

GEOLOGICAL
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DEPARTMENT OF ENERGY
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PAPER 68-8

THE PREPARATION OF POLISHED SECTIONS
AT THE GEOLOGICAL SURVEY OF CANADA

C. R. McLeod



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ABSTRACT

Procedures used in the production of polished sections are divided into three main stages:
(1) mounting and impregnation of samples, using vacuum;
(2) grinding, with diamond-impregnated laps; and
(3) machine polishing, using diamond-oil mixtures on lead laps.

THE PREPARATION OF POLISHED SECTIONS AT THE GEOLOGICAL SURVEY OF CANADA

INTRODUCTION

An ore polishing laboratory was established by the Mineral Deposits Section, Geological Survey of Canada, in 1963, in an attempt to improve the quality of polished sections required for the study of opaque minerals. Before this time most polishing had been done using hand methods and results were frequently unsatisfactory. To assist in selecting equipment and techniques, similar specimen material was sent to four laboratories for polishing, and a comparison was made of the surface qualities. As a result of this study, a Depiereux ore grinder, commonly called the Dürer polisher, was purchased and put into operation. A second machine was added in 1966. Sections polished with these machines have proved most satisfactory both for optical examination and for electron microprobe work. Their surfaces are almost relief-free and exhibit well-defined grain boundaries and mineral relationships, a condition not easily achieved by hand polishing.

The simplified flow sheet (Fig. 1) outlines the steps involved in the preparation of polished sections at the Geological Survey's ore polishing laboratory. Many of the details in techniques and procedures described in this report have been developed primarily by the writer and it is hoped that they may be of assistance to others in overcoming some of the problems involved in the preparation of polished sections. Helpful suggestions by Dr. G. Aletan, formerly of Nova Scotia Technical College, and discussions with Dr. J. A. Chamberlain, Geological Survey of Canada, and P. O'Donovan, Mines Branch, are gratefully acknowledged.

PREPARATION AND MOUNTING

All material to be polished is mounted in plastic within bakelite rings especially designed for the Dürer polisher. Rings commonly used are 40 or 26 mm outside diameter, with 3 mm walls. Diamond saws are normally used for cutting specimens to ring size, but use is also made of water-cooled diamond coring drills adapted for use with a standard drill press. These drills cut a rock core which can be sawn into discs or wafers that will almost completely fill the mounting ring, thus allowing maximum use of the area that can be polished. Alternatively, a sawn slice can be trimmed to size with a diamond saw, with tile nippers, or by grinding, if only a little material need be removed. The edge of the wafer should be perpendicular or at an acute angle to the surface to be polished; i. e., the section

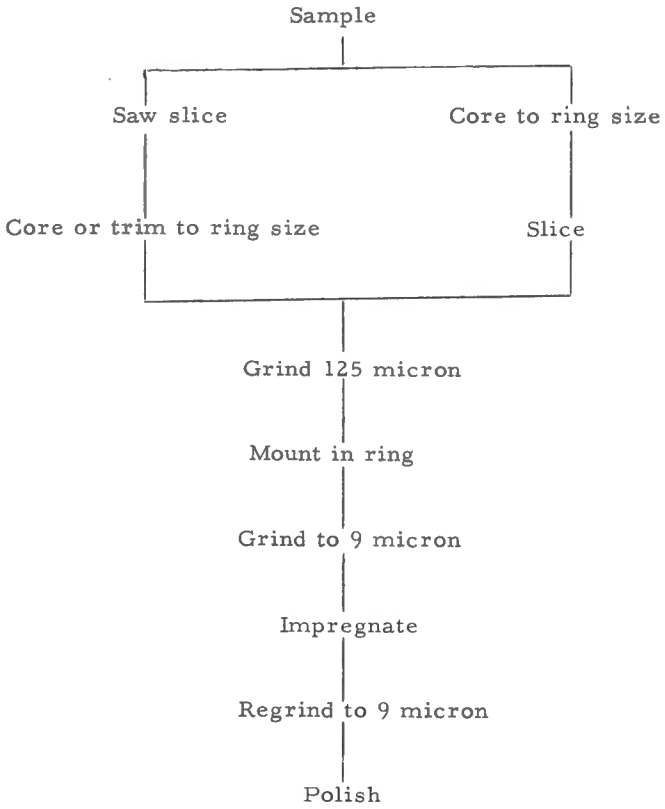


Figure 1. Simplified flow sheet outlining steps in preparation of polished sections.

is mounted so as to prevent the plastic tapering to a thin edge at the polishing surface. This thin edge may separate from the slice, leaving a crack that can trap abrasive or cause damage to the surface of lead laps on the Dürerer polisher. Preferably, the edge should be perpendicular or nearly so, and this is readily accomplished by grinding on the coarse (125-micron) diamond grinding lap (see description in section headed 'Grinding'). The surface to be polished is ground on the same lap prior to mounting to remove unevenness caused by the diamond saw.

