Chair of Engineering Geology
Technische Universität München

The preparation of thin sections, polished sections, acetate foil prints, preparation for elutriation analysis, and staining tests for the optical and electron microscopy

An introduction by Günter Grundmann and Herbert Scholz

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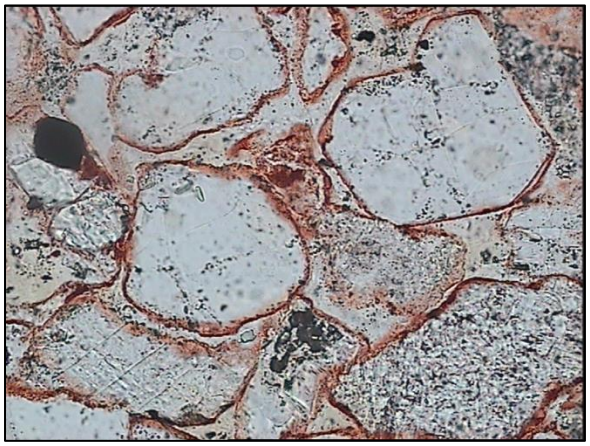
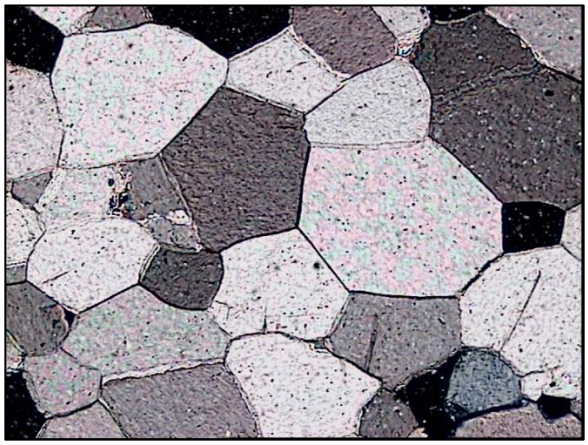
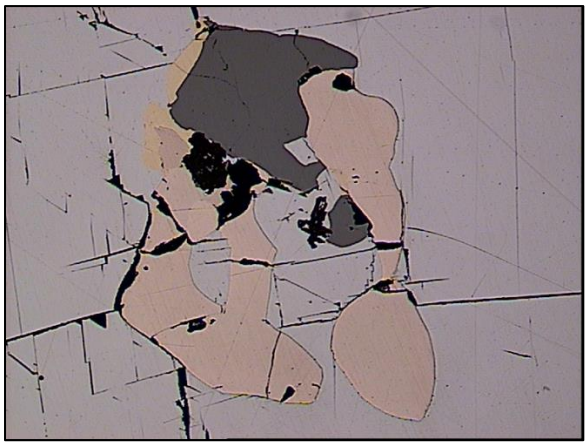


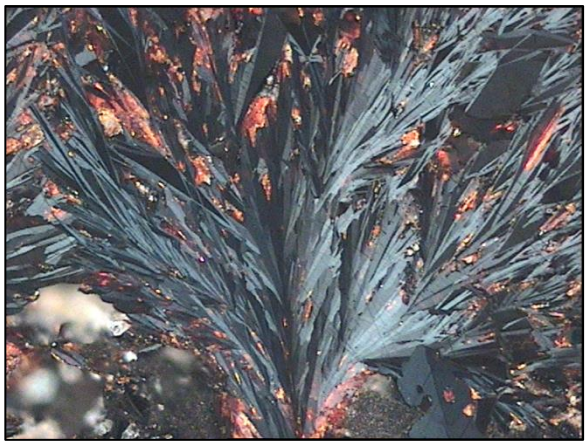
Red colored sandstone; thin section, 1 Polar.



Fine grained Marble; thin section, X Polars.



Galena, pyrrhotite; polished section, 1 Polar.



Lepidocrocite: polished section, X Polars.

