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Polishing technique for geologic samples

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Abstract

By the use of only one piece of equipment, exceptionally flat, polished thin sections and plugs having few defects may be produced from a variety of geologic materials. A horizontal lap unit, with exchangeable lap wheels and an automatic polisher, is used for all steps from grinding to final polish. Diamond abrasive compounds are used exclusively. The compounds are embedded in a chemotextile material, producing fixed grain laps that remove material by planing action until scratches are no longer visible with light optic microscopes. After each step, sections are cleaned with an ultrasonic cleaner. Meticulous lab technique is important.

Introduction

Preparation of polished sections with a flat surface, free from pits and scratches, has been an art traditionally involving many variables. Recently great strides have been made in polishing techniques by using diamond compounds and advanced equipment. Commonly, the new equipment is specialized, as well as costly, and beyond the means of most small laboratories. This paper describes a technique for producing an excellent surface on round plugs and petrographic and round thin sections of a variety of materials ranging from coal to sapphire, using one piece of equipment for all stages.

Equipment

The principal item of equipment is a horizonal lap unit with an automatic polishing attachment and six interchangeable brass or aluminium lap wheels. The author used a Buehler Low-Speed Polisher, a Whirlmet Automatic Polishing Attachment with a 1-inch specimen carrier for polishing plugs, a thin-section specimen carrier, 3 Petro-Thin Slide Holders for 27 × 46mm glass slides, and 3 Petro-Thin Slide Holders for 1-inch diameter glass slides. A Leco Fini/Pol with thin-section holders and plug holders may also be used. An ultrasonic cleaner is required for cleaning the samples after each step. The equipment must be located in a clean laboratory. A cabinet with doors or drawers should be available for storing the lap wheels. Assigning overall supervision of the laboratory to one person is strongly recommended. A community laboratory is not likely to be maintained in the immaculate condition required by this technique.

Sample mounting

Mounting techniques are described in *The Analyst* and Woodbury *et al.* (1970). Since plugs are processed without holders and applied directly to the lap surface using a specimen carrier, they must be precisely the right diameter, round and smooth. The simplest way to achieve this is by using bakelite ring forms and epoxy.

General grinding and polishing

The most important phase of the grinding and polishing technique is cleanliness. Without meticulous laboratory technique this procedure will not produce a superior section. The first step is cleanup of the work area. Also the technician's fingernails must be scrubbed with a stiff brush. The samples and sample holders must be cleaned in an ultrasonic cleaner before starting and after each step. Water with a liquid soap will suffice for cleaning loose grit; inhibited 1-1-1 trichlorethane works well for diamond pastes that have been used with an oil extender fluid. The 1-1-1 trichlorethane should be discarded or filtered frequently to avoid contaminating the laps.

Plugs are applied directly to the lap using a specimen carrier with openings corresponding to the plug diameter. Thin sections are applied to the sample holder with a small amount of vacuum grease.

The purpose of the grinding and polishing technique is to create a flat cross section free of defects. A polished surface results, but the degree of polish is not the only criterion by which a finished section is judged. Unfortunately, the word "polishing" does not adequately describe this method of sectioning.