For mounting, the slice is placed within a bakelite ring on a 1/16- or 1/32-inch teflon shim that is slightly larger in diameter than the ring. The ring is held tightly against the shim with spring-loaded hooks (Fig. 2). The teflon shim acts as a gasket to prevent leakage of plastic, and the lubricity of the teflon allows easy removal of the section after the mounting plastic is cured. Lead shims, lightly greased, may also be used but generally are more difficult to remove, and, unlike teflon, require a mechanical flattening device if they are to be reused. Identification can conveniently be scribed on the rings using a jig (Fig. 3).

For best results the mounting plastic used should be one that polishes readily without a tendency to flow or smear, have good adhesive properties, cure without entrapped air bubbles, and show a minimum of contraction during the curing process. The most satisfactory of several tested is Araldite 6060 used in combination with Hardener 901, both products of Ciba Company Limited. This combination is most suitable if cured at a temperature between 115 and 120°C. The resin, which at room temperature is a brittle solid, is weighed and then melted at 125-130°C, and the hardener, a powder, is added to the hot liquid resin (30 per cent hardener by weight). When the hardener is thoroughly dissolved, the mix is poured into the pre-heated (about 125°C) ring-mould assemblies containing the slices. For convenience in handling, 6 or 8 moulds are placed in a shallow metal tray, and these can be filled at one pouring. This should be done as quickly as possible to prevent undue cooling of the moulds and plastic mix. Immediately after pouring, the tray of moulds is placed in a vacuum oven at about 125°C. The air is evacuated until the plastic begins to foam and is then let slowly back into the oven. This process, which may be repeated two or three times, helps remove air from the plastic, and to a certain extent, from the sample, and results in partial impregnation of porous material by the mounting plastic. After the above procedure has been carried out, trays are placed in an ordinary laboratory oven for curing at 115-120°C. One disadvantage of the resin-hardener combination is that it requires 12 to 16 hours curing time at the temperature stated. It may be cured more quickly at higher temperatures but greater shrinkage results. Excessive shrinkage is detrimental as it may result in the mount loosening in the ring to such an extent that it may fall from the ring. A contraction crack between the plastic and the ring or between the plastic and the slice is difficult to impregnate satisfactorily. With the Araldite mix mentioned, separation between the plastic and the ring is rare, but cracks frequently occur around the edge of the slice (commonly

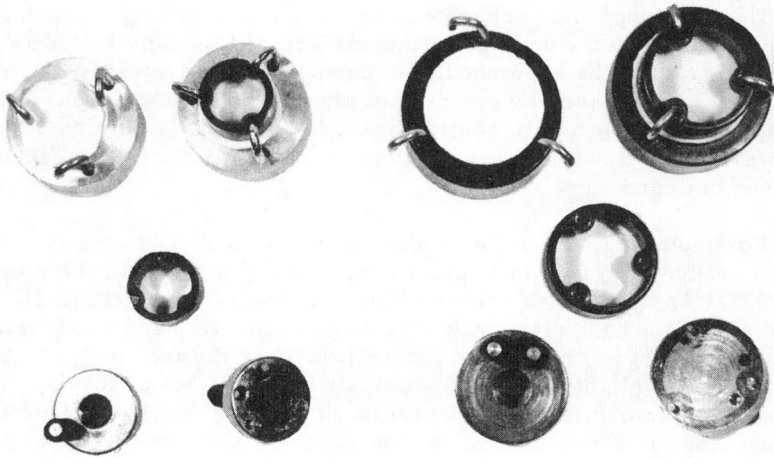


Figure 2. Top - Clamping dies and mould assemblies; centre - bakelite rings; bottom - pressure plates for 26 mm size (left) and 40 mm size (right). (GSC 200347-A)