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A) THIN- AND POLISHED SECTIONS OF ROCKS

1. Basics for the preparation of thin sections and polished thick sections

1.1 Structure of a petrographic thin section

The layered structure of a standard thin section for petrographic and ceramic purposes is illustrated in an enlarged schematic cross-section in Fig. 1.

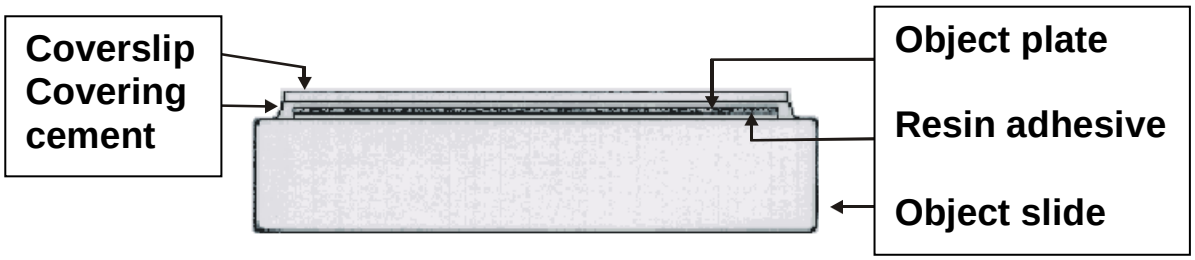


Fig. 1 The layered structure of a standard thin section

Coverslip
Requirements: dust free, dry. Plane-parallel, tolerance max. +/- 0.01 mm. Standard dimensions: 24 x 32 mm, from 0.16 to 0.18 mm thick.

Covering cement
Requirements: dust free. Completely transparent. Refractive index 1.54 preferred. Free of stress birefringence. When covering fluid, after covering solid, cover glass must not slip around. The cement must not turn yellow and become cloudy.

Object plate
(Rock, glass, ceramics etc.). Requirements: dust free, dry. Plane-parallel, tolerance max. +/- 0.01 mm). Free of outbreaks, fractures, deformations and scratches. Ground and lapped for polishing or covering.

Resin adhesive
Requirements: dust free. Completely transparent. Refractive index 1.54 preferred. Free of stress birefringence. Short solidification time. High grinding hardness and adhesiveness. Must have a low viscosity during processing in order to penetrate as deeply as possible into the pore space of the sample. Must not turn yellow and become cloudy.

Object slide
Requirements: dust free, dry, plane-parallel, tolerance max. +/- 0.01 mm ('Giessen' Format: 28 x 48 mm, 1.0 to 1.3 mm thick). Polished and slightly inclined edges. Caution risk of injury! Only the object surface to be grinded with 600 SiC suspension for better adhesion of the cement.

1.2 Selection of the object section and its three-dimensional position

When selecting the hand specimen in the field and when selecting the thin section after sawing of the material, it must be considered important that the selected section is representative of the studied region. Therefore, when sampling from inhomogeneous subareas

the selected field size must always be considered (mountain range, mountain, quarry, outcrop, partial profile, geological formation, rock, hand specimen section), the geographical spatial position of the sample (tectonic data as strike and dip, top-bottom determination, direction weathering etc.) and its structure (structure and texture, see below).

It needs no further explanation to the special importance of constant monitoring and evaluation of the objects with a magnifying glass, hand lenses and / or the stereo microscope from the beginning of investigations and between the individual work steps.

1.3 "Structure" and "texture" in petrological terms

Structure - petrological (English and French: ‘structure’; German: ‘Struktur’)

The structure (structura = fabric, derived from the Latin struere = to build) comprises

⇒ the outer shape of the grains
⇒ the particle shape
⇒ the relative and absolute grain size.

(Determining the conditions of formation: igneous rocks, slag - rapid cooling - small grains, slow cooling - big grains) Keywords: euhedral, subhedral, unhedral

Texture - petrological (Caution English and French: ‘structure’! German: ‘Textur’)

The texture (textus = pattern) is the three-dimensional arrangement and distribution of the components.