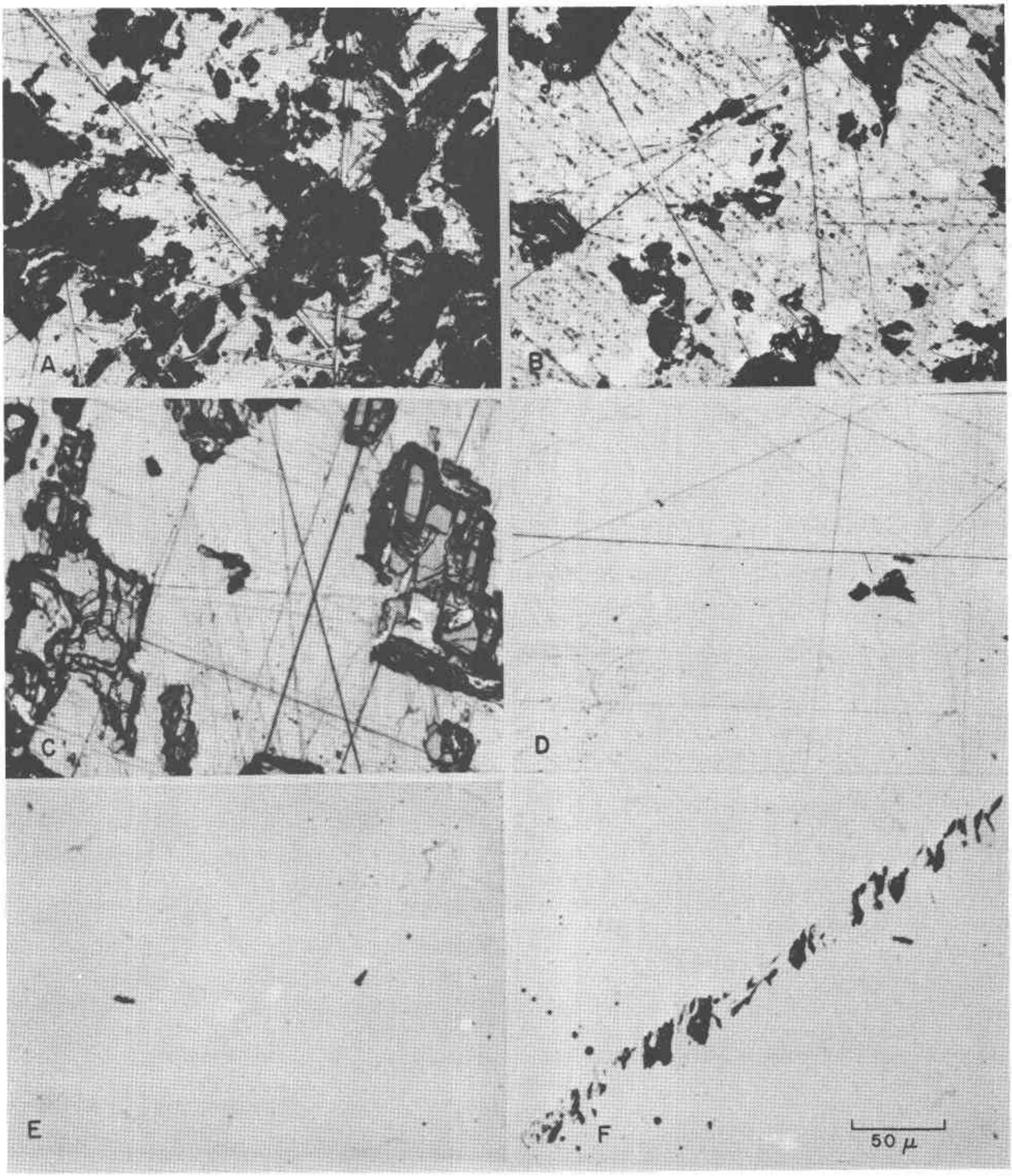

Fig. 1. Polishing sequence on sphalerite with minor chalcopyrite from Joplin, Missouri. (A) 90μ, pits large and deep; (B) 30μ, pits slightly smaller, and less deep; (C) 15μ, pits only slightly smaller, but they are now shallow; (D) 6μ, pits are almost entirely gone, scratches are still evident; (E) 1μ, finished surface; (F) polishing sequence rushed, subsurface deformation from a 90μ scratch not removed, causing a line of pits in the final surface.

Four principal variables of importance are: hardness and shape of abrasive particles, method by which abrasive removes material, type of lap surface, and size of abrasive particles. The abrasive must consist of particles having sharp corners and a hardness sufficient to remove material easily. Harder abrasives are less sensitive to variations in sample hardness, so less relief will be created.

Abrasives may affect sample surfaces in several ways:

(1) Grains that are not fixed to the lap surface will roll between the sample-lap interface. Grains with a high degree of sphericity and roundness will have little effect; blocky grains with sharp corners will dig into the surface and crush or pluck out material (Ramdohr, 1966). This method will also create a deep zone of deformation beneath each pit (*The Analyst*) and is undesirable for anything except rough grinding.

(2) Grains that are fixed to the lap surface remove material by planing. Blocky grains with sharp corners are preferable. This technique creates a minimum of subsurface deformation.

(3) Very fine-grained abrasive suspended in solution on a soft lap surface will polish some materials by a combination of rolling grain, fixed grain, and by smearing out the upper surface (buffing). While this procedure will produce a polished surface, the relief created obscures grain boundaries, causes cross contamination between phases, and yields poor analytical data. Although probably suitable for classroom ore microscopy, this technique is not generally recommended for research.

In general a soft lap surface will create relief; a hard, flat lap surface will produce a flatter section. The final variable is the size of the abrasive particles. A finer abrasive powder will produce a finer scratch. Thus, a sequence of coarse to fine abrasives will produce a successively smoother surface. Ultimately the scratches will not be visible.

If these variables are randomly adjusted in a trial-and-error method, a superior surface may result. This method could then be classified as an art. If, however, the above variables are maximized to produce a superior surface, the technique becomes routine and can be easily taught. In summary, the variables are fixed as follows: diamond abrasive is embedded (that is, fixed) in a chemotextile lap cover having a pressure-sensitive adhesive back (Texmet, available from Buehler Ltd., or Pan K, available from Leco Corp.) for all steps from grinding to final polish. Each step must have its own lap wheel and cover. Do not use too much diamond compound, or the excess grit will revert to a rolling action.