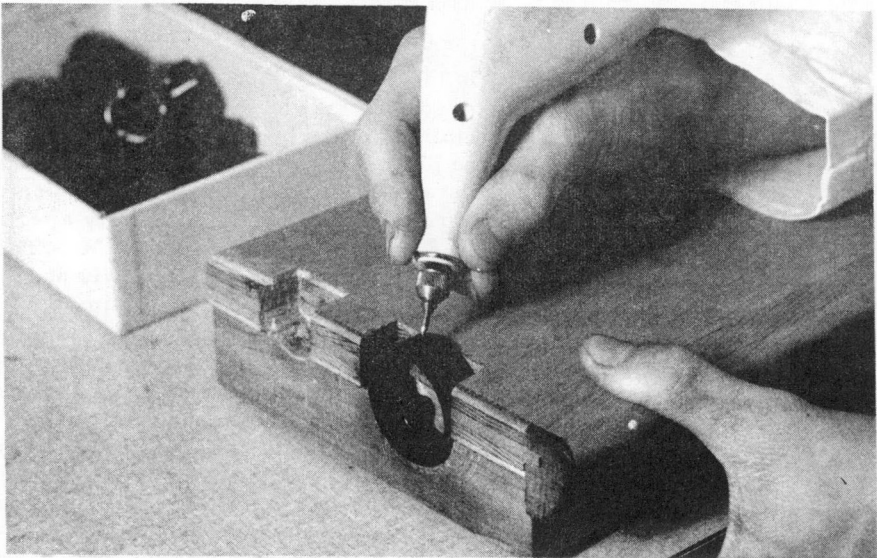


Figure 3. Jig for holding bakelite rings while scribing identification with vibrating engraver. (GSC 200347-F)

within it), and less than 1 mm from the edge. This type of crack seems to appear more frequently in metallic minerals, and is probably caused by contraction of the slice while cooling.

When a 'quick mount' is required, an epoxy glue is used. Duro 'E-POX-E' was found to be the most satisfactory of the several brands tested. It can be purchased in bulk and transferred to polyethylene bottles with spout tops for ease in dispensing. It consists of resin and hardener, both liquids, that are mixed in equal proportions at room temperature, with some latitude allowable in the resin-hardener ratio. Curing time at room temperature is 24 hours or more, but at 70-80°C curing is accelerated considerably, and mounts are ready for grinding in 2 hours or less. As with the Araldite mix, moulds are pre-heated to curing temperature, and mounts are subjected to vacuum treatment prior to curing. The epoxy does not attain the hardness of Araldite, but shows no tendency to 'grab' on the Dürerer lead laps, as may happen with some types of mounting plastics. Because it can be cured at relatively low temperatures, epoxy is used as the mounting medium if the presence of temperature-sensitive sulphides is known or suspected.

GRINDING

After curing of the plastic, sections are taken from the clamping dies and the teflon shims are removed. No loose abrasive is used in the grinding process. Instead, grinding is carried out on a series of Buehler diamond-impregnated grinding laps having diamonds set in an electro-formed nickel bond (Fig. 4). The size-grades used contain diamond particles of 125, 62, 30, 15, and 9 microns, respectively. Other sizes are available but this series has proved to provide a satisfactory range. The size of the diamond particles projecting from the bonding metal determines the rate of cutting and the smoothness of the resultant surface. The action is of a planing nature, and there is no tendency to create relief, nor for abrasive to become embedded in the section and be carried to a finer stage of grinding or polishing. In fact, there is no necessity for cleaning the sections between grinding stages nor is there much evidence of plucking, even with brittle minerals. This type of lap should not be used for grinding metallurgical specimens, as 'loading' of the lap results. However, sections containing small areas of ductile metals or minerals such as native copper or gold can be ground satisfactorily.

Sections are hand held against the rotating laps with running tap water used as a coolant and lubricant. To hasten cutting, initial pressure is heavy, especially at the 125-micron stage, but pressure at each stage is lessened as grinding proceeds. At the first stage grinding must be sufficient to remove any plastic covering the slice to be polished, and if the slice was not ground prior to mounting, effects of the saw cut must be removed.



Figure 4. Diamond impregnated grinding wheels. (GSC 200347-D)

Vanderwilt (1928) found that the use of too coarse an abrasive produced subsurface shattering that resulted in plucking during the polishing process. Experience with diamond-impregnated laps suggests that if properly carried out, such a grinding process results in sections amenable to high-quality polishing methods. In the writer's opinion each successive grinding stage should remove not only the visible surface effects of the preceding stage, but a layer of perhaps two or three times this depth. The more delicately this is done, the less danger there is of creating new deleterious effects.

