish for the sake of much greater speed in obtaining the polish. The equipment necessary is simple and can be made in any machine shop in a comparatively short time. The abrasives used are obtainable commercially and do not require further sizing. The polish obtainable is good enough for many problems.

Fig. 11. Paper lap polishing equipment.

Specimens can be polished either mounted or unmounted. The flat surface is best obtained by sawing but can be made by grinding a chipped face. It is desirable to carry out the fine grinding on a bronze-lead lap. After a satisfactory matte surface is obtained, the final polishing is done dry on a paper lap as follows:

A sheet of Iroquois paper toweling, or paper of a similar structure, is spread over the lap and held in place by a spring metal ring which fits around the edge of the lap. Onto the lap surface is then spread a moderate quantity of abrasive which is rubbed in with a smooth, circular steel disk, pressed by hand against the lap while it is rotating. The lap is then started and a short period of running done with the steel disk after which it is ready for the specimen. The specimen is held on by hand using a moderate amount of pressure. It is rotated around its own axis and at the same time is moved back and forth from the edge to the center of the lap. We use an 8-inch horizontal iron lap which runs at approximately 1725 r.p.m. and is mounted directly onto a shaft of a ball-bearing motor as shown in Fig. 11. The average specimen requires from 5 to 20 minutes for the development of a scratch-free surface of moderate relief.

The method is faster than a celotex or lead lap and gives much less relief than a cloth lap. The paper is not strong enough to permit the use of a mechanical head. The method is entirely satisfactory for many types of ores. Other ores, however, are susceptible to the heat developed and oxidize sufficiently to materially affect the surface. Such specimens can often be improved by rubbing on a black rubber sheet such as is used as a floor sheet in automobiles. Figure 8 shows the relief developed in an ore whose mineralogy and texture form maximum relief. Figure 12 shows the polish attainable on an ore of more favorable texture.

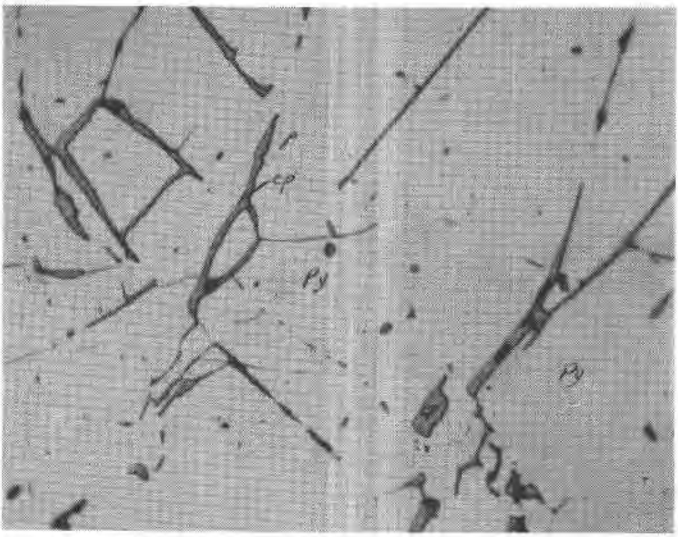

FIG. 12. Paper lap polish. Chalcopyrite veinlets (Cp) in pyrite (Py). Mag. 55 diameters.

CONCLUSION

The development of a high quality polished surface is both physically and mechanically a much more difficult task than the preparation of a thin section of a rock. It is hoped that the foregoing concepts may aid in increasing the ease of preparing such sections and thus facilitate their general use.

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