Embedding the abrasive particles on a freshly-charged lap by running a dummy sample for a few minutes is advisable. Extender fluid should be used to insure an even distribution of abrasive. When the lap is in use, a minimum of additional fluid must be added periodically to lubricate the surface, preventing the sample from generating excess heat and from wearing into the lap cover. All lapping is done with one to two pounds pressure per square inch of sample surface. Sections should be inspected with a microscope between steps (after cleaning in ultrasonic cleaner) to make sure scratches from preceding steps have been removed and to detect if the lap has become contaminated. Diamond lap surfaces should not be touched with the hands and each lap should be stored in its own zip-lock plastic bag. The lap should be placed in the bag with the same surface of the bag in contact with the lap each time (bags can be labeled indicating grit size and which portion of the bag should touch the lap surface). Turning the bag over may transport contamination from the lap spindle to the surface of the lap. If a lap cover becomes contaminated and is replaced, the plastic bag should also be replaced.

When replacing a lap cover, the lap is warmed and the material is peeled off, leaving a residue of adhesive. This adhesive may be removed by using alcohol and fine steel wool while the lap wheel is spun by the motor unit. Cleaning the lap wheel in the ultrasonic cleaner and washing hands is recommended before applying the new lap cover. Resin-bonded 30- to 50-micron diamond lap covers were satisfactory, but chemotextile lap covers produce a flatter surface. Metal-bonded diamond lap wheels were not evaluated.

Automatic grinding

The purpose of this step is to produce a flat surface on the sample parallel to the lap surface, to remove surface deformation and any imbedded silicon carbide grit from coarse grinding. If the thin sections to be polished were produced on a machine having a bonded diamond grinding wheel the above has already been achieved, and the polishing procedure may start at the 15-micron step.

Fine grinding is carried out using 90-micron diamond paste (available from Jack Schuller, Inc., or by special order from Leco Corp.) and should be run until all surfaces of the plug show contact with the lap and pits produced by the rough grinding step have been removed. With most materials, 10 to 15 minutes of grinding are sufficient. Less time is required for softer materials; more time for harder materials.

At this point many materials can go directly to the polishing step. In comparing the surfaces produced by the 90-micron diamond lap to those produced by the 90-micron (140-grit) silicon carbide paper, the diamond lap produces a superior surface. Even when compared to 15-micron (600-grit) silicon carbide paper, the 90-micron diamond is clearly superior.

Samples that pit easily (for example magnetite or sphalerite) or are very hard will require more time on the 90-micron lap, and may also require 10 minutes on a 30-micron lap. In general, samples that are easily deformed or weakened (evidenced by pitting) or are very hard will yield better results if smaller increments in grit size are taken between the initial 90-micron fine grinding and the 1-micron final polish. Conversely, samples that are soft and show little pitting may often yield excellent results when using a minimum number of steps, saving time and effort.

Polishing

The first polishing step is 15-micron diamond paste, producing a flat, glossy surface. During this step the final thickness adjustment is made on thin sections. Five minutes will produce a satisfactory surface on most materials, although a longer time may be required on exceptionally hard samples, or to adjust the thickness of thin sections. This step is useful for producing thin sections that are thinner than can be achieved on most equipment, and is particularly useful in producing thin sections of coal.

The next steps are 6-micron diamond paste followed by 1-micron diamond paste. When polishing easily tarnished materials, water is recommended as an extender fluid on the 1-micron lap (water-soluble diamond paste is necessary). The final cleaning should be done in distilled water, followed by removing the surface water with pressurized air or freon. When using water as an extender fluid, care must be taken so the lap does not dry. The lap should be inspected frequently. If desired, one-quarter micron diamond paste may be used as a final step after the 1-micron diamond paste. However, keeping the one-quarter micron lap free from contamination is very difficult; the lap may be contaminated solely by replacing the lap cover. In most cases the 1-micron diamond produces a very satisfactory surface.

At this point, trying to improve the final polish with one of the exceptionally fine-grained polishing oxides is tempting, but their inferior hardness will produce relief and may buff malleable materials. In addition, these oxides may introduce contamination that would interfere with a microprobe analysis, whereas diamond would not contribute to most analyses. The extra cost of diamond is more than compensated for by the superior results, the small quantities necessary, and the saving of technician time.

Appendix

Addresses for supply houses mentioned in text.

Buehler Ltd., 2120 Greenwood St., P.O. Box 1459, Evanston, Illinois, U.S.A. 60204

Jack Schuller, Inc., P. O. Box 420, Park Ridge, Illinois, U.S.A. 60068

Leco Corp., 3000 Lakeview Ave., St. Joseph, Michigan, U.S.A. 49085

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