In the Geological Survey of Canada polishing laboratory, the lapidary table has two power units; one providing speeds of 550 and 1100 r.p.m., the other with infinitely variable speeds up to 1200 r.p.m. Generally, the 125- and 62-micron grinding stages are carried out at 1100 r.p.m., whereas the three finer stages are done with the variable speed motor at much lower speeds. The variable speed motor is commonly used for any hand polishing work that may be required.

IMPREGNATION

After grinding on the 9-micron lap, sections are examined carefully under a stereo-microscope. Bubble holes at or near the surface of the mounting plastic are enlarged using a needle sharpened to a chisel or tapered point, as epoxy used to fill these holes may not always adhere satisfactorily to the smooth-sided bubble holes. If holes are deep, it is advantageous to cut them to a funnel shape so that the epoxy can enter them more readily.

Sections are warmed to about 75°C, a coating of freshly mixed epoxy is spread over their surfaces, and they are then placed in the vacuum oven at about the same temperature. The heat of the sections thins the epoxy considerably, making it less viscous and better able to penetrate openings in the sections. Air is evacuated and then is returned slowly to the oven, the air pressure forcing epoxy into fractures, pits, and holes in the section. Commonly three or four sections are treated at a time, and, to achieve best results, care must be taken not to leave the sections too long between application of the epoxy and return of the air after evacuation, as the heat accelerates the curing to such an extent that the mix starts to thicken within a few minutes. A generous coating of epoxy and a slow return of air helps prevent the formation of new bubbles in large cavities. With caution, much of the excess epoxy can be removed with a wooden spatula prior to curing.

After the epoxy has cured for about 2 hours, sections are edge-bevelled and reground to the 9-micron stage. Edge-bevelling of the bakelite rings is generally done on the 62-micron lap by rotating the section lightly against the revolving lap at angles from about 30 to 60°, thus providing a rounded edge that will not gouge the lead laps, nor tend to cut or tear the cloth covering of those used in hand polishing. If the layer of epoxy to be removed is thin, grinding may be started at the 30- or 15-micron stage, but if considerable excess epoxy is present, grinding is started at a coarser stage. Ideally, the epoxy should be removed so that at the end of the 15-micron stage only a thin uniform layer is left for removal with the 9-micron lap. In this way there is little danger of removing too much, and possibly cutting through the impregnated layer at the surface of the section. In practice, however, it is somewhat difficult to remove the plastic uniformly parallel with the plane of the surface before impregnation. Experience in holding the section and applying pressure properly, and frequent checking under the stereo-microscope to determine the rate and manner of cutting, can result in providing a well-impregnated surface for polishing.

The importance of attention to detail in pre-polishing procedures cannot be overemphasized, as it is practically impossible at the polishing stages to eliminate or correct defects attributable to improper or insufficient grinding.

POLISHING

DÜRENER POLISHING

Two Dürener automatic polishers (Fig. 5) are used for most polishing requirements at the Geological Survey of Canada where only a limited amount of hand polishing is done. Rehwald (1966) described the polisher and outlined the procedure for its use, and recently Saager (1967) has reported on a different technique, using this machine. The polisher is capable of handling six sections at a time, and polishing is done on interchangeable metal laps that rest on a water-cooled base. The head and lap base rotate in opposite directions at slightly different speeds, and are axially displaced so that wear on the lap surface is more evenly distributed than if the sections were tracking in one path. In addition, the individual sections revolve about their own vertical axes. A pressure plate, with three small studs that fit corresponding holes in the bakelite rings, is required for each section (Fig. 2). Pressure on sections can be varied by means of lead weights applied individually to the tops of the spindles. Diamond powder is generally used as the abrasive, and liquid paraffin (mineral oil) as the lubricant. Its viscosity can be varied by dilution with kerosene to compensate for seasonal changes



Figure 5. Dürener automatic polishing machines. (GSC 200347-B)

in coolant temperature. A constant flow of 2 to 3 gallons per hour of tap water under low pressure cools the lap base.

Commonly, three stages of polishing are employed with the Dürerer polisher. The lead laps supplied by the manufacturer vary in hardness according to their antimony content. The hardest lap (highest Sb content) is used with the coarsest abrasive, or first stage of polishing. The laps normally used, in order of decreasing Sb content, are designated as numbers 3, 5, and 6, and are colour coded with green, yellow, and black borders, respectively, for ease in identification.