Here are three aspects to consider:

⇒ orientation of the components
⇒ the distribution of the components
⇒ the degree of space filling of the material

Concerning the orientation:
The random arrangement of the plate-like and sheet-like components (mica) in a granite: isotropy = no preferred direction.
The sub-parallel distribution of leaflet-shaped or columnar elements along the sedimentary bedding (stratification, embedded), or along the foliation plane in metamorphic shales and schists (German: ‘Schieferung’).

Concerning the distribution of the components:
The distribution of the constituents may be homogeneous or inhomogeneous because of the material or particle size changes in sediments (alternate bedding, inter laminate layers). Lamination banding and foliation in metamorphic rocks.

Concerning the degree of space filling of the material:
The space filling of a material is described by 'porous' (volcanic slag) or 'compact' (most metamorphic rocks). In magmatic rocks we speak of 'massive', if the texture appears directionless-grained to directionless-compact with an isotropic orientation and homogeneous distribution of the mineral components.

⇒ Conclusion:
When taking samples from geological outcrops or Cultural Heritage, the spatial orientation (cut position) of the preparation must necessarily be reproducible in terms of the locality. This requires an in-depth detailed mapping and documentation of the extraction point!

1.4 Pre-treatment of brittle specimens

Many materials show clefts, fissures, cracks, fractures and pore space, which must be completely sealed as much as possible before the sawing and grinding operations. While processing the material removal suppressed inevitably in these cavities of the preparation and the tools (saw blades, grinding discs, abrasive tools). One or two component resins such as 'Araldite D / HY 956' / Fa. CIBA and 'Technovit' / Fa. KULZER largely meet these requirements and strengthen the material permanently.

1.5 Resins for embedding: Requirements

The main features of an appropriate mounting resin are a
- low viscosity and a long open time prior to solidification,
- bubble-free solidification,
- high adhesion,
- sufficiently high grinding hardness

Cold mounting have the advantage that temperature-sensitive products are not affected and altered compared to systems with strong exothermic reactions. In preparations that are examined in Scanning Electron Microscopes, the embedding must be able to withstand the electron beam without deformations and other changes. Furthermore, no gas may escape under high vacuum from the embedding and mounting resin.
Some trade names of embedding media are given in section C.2 "Small sized equipment and articles of consumption" (page 24).

1.6 Sawing and cutting

For a well-equipped preparation lab four different types of rock sawing machines or equivalents are recommended:
1) Rock saw with jig and automatic support, water or petroleum-cooled for cutting depths between 15 and 20 cm, fitted with diamond saw blades between 40 - 50 cm ∅.
2) Rock saw for manual feeding with cutting depths up to 10 cm, fitted with diamond saw blades up to 25 cm ∅.
3) Rock saw for automatic support or manual support with parallel sliding arm for separating thin section blocks or fine saw cuttings. Cutting-depths of up to 5 cm, diamond saw blades up to 15 cm ∅.
4) Diamond wire saw for cutting rare materials, very small or very valuable objects that need to be cut extremely carefully and gently. Wire length 10 m. Cutting depth 6 cm. Support by hand, with gravity or electrically. Cutting widths from 0.1 to 0.35 mm.
   The right choice of the saw blade is crucial for a possible smooth and fast cutting. Hard, granular materials should be cut with bronze sinter diamond saw blades, soft materials should be cut by steel sintered diamond saw blades. There are saw blades closed, or open, or with slotted cutting edges. These types of saw blades have a relatively short life, but

guarantee a careful cutting. A slightly coarser blade, but much cheaper is a soft steel discs, in which the diamond grit is pressed on the outer cutting edge mechanically in notches. Medium-sized specimens should be cut by hand, and contrary to many companies-recommendations one should avoid complicated and expensive jigs or automated supports.

