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TECHNICAL NOTE ON THE POLISHING OF MINERALS AND ROCKS[1]

by

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RESUME.- L'examen microscopique de minéraux en lumière réfléchie requiert des sections polies présentant un poli spéculaire. Les roches ou les minerais granulaires ou fibreux, non consolidés doivent recevoir des traitements spéciaux.

La routine de polissage se décompose en 5 phases qui sont successivement prises en considération tandis que sont particulièrement développés les points suivants : la préparation des échantillons indurés ou sableux; la préparation des moulages de support; le meulage et le polissage.

ABSTRACT.- Microscopic examination of minerals in reflected light requires specular polished sections. Unconsolidated, granular or fibrous rocks and ores necessitate special processes.

The polishing routine is decomposed into five phases which are successively considered and the following points are particularly emphasized : the preparation of indurated or sandy samples; the preparation of moulding supports; the samples moulding; the grinding and the polishing.

1.- PREPARATION OF SAMPLES

1.1. PREPARATION OF COMPACT SAMPLES

Samples of rock brought to the laboratory for various studies should be sawn according to their form, place and structure. The sawing is done, preferably, using a diamond saw. A plate, 5 to 7 mm thick is sawn. The retained surface is refined, either using a diamond wheel, or abraded on a cast iron lap using silicon carbide as abrasive and water as lubricant.

The coarseness of grain used to attain this, is around 400 mesh, to avoid deep scars; this permits to remove the sawing marks.

When the scratches are too pronounced, especially in hard minerals, it is preferable to use 200 mesh grains, as this reduces the time of abrasion; but in this case, it will be necessary to grind the sample surface using successive powders of 300, and then 400 mesh.

The interesting fragment of the sample retained will be cut into a square approximately 2 mm on each side.

The live angles of the surface will be preserved to permit a better adherance of the resin-mineral contact.

The sample should be heated to 60°C for about an hour to dry.

The dimensions noted above are required in order to use our moulds.

The sample marking must not be done on the surface to be polished, as the ink penetrates deeply into and colours certain minerals.

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1.2.- THE PREPARATION OF SANDY SAMPLES

A preparation prior to coating is required. If it is necessary to dry the dusty matter property, then to clean it using acetone or carbon tetrachloride, to dry again the quantity needed to sill the mould to more or less a depth of one mm. It is advised to have the grain size as regular as possible to avoid decantation during setting.

2.- THE PREPARATION OF MOULDING SUPPORTS

The 1 mm thick laminated lead lap, will be smoothed, and cleaned, as well as the bakelite supports used in our laboratory.

Using resin (described below) or a glue made of two components (easier), the supports will be glued to the lead lap. This operation, carried out at about 50°C, permitting the glue to be more fluid, will facilitate the handling and will decrease the setting time.

Different mould models are available on the market.

3.- MOULDING SAMPLES

The degassed cold resin DRL and the hardener HY 951, made by CIBA firm are used. It is charaterized by minimum shrinkage for a maximum hardness.

Other resins are available on the market, in particular those from the STRUERS and BUEHLER firms. Moulding under pressure is to be avoided as it is expensive. In addition, the minerals can undergo cataclastic weathering. After having thoroughly cleaned and labelled the samples, they will be placed in their support to be coated. The whole is introduced in a vacuum drier at around 50°C.

The resin is mixed with the hardener (usually in the proportions given by the manufacturer), of 10 parts resin to 1 part hardener and placed in the drier to become fluid. After being mixed, it will be poured into the moulds to the maximum of the capacity necessary to have a certain mass and to prevent an ulterior deformation of the section.

The plate is put back into the drier for a few minutes. Then using a spatula, the samples are agitated in their moulds with a back and short movement to avoid the accumulation of air bubbles under them.

The rock is centered in the mould, if the samples are porous, the vacuum is made several times, so that the resin can penetrate the mineral pores.

In the case of sandy materials, it is necessary to mix the resin thoroughly, so that the grains are well covered. It should stay in the drier foc $\pm$ 5 minutes. The process can be repeated if necessary. The reference label is set into the resin before it hardens. The unmoulding consists of loosening the pieces from the lead laps.

The reticulation of the resin is slowed by dampness in the samples, therefore, it is necessary to use absolutely dry materials. The resin and the hardeners should be kept in a cool, dry place as they are extremely sensitive to humidity.

Contact with the skin and eyes, as well as inhaling the products, must be avoided during handling.

4.- GRINDING

Using the sample obtained, the front face must be trimmed a cast-iron lap with a 600 mesh emery, which removes the resin excess and makes the rock appear.

In the case of powdery material, it is necessary to grind longer so that the full diameter of the grain appears on the surface if the abration thickness is considerable, the coarsness of the initial abrasive must be increased (to save time), being careful to finish with staggered abrasives (ex.: 240, 320, 400, 600, 1200 mesh) ending with 2400 mesh.

The next step consists of bevelling the ridges of the section to avoid tears in the cloth during polishing. This procedure is accomplished by using a diamond disk (grains of about 60 microns and water as lubricant). The surface is also tooled during several minutes to efface the disturbances caused during the previous phase.