Hallimond (1954) successfully used solid nylon laps with diamond abrasive for polishing mineral specimens, and the writer experimented with both nylon and teflon lap surfaces on the Dürerer machine. Sheets of nylon and teflon, each 1/4 inch thick, were glued to worn lead laps. Polishing action appeared to be better with nylon than with teflon, but no better than with lead laps, and scratches were generally more numerous and deeper than when using lead laps. Heat dissipation is retarded by the low conductivity of both nylon and teflon. Heat build-up is considerably greater than with lead laps, and could adversely affect temperature-sensitive minerals.

The use of diamonds as an efficient abrasive in mineral polishing has been recognized by, among others, Barringer (1953-54), Hallimond (1954, 1956), Sampson (1956), and Stanton (1957). Using the Dürerer polisher, the writer found that diamond abrasive produces good results in less time than is required when using the polishing pastes supplied by the manufacturer. Rarely, individual diamond grains may become embedded in soft, ductile, or malleable minerals, but this rarely happens and the slight disadvantages of such embedding are more than compensated for by the faster polishing achieved. Diamond pastes are available from several sources, or diamond powder can be mixed with an appropriate carrier to form a paste, but the writer prefers to use powder and apply it directly to the laps. Sizes graded as 2-6, 1-3, and less than 2 microns are used with the green, yellow, and black laps, respectively, for the three polishing stages.

A green (No. 3) lap with the surface in good condition is used for the first polishing stage. It is placed on the machine and carefully cleaned by wiping the rotating lap with white unleaded gasoline or pressure appliance fuel. A clean tissue is then used to apply the lubricant to the moving lap forming a generous but not excessive film over the entire lap surface so that it feels slightly moist to the touch. The lap is charged by getting a smear of diamond powder on an oil-moistened finger tip, and spreading it carefully over the path of travel by slowly rotating the finger tip against the moving lap, distributing the powder as evenly as possible. The initial charge on a newly-surfaced lap is slightly heavier than is required on a worn one. Generally, one or two 'finger-tip loads' are sufficient for charging even a newly-surfaced lap. Over charging can result in sections 'grabbing' on the lap, which causes them to tip and be ejected from the machine. Another possible

result is damage to the lap surface, either by the edge of the section or the pressure plate denting the lap on ejection of the section, or by small shallow patches of lead torn from the lap surface leaving a mottled appearance.

Six sections are loaded on the machine with pressure plates providing the link between the driving spindles and the mounted sections. Maximum weight of about 2500 grams per spindle is commonly used at all polishing stages for 40 mm sections; for 26 mm sections the weight is usually reduced to about 1200 grams per spindle. Normally, the machines require little or no attention if proper amounts of abrasive and lubricant are applied. Sections are checked after 1 1/2 to 2 hours, and the lap is cleaned, lubricated, and recharged before sections are returned to the machine. The length of time required at this stage is variable, being dependent on the nature and characteristics of the minerals present in the section, and quality of the final polish that is desired. It usually varies between 4 and 16 hours (the average is about 8 hours for 40 mm sections), but in extreme cases may range from 2 to 40 hours. The 26 mm sections generally take considerably less time than 40 mm ones. Completion of the stage is determined by microscopic examination. Ideally a section should show no traces of the previous grinding stage, and no large pits should remain. Soft minerals, such as galena, commonly show a matte surface, whereas harder ones exhibit a polished surface with relatively coarse scratches. Tiny pits can be removed at the second polishing stage, but larger ones or grinding scratches can only be removed at the second stage after lengthy polishing. At the first stage polishing action normally starts at the periphery and works toward the centre of the section, but even prolonged polishing at this stage does not appear to produce convexity of the surface sufficient to hamper subsequent stages. Rarely are six sections finished the first stage at the same time, and it has been found expedient to put several sections through the first and second stages by inserting a new section as one is completed, rather than working strictly by sets of six, one stage succeeding the next. In order to check the quality of polish, sections can be adequately cleaned by carefully wiping them with a tissue moistened with unleaded gasoline or alcohol, but such cleaning may be supplemented by ultrasonic cleaning between stages.