1.7 Coarse grinding, fine grinding and lapping

In order to better understand the surface treatment of various materials, the processes and problems of grinding processing need some explanation, in particular those of heterogeneous rocks, ores and construction materials. In cross sections of materials with extremely different hardness (metals, graphite, talc intergrowth with extremely hard or cleaving substances, quartz, mica) polished surfaces with minimum relief are required. In this case, one should apply the "rolling grinding" or "lapping" method in water and /or oil soluble suspension, a particularly gentle and precise method (see below).

1.7.1 Sample cleaning between the individual steps

In addition to the details of grinding, fine grinding and polishing, we need to discuss the absolutely necessary cleaning of the sample when changing from coarser to finer abrasives. Compared to the mechanical cleaning the by far the best results achieve today the indispensable ultrasonic cleaning equipment with an efficiency of around 99%. These are stainless steel tanks, which are equipped on its underside with sounders. The sounders staggered suitable liquids (water, etc.) in the tank in ultrasonic vibrations, which spontaneously produce tiny vibrating bubbles. These act as countless microscopic brushes in micro seconds and penetrate even the farthest corners of open pores or cracks of a sample. All loosely adhering particles such as abrasives and possibly loose material of the sample can be reliably removed.
Attention! Health!
The sample must not be immersed with fingers but only with a clamp or gripper in the ultrasonic bath, because the ultrasonic waves may cause injury in your hands!

1.7.2 Coarse grinding and fine grinding (I): The ‘rolling’ grinding process

Fragments are removed from the work piece surface during grinding, which should receive a high surface quality and high dimensional and geometrical accuracy. We distinguish the ‘rolling’ grinding process and the ‘cutting’ grinding process.

During the rolling grinding process loose, unbound abrasive are moving between the tool (grinding pad) and the specimen (preparation) under greater or lesser pressure with constant changes of direction. The loose rolling grains provide a scratch-free and velvety touch surface. The abrasive can be used dry or in a liquid as a lubricant in loose grain. A disadvantage of the rolling grinding is that finest fractures occur at depth especially in brittle materials, which only become visible in the finished cut. This could mislead to the conclusion that there was here a naturally disturbed structure.

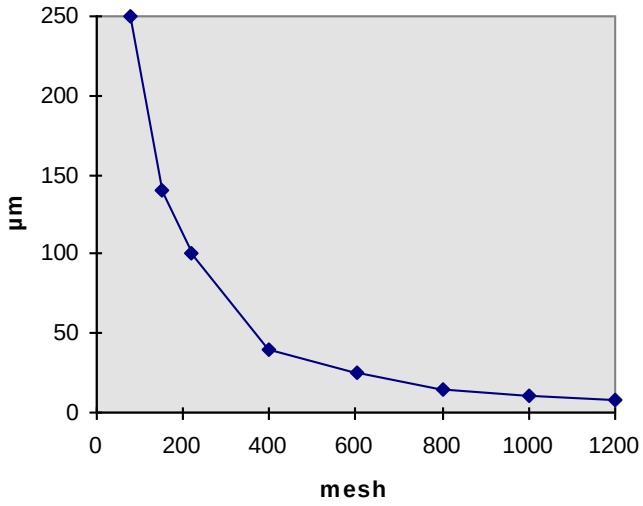
1.7.3 Grinding suspension: lubricants and abrasives

Lubricant and abrasive together form the grinding suspension.

Depending on the nature of the specimen water, petroleum, paraffin oil or special alcohol-based liquids are used as a lubricant.

1.7.4 Abrasives: grain size - "mesh" and "µm"

Proven abrasives are corundum (Al_2O_3), silicon carbide (SiC), boron carbide (BC) and diamond (C) with fine to very fine grain sizes.
In practice, there are generally two different specifications for the grain size of abrasives:
1) indication of the particle size in 'mesh' with steps in ten or hundred or thousand, for example, 80 grain, 220-grain, 1.000 grain, etc. These figures indicate the number of mesh per unit area (square centimeter) of a sieve through which the particle size fraction was classified. This means that with increasing "mesh" number, the grain size becomes smaller.
2) Indication of the particle size in microns = µm micron = 10,000 angstroms. Decisive is the mean grain diameter of the abrasive in microns.