Vanderwilt (1928) exposed his theory concerning the grinding of rock sample; his investigation is still current today; he has recorded two distinct phenomena.

The first is the abrasion of grain quickened by a rolling movement, the surface has then a granular and dull aspect; but it is not possible to obtain a polish by trying to continue to refine the sample surface; furthermore, deep disturbances (cracks or chips) can reach three times the diameter of the abrasive grain.

The second phenomenon is the abrasion by fixed grain which does not give rise to chips but rather grooves, with a depth two times smaller than the diameter of the grain used. There is no formation of cracks or only few.

Still according to Vanderwilt, the polish obtained results from the formation of grooves more and more minute. The grinding phase is carried out on the basis of these various considerations.

The outline of the following phases is done using silicon carbide paper under water, with granulometry of 320, 400, 600, 1200 and 2400 mesh. The papers are placed on glass or perfectly smooth machined steel plates; the sample is rubbed with a rotary movement moving over the entire surface of the abrasive paper lubrified with water. The time needed for the different phases varies depending on the hardness of the rock, but never exceeds 3 to 4 minutes.

As soon as the best possible surface finish is reached with a given mesh, there is no need to continue. If a bow-drill is available for grinding, the rotation speed should be about 100 rotations per minute. These procedures are carried out under a trickle of water to clean out the grinding debris.

It is indispensable to clean the sample between each granulometry change using liquid soap and a nail brush or even better, using an ultrasonic machine.

The inspection of the section surface condition must be done using a reflected light microscope. If larger or deeper scratches appear among those attributed to the grain used, it will be necessary to go back and use a diamond plate or paper of a bigger granulometry and to start the previous cycle over again.

It is important to do this very carefully as at the following stage these deep grooves will never disappear. It is advisable to choose abrasives of a perfectly classified granulometric composition; thus, there are no disturbances during the different stages of the grinding.

It is possible to replace the abrasive paper by diamond grinding wheels of successive granulometry scaled from 60 to 5 microns, which have the advantage of having the grains well held on the support disk by the binding material. Due to this fact there are fewer disturbances than when using silicon carbide paper.

5.- POLISHING

5.1.- GENERALITIES

Polishing methods cannot be applied in a systematic way. They must be accompanied by microscopic inspections after each operation and adapted according to the sample properties.

The principal difficulty of this technique is this adaptation. There is no absolutely safe method that can be applied in every case. It is probable that such a method will never exist.

The technique was greatly improved at the beginning of the '60's by the perfecting of an automatic polisher, marketed by the DEPIREUX firm of Düren. The work of the engineer G. Rehwald has allowed the transition from fine polishing to specular polishing.

The abrasive grains are fixed to lead laps and that permits their incrustation and fixing on the surface, without risking the deformation of the latest (smoothness) as rubber or cloth disks. In fact, the substance must be soft enough to allow the partial coating of small sized grains (less than 15 microns), and adhesive enough to retain it during polishing.

This method requires a highly developed technicality and handling. It is described in «Applied ore microscopy» by G. Rehwald (1966).

It is still in effect for the polishing of soft minerals such as gold, bismuth, silver in association with very hard minerals (quartz, pyrite, marcasite). It is obvious that the finish and smoothness obtainable on specific samples with an abrasive of specific granulometry, depend on the support of the abrasive. The softer the support, the better the obtained finishing is. The harder, the smoother.

The choice is therefore a compromise between two opposed criteria. Furthermore, the support must be very durable (increasing the return) and frequent changing inevitably has, as its consequence, the loss of non-used abrasive.

During the last few years, cloths having characteristics close to those of the lead lap have appeared on the market. This contribution is the sign of a further evolution of polishing methods.

5.2.- MATERIALS

5.2.1.- Polishing cloths

STRUERS firm from Danemark produces several kinds of cloths : **Hard type** - used in the first stage of polishing, especially for mineral of hardness from 4 to 10 (Mohs scale); **Pan w type** - used for the second and third stage, specially developed for mineralogical polishing. It also used during the first stage of polishing soft metals and minerals.

The support plate is made of hardened steel or formerly of brass, but, in any case, it must be perfectly smooth (checked at regular intervals).

5.2.2.- The abrasives

The most adequate abrasive is the diamond because of its technical characteristics. The specific characteristic of a diamond paste is the homogeneity of the strictly classed grains according to their size and form. The grains will always be uniform in a cluster so that each one participates in the grinding of the sample. It is necessary that the paste possesses adequately homogeneousness and concentration. They must be water or alcohol soluble. The binding material must be neutral and preferably without colour (colouring of the mineral).

The standard abrasive used for grinding is silicon carbide, but boron carbide is the most adequate as it splits into approximately cubic grains which are preferable for grinding, contrasting with silicon carbide which forms a rather long splinter. Unfortunately, boron carbide is more expensive.

It is useful to have plates that can take magnesium or cerium oxide pastes for finishing. Chromium oxide is to be avoided as it offers no additional advantages, and, on the contrary, gives rise to confusion with copper carbonated mineral because of its colour when deposited in fissures.