The procedure for the second polishing stage is similar except that less lubricant and less abrasive are required. About one 'finger load' of 1-3 micron diamond powder is used on the yellow lap. The time required is considerably less than for the first stage, if the first stage has been performed satisfactorily. The chief function of the second stage is to eliminate minor pits and remove the effects of the first stage, leaving a finer network of scratches. Softer minerals may have a fine matte surface but harder ones should be reasonably well polished. Ideally sections that have been through the second stage should be completely free of pits.

For the third stage the procedure is similar, but again less lubricant and abrasive are used, the lap being barely moistened with oil. Diamond powder of less than 2 micron diameter is used on the black lap. It is advisable

to apply this powder with a different finger tip than used for the coarser powders. Only a sparse 'finger load' is required. An excess of oil must be avoided as it may result in minor relief and an undesirable matte surface on softer minerals. This stage can usually be completed in about one hour, and the resultant surface should be well-polished and relief-free, with only extremely fine scratches not detrimental to optical examination or photomicrography, even at high magnifications. Grain boundaries, even between hard and soft minerals, should appear sharp, providing better opportunity to determine mineral relationships. Narrow reaction rims of various kinds and small inclusions or exsolution lamellae are usually well-preserved and readily discernible, whereas with poor polishing such features may be lost or masked because of plucking or relief.

Unfortunately, because of the large range of physical characteristics of minerals, not all respond uniformly to the procedures described, and adaptation to individual situations is frequently necessary. Some peculiarities may not show up until polishing is well advanced, and in some cases it may be necessary to repeat certain steps in the procedure in order to overcome difficulties. A few examples of such problems follow. (1) Extremely friable material may require special attention to impregnation, and it may be necessary to substitute a less viscous and slower curing impregnating medium for the epoxy normally used; Scotchcast Electrical Resin No. 3, a product of 3M Company, is useful for this purpose. (2) Sample material taken from near a dynamite blast may be incipiently fractured, or such fracturing may be caused by mechanically breaking a chip preparatory to mounting. Brittle minerals are especially susceptible and it is difficult to prevent subsequent plucking along microfractures. It may be necessary to substitute the gentler but slower polishing action of the second stage for the faster but harsher first stage, but, consequently, considerably longer polishing time is required. (3) Sections composed chiefly of hard, competent minerals such as quartz (containing, for example, minor sulphides such as chalcopyrite, galena, or pyrrhotite that tend to pit during the grinding process) may take considerably longer at the first polishing stage because of the relatively slow removal rate of the quartz.

Occasionally it is desirable to improve the quality of polish beyond the third stage. Using the machine, this may be done with 'Linde B' (0.05 micron) gamma alumina mixed in a liquid tar base, and applied sparingly to the No. 7 or 'clear' lead lap, lubricated with a minimum of oil. Sections can also be 'touched up' by light hand polishing with the same abrasive mixed with distilled water to form a slurry, and used on an appropriate cloth lap. Occasional anomalous results with the electron microprobe suggest hand buffing is advisable on sections intended for such use. Caution must be exercised because polishing on a soft, napped cloth, can quickly produce relief.

HAND POLISHING

Hand polishing is not currently being done at the Geological Survey on a production basis, but supplies and equipment are available for those wishing a quick polish by hand methods. Abrasives include diamond paste of various size grades, tin and aluminum oxides, and silicon and boron carbide powders. An assortment of polishing cloths is also maintained; experience shows that choice of cloths and abrasives for hand polishing is influenced by individual needs and preferences. Grinding and impregnating procedures are identical to those described for machine polishing.

GRAIN MOUNTS

Frequently it is necessary to check the composition of loose granular opaque material. This may range in size from coarse natural sand or rock fragments to mechanically ground material of minus 250 mesh size, or smaller. For mounting, a plastic 'blank', commonly of Araldite, is cast within a bakelite ring. After curing, the surface is ground flat and a depression of appropriate size is cut in the flat surface to accommodate the loose grains. A knurled steel rotary cutter (Fig. 6) is convenient for making larger depressions, but for fine-grained material a shallow trench or series of trenches or holes can be cut with a chisel-pointed needle. Ideally, the depressions should be only deep enough so that a layer of grains will be about half below and half above the original flat surface. If the grains are small they are best transferred to the depressions while viewed under a stereo-microscope. Once the grains are in place, the section is warmed, and epoxy is gently dropped over the grains. The section is placed in the vacuum oven and the air evacuated. Entrapped air may remain in the epoxy, but if the layer of epoxy is sufficiently thick, the air bubbles tend to be near the surface and are usually completely removed with the excess epoxy during the first grinding stage. Another method used, if sufficient sample material is available, is to first make the depressions and pre-heat the blanks, then mix the sample with a small amount of epoxy in a disposable dish and transfer this mixture to the depression prior to vacuum treatment. Wooden spatulas (coffee stirring sticks) or toothpicks make convenient and inexpensive disposable mixing tools, and, to avoid contamination, should be changed for each sample. Relatively coarse-grained material may be mounted by placing the loose grains in the mould assembly and following the procedure for mounting of slices described previously.