MM	mesh	µm
1500	150	100 - 140
1800	180	80 - 110
2400	240	30 - 70
3200	350	25 - 50
3600	400	30 - 40
4000	600	20 - 30
	800	10 - 15
6000	1000	8 - 12
8000	1200	5 - 10
12000	1400	2 - 6

Fig. 2 Graphic and table show the number of mesh versus particle size in µm (microns). The column "MM" indicates the reference numbers of the type designation "Micro-Mesh".

1.7.5 Lapping

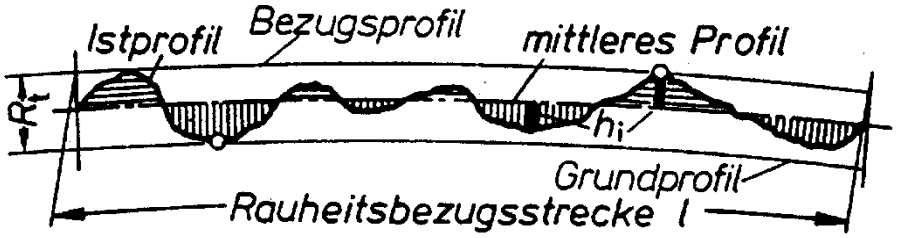
The rolling grinding process of metallic materials is referred to as 'lapping'.

The tools in use are plane discs or plates made of cast iron, cast steel or glass. Lapping can be carried out both manually and with lapping machines. When lapping the dimensional and form accuracies have to be standard to 1 µm and roughness (see explanation below) of less than 0.1 to achieve µm. By lapping the inevitable resulting in intersecting loops of soft skin in the ore petrography Bailby the layer (explained below) is removed. When lapping abrasive and lubricant be applied by a pump on the lapping plate. The suspension has to be constantly stirred to ensure a homogenous uniform viscosity.

1.7.6 Roughness, depth of roughness

The chip removing process produces surfaces composed of grooves, ribs, scales and crests, depending on the pattern (structure, texture) of the sample. The size of the roughness is

usually given by the lowest depth of roughness. The shape deviations from an ideal flat surface can be used as so-called actual profile between a base profile and a reference profile (see Fig. 3). With each subsequent refinement of the previous surface and the previous grit the surface roughness must be completely removed twice. This ensures that the deep-reaching destruction of the previous grinding process are fully captured and eliminated.



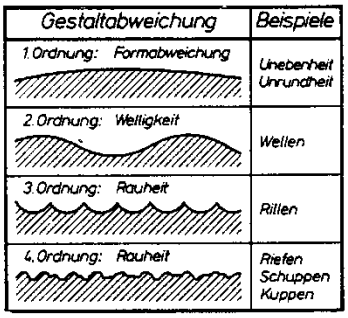


Bild 177/1: Gestaltabweichungen von Oberflächen (Profilschnitte überhöht dargestellt)

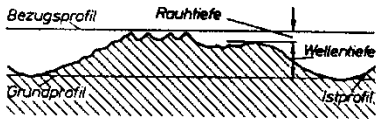


Bild 177/2: Gestaltabweichungen einer ebenen Fläche (überhöht gezeichnet)

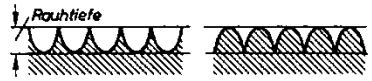


Bild 177/3: Oberflächenprofile gleicher Rauhtiefe, aber verschiedener Tragfähigkeit

3.3.15.2 Welligkeit

Die Welligkeit (Bild 177/1) einer bearbeiteten Fläche kann z. B. durch unrunden Lauf eines Fräsers oder einer Schleifscheibe, ferner durch Schwingungen der Werkzeugmaschine oder des Werkzeuges verursacht werden.