5.2.3.- Lubricants

Lubricants are generally supplied by manufacturers, and are mainly a mix of alcohol with a little oil. Petrol may also be used.

5.3.- POLISHERS

The Rehwald type polisher (see references in the previous text), allows the polishing of six samples simultaneously. All the specialized firms produce polishers with different characteristics, but they are sometimes very similar. A study of the market is necessary when buying, as new models may be put on the market at any time. The diamond paste must be applied homogeneously using a clean finger on the surface of the polishing cloth which should be moderately sprinkled with the ad hoc lubricant.

Using a specially chosen sample or a polished section of metallic carbide or a polished sample containing a maximum amount of hard minerals, it is possible to realize a good impregnation of the grains and avoid certain unwanted scratches. An excess of lubricant gives rise to migration of diamond grains towards the periphery.

Constant supervision is necessary to maintain the required degree of humidity (pull), because the high constraint excerted on the surface to be polished (function of specific pressure). To fully understand the polishing process, I will give information concerning the characteristics of the Rehwald type polisher. The opposing movements of the disk and the parts holder are coordinated so that the trajectories sailed by the section change without interruption and as a consequence the disk remains as smooth as possible. The plate turns at the speed of 42 rotations per minute, the head of the pin holder at 38 rotations per minute, the pins at the speed of 152 rotations per minute. The weight of the pins fixing the polishing pressure is about 1750 grams.

The addition of lead weights to the pins increases the polishing pressure up to 4000 grams. The specific pressure, with the sections used in our labs, can therefore be adjusted from 300 to 700 grams per square centimeter.

A cooling device for the polishing disk is provided to prevent overheating during work. Between each phase, it is necessary to clean the sections thoroughly to avoid a migration of grains of different granulometry in the cloths.

5.4.- POLISHING PHASES

First phase

Preliminary polishing-grains of 6 to 8 microns, length of time 20 minutes. Choose and distribute the samples according to their hardness, hard type cloth (STRUERS) and PAN-W type for sections containing soft minerals.

Soft minerals

Galena, bornite, coveline- only use the pin pressure. The scratches are quite marked; chips are numerous; the surface is mat to semi-gloss.

Minerals of medium hardness

Sphalerite, chromite, limonite- supplementary grinding pressure of 250 grams. A few chips and quite marked scratches appear; the surface is semi-gloss.

Hard minerals

Pyrite, rutile, magnetite, cassiterite- supplementary grinding pressure of from 250 to 300 grams. The surface is glossier than for the above minerals, the chips and the scratches are not so important.

If under microscopic examination some samples are sufficiently polished they can be withdrawn, and the process is continued with the remaining sections. On the whole, it is noticed that the scratches become more abundant as the minerals grow softer.

If surface weatherings are noticed because of the removal of interstitial gangue or mineral, it is absolutely necessary to resurface the sample using resin and to start the grinding and polishing processes, over again otherwise the removed grains will contaminate the polishing plates. Some abrasives can also lodge themselves in the holes formed, and then work freely in the following phases. The regular microscopic examination of the section necessitates cleaning using alcohol and extra soft paper.

Never use acetone or carbon tetrachloride as it dilutes the resin and leaves a film on the sample surface.

Second phase

Intermediate polishing-grains of 3 to 4 microns about 15 minutes. Cloth type PAN-W.

Soft minerals

More chips, fewer scratches, locally polished zones.

Minerals of medium hardness

Same as above.

Hard minerals

Glossier surfaces, finer scratches.

These two phases are the most important and must be accomplished carefully with adequate lubrication.

Third phase

Fine polishing-grains of 1 micron for about 10 minutes. The pressure is the same as for the first phase.

Soft minerals

Uniformly fines scratchs, very small chips.

Minerals of medium hardness

Extremely fine scratches, more or less parallel, or no scratches at all.

Hard minerals

Without chip or scratch, very little relief; the polishing time may be prolonged.

It is important to be attentive in supervising and in the present process, after a few minutes a sample should be taken out. It should show a deposit of lubricant. With practice, it is possible to know by the noise of the machine when the disk becomes dry.

Thoroughly clean the samples ultrasonically or with a silk brush and liquid soap.

Fourth phase

Last polishing - Magnesia or alumina paste of 0,5 microns or less, without polishing pressure, using PAN-W cloths.

It can also be done on an ordinary polisher or by hand during few minutes. The minerals should not show any scratches or very few and no chips at all: the relief is not very evident. A cloth type «MOL» can be used, especially for soft minerals but it requires regular microscopic inspection as the relief becomes more important.

If, under microscopic observation, some parts of the surface appear irised, because the decompression of the lubricant in the mineral interstices, it must be carefully cleaned using alcohol and ultra soft paper.

CONCLUSION

A certain experience is required to acquire and master the polishing technique. Even now, there are minerals associations that cause some difficulties. In the same way, if other materials appear on the market, after profitable and probing experiments, their gradual incorporation is necessary.

In fact, a multiplicity of diversified operations must be limited as the time wasted can be enormous. It is preferable to limitate the number of changes.

This operating method is not limited. It has been noticed in the different laboratories visited that the outline remains applicable but there is a diversity concerning the detail, and especially in materials used.

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