Caution must be exercised in grinding, especially with fine-grained material, as a layer of grains can be completely removed in seconds at the coarse-grinding stage. Frequent checking with a stereo-microscope is advisable to help prevent such accidents. Impregnation of grain mounts may not be necessary unless material is coarse, or unusually porous or fractured. Grains produced by natural weathering processes tend to polish better than grains liberated by crushing and grinding, presumably because

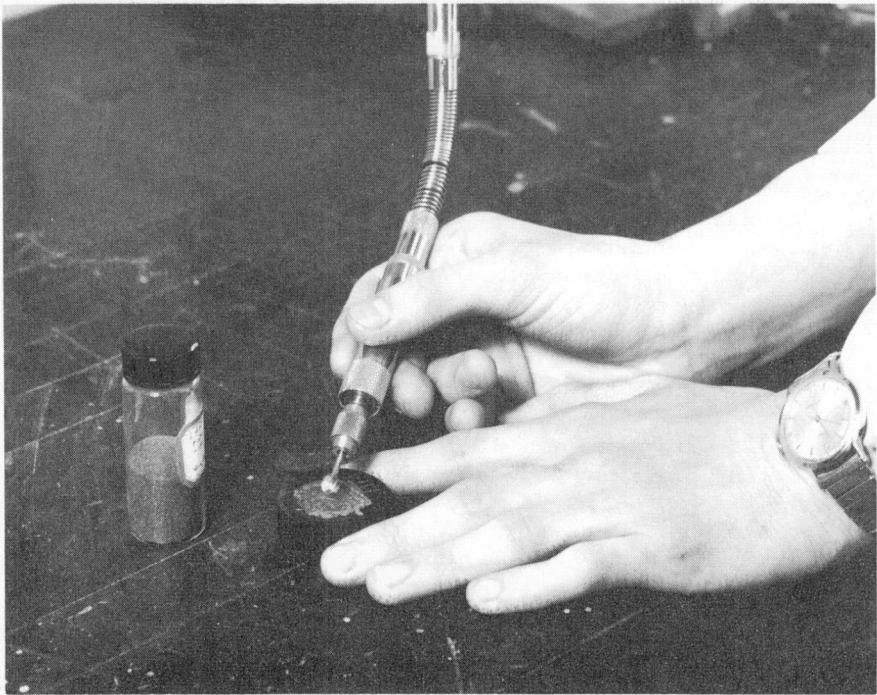


Figure 6. Rotary steel cutter used to make depression in plastic blank preparatory to mounting grains for polishing. (GSC 200347-E)

the latter process causes incipient fracturing in individual grains, thus making them more susceptible to plucking.

With fine-grained material it is frequently possible and often desirable to bypass the coarse-polishing stage. Polishing can be readily achieved with most grain mounts using only the second and third stages, grain mounts commonly polishing much more quickly than solid sections

Using a procedure similar to that for grain mounting, holes may be made in a plastic blank to accommodate single crystals in specific orientations for polishing. They are set with epoxy and grinding and polishing are carried out in the normal manner.

LAP RESURFACING

A special lap resurfacing device is available with the Durener polisher (Fig. 7). This enables the operator to cut a new surface on a worn or damaged lap and avoids the inconvenience of having such work done by a

machine shop. Generally, a lap can be resurfaced in less than half an hour. Laps should be resurfaced when worn smooth or if damaged, although a dented or scratched lap can be used if there is no raised lip or ridge around the depression. The resurfacing device has a cutting knife on a carriage that is automatically fed along the radius of the lap. The depth of cut can be readily adjusted, and it is necessary to remove only a thin layer of the surface. Abrasive embedded in the lap will eventually wear away the tip of the cutting tool, and it must be reground to provide a properly rounded cutting edge as described in the manufacturer's instructions. This can be accomplished by means of a hand carborundum stone, or with care, on a rotary tool grinder using a fine abrasive wheel.