3.3.15.3 Rauheit

Die Rauheit (Bild 177/1) setzt sich bei spanend bearbeiteten Flächen aus Rillen, Riefen, Schuppen und Kuppen und schließlich auch aus der Gefügestruktur (Gefügeaufbau) des Werkstoffs zusammen. Rillen entstehen durch die Form der Werkzeugschneide und außerdem auch durch den Vorschub und die Zustellung des Werkzeugs. Riefen entstehen bei der Spanbildung, da sich der Werkstoff nie vollkommen glatt abtrennen läßt.

Schuppen und Kuppen entstehen beim Strahlen, z. B. Sandstrahlen. Auf den Gefügeaufbau der Werkstückoberfläche können chemische Einflüsse, z. B. Beizen oder Korrosion, einwirken. Meist überlagern sich verschiedene Gestaltabweichungen **(Bild 177/2)**.

Die Rauheit einer Fläche läßt sich bei geschruppten Teilen schon mit bloßem Auge erkennen. Aber auch feiner bearbeitete, glänzende Flächen sind nie ganz glatt. Die Rauheit wird mit Sondermeßgeräten gemessen. Wenn bei einer Spielpassung die Paßfläche eine Rauhigkeit besitzt, die sich aus steilen Spitzen zusammensetzt **(Bild 177/3)**, so nützen sich diese Unebenheiten um so schneller ab, je größer die Rauhtiefe und die Lücken zwischen den Spitzen sind. Dadurch wird das ursprüngliche Spiel entsprechend vergrößert. Andererseits wird eine Preßpassung um so weniger fest, je mehr Werkstoff beim Ineinanderpressen der Teile in die Lücken ausweichen kann.

Fig. 3 Graphical presentation and definition of roughness and depth of roughness.
(from: Technical qualifications for metalworking professions, G. Würtemberger, 1976, Edition 41th, Verlag Europa-Lehrmittel)

1.7.7 Coarse grinding and fine grinding (II): The ‘cutting’ grinding process

During the use of the cutting and grinding process the abrasives are sitting firmly anchored in an abrasive (massive abrasives, see below) and cut or tear out of the specimen chips or irregularly shaped fragments. During the grinding process naturally abrasive grains are torn out of the grinding tool, too. If the contact pressure is too strong, brittle material can be broken like a mosaic of individual grains in particular in thin section preparation.

Natural abrasives are: quartz, corundum (smirgel), garnet and diamond.

Artificial abrasives are: synthetic corundum, silicon carbide and boron carbide.
Synthetic corundum is produced in an electric furnace at about 2000°C from bauxite (a mixture of aluminum hydroxides) and purified clay. Silicon carbide is produced in the electric furnace with a mixture of quartz sand and anthracite coal. There are in this case the so-called gray and green grades to distinguish.

Fixed abrasives are tools (bronze - or steel discs, abrasive papers, etc.) consisting of an abrasive and a binder. The grains of the abrasive are generally irregularly shaped. For each abrasive applies: The more uniform and rounded grain shape, the higher the quality of the ground surface. Extremely needle-shaped grains prove to be particularly harmful because they can get stuck in cracks or pores in the sample, can cause breakouts or even deep-seated scratches. As fixed abrasives natural and artificial materials are used.

1.7.8 Fixed abrasives: hardness, texture and sharpen of grinding discs

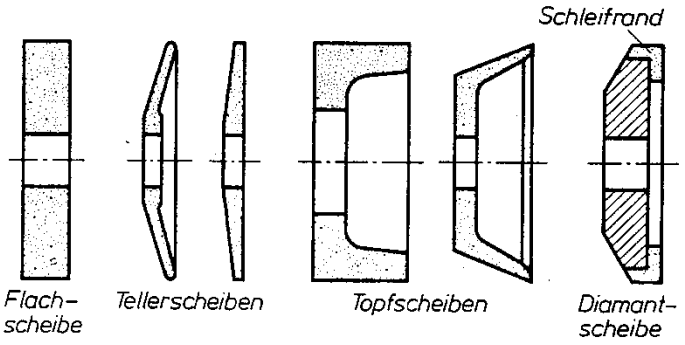


Fig. 4 Forms of grinding discs. (from: Technical qualifications for metalworking professions, G. Würtemberger, 1976, Edition 41th, Verlag Europa-Lehrmittel).