The surface of the lap should be perfectly flat or very slightly convex along the radius, with peak convexity on the path of travel of the sections. The contour of the surface can be satisfactorily determined visually by holding the sharp bevelled side of a steel straight edge lightly on a newly surfaced lap. Oblique lighting directed at the contact of the straight edge with the lap from the side opposite the viewer best shows the configuration of the lap surface. Altering the contour of the cut along the radius requires judicious widening of the groove in the back of the horizontal bar on which the

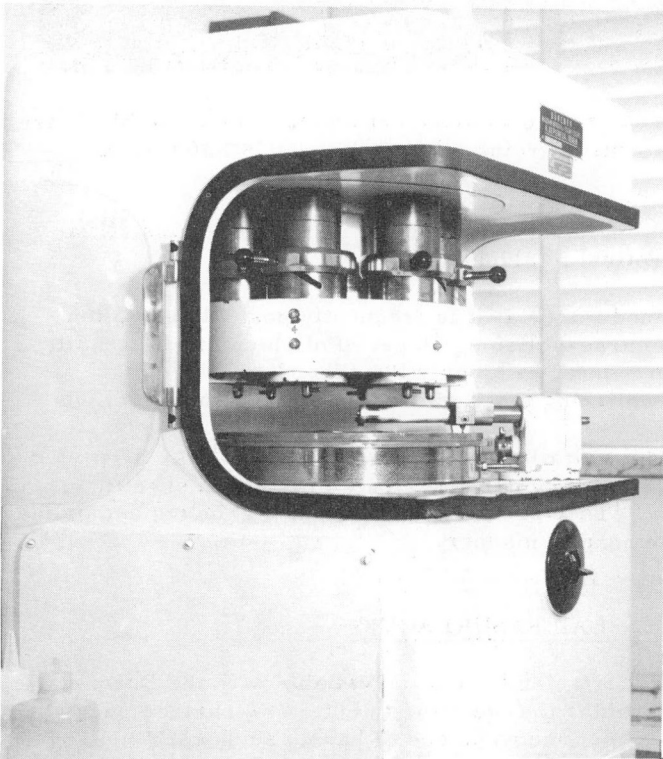


Figure 7.

Lap resurfacing device. Carriage with cutting tool rides on horizontal bar and is driven with screw feed geared to sprocket activated by pin in lap base.
(GSC 200347-H)

carriage rides. A wedge, with adjustable tension, slides in this groove and determines the path of travel of the tip of the cutting tool. Slight alteration along the edge of the groove can improve the plane of the lap surface.

Laps should be marked so they are always placed on the lap base in the same orientation. Kerosene is normally used as a cutting fluid when resurfacing. After a lap has been resurfaced, it should be wiped free of small cuttings and kerosene, and a coating of mineral oil applied to prevent oxidation of the surface while the lap is not in use. A newly surfaced lap results in faster polishing action than is the case when a lap is worn. This is probably because: (1) the ridges left by the cutting tool hold the abrasive in positions more favourable for efficient polishing action; and (2) the accompanying grooves or troughs allow sludge and cuttings to move downward from actual contact with the surface of the sample.

Sections that contain sharp-edged pits or cracks are most likely to cause damage, and they tend to damage a newly surfaced lap more readily than a worn one. Proper impregnation and grinding reduce the probability of such damage, but it may occur in spite of careful attention to precautionary measures. It is believed that lead is initially scooped up into a hole, forming a ball which in turn scratches the lap. These scratches have raised edges and these ridges provide easily accessible lead for other holes; in a very few minutes this action is compounded to such an extent that the lap must be resurfaced. To lessen the chances of such damage, sections that cannot be impregnated and ground without pits remaining should be polished on a partly worn lap.

SUMMARY

The quality of the end product is dependent on constant attention to detail in all four phases in the preparation of polished sections, viz. preparation and mounting, grinding, impregnation and regrinding, and polishing.

Although it is readily conceded that polishing with the Dürer machine does not represent a quick polishing method it does appear that the sacrifice of quantity for quality is justified by the detail revealed in sections made in this manner. Although training, skill, and judgment are required for operating the machines, these abilities can be acquired more quickly than the finesse necessary for the art of hand polishing.

Finally, standardization of technique is impossible, even with 'automatic' polishers, and adaptation to individual situations is necessary with the diversity of material encountered in ore polishing. Examples are given in this report to serve as a guide in dealing with such problems.

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