Under the hardness of solid grinding wheels we do not understand the hardness of the individual abrasive grain, but the strength with which the abrasive grains are held in place by the binding. The pressure during pressing of the grinding wheel affects their hardness. There are seven degrees of hardness to distinguish between extremely soft to extremely hard.
The structure of the fixed grinding wheels describes the size of the pores between the individual abrasive grains (Fig. 5). The nature of the structure is referred to with the numbers 0 to 14. The structure is so porous, the greater the number. In discs with an open, i.e., porous structure, the grinding chips do not stick as firmly as in those with dense structure. Open grinding wheels stick slightly and remain long usable long, but wear out relatively quickly. Solid grinding wheels wear out more slowly.

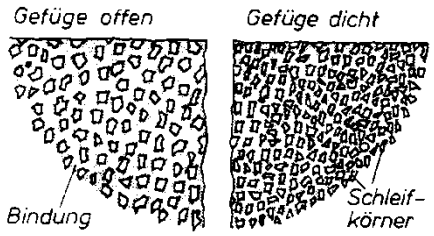


Fig. 5 Structure of grinding wheels.
Left: 'Gefüge offen' = open structure.
'Bindemittel' = binding agent
Right: 'Gefüge dicht' = closed structure.
(from: G. Würtemberger, 1976, Edition 41th, Verlag Europa-Lehrmittel).

The **sharpening of a grinding disc** is the removal of dull and / or striking surfaces with an appropriate sharpening rod. It has the purpose to achieve a precise concentricity or a flat surface, also to remove the contaminated layer to break the dull abrasive grains out and expose sharp grains. This also reduces the frictional heat during grinding.
⇒ Conclusion:
With coarse abrasive grains, the cuts and disruptions of the structure are much more intense than with fine abrasives. With increasing contact pressure, the degree of destruction is increasing. Hard bound, scratching or cutting abrasive grains cause deeper cuts and cracks in the substrate as unbound, rolling abrasive grains.

1.7.9 Recommendations for grinding of various materials

⇒ medium to fine grained sulfidic ores can be processed on grinding wheels with permanently bonded abrasives (sand paper, emery cloth, diamond sintered metal discs). Grain sizes coarser than 200 mesh to be avoided.
⇒ Metals and other tough materials should only be processed with rolling loops ("lapping"). Fixed grain bond grinding wheels smudge quickly by metal chips and become dull. The energy and sharpness of abrasive grains is greatly reduced by chewy chips, because the surface bonded quickly. In this case the specimen slips slightly on the dull surface.
⇒ In particular, brittle materials with good cleavage (eg, mica, calcite, galena) should be ground very gently with only mild pressure. If necessary, oversized pores or scratches after ultrasonic cleaning must be impregnated with mounting resin again.
⇒ Materials with a loose particle association of all grain sizes (earthy, sandy substances) should only be processed by rolling grinding with relatively fine-grained abrasives. Here, the cut surface should be impregnated as deep-reaching as possible prior to grinding.
⇒ particular hard and tough materials should be handled with additional grinding steps and lower grading of abrasive grains. An increase of the contact pressure in this case causes not necessarily an acceleration of the grinding progress.

With decreasing particle size the fine grinding process passes into the polishing. Abrasive grain above the 1200 mash or below 10 μm grain diameter are referred to as a polishing agent. Surfaces that are processed with even finer grains at rolling grinding process remain dull and velvety. A polish will not be generated. Rather often, the specimen is fixed on the surface due to the strong adhesion. A gentle further processing is extremely difficult or even impossible. For any further polishing steps therefore specially developed polishing wheels have to be used.

1.8 Polishing

This procedure connects the rolling precision grinding or lapping of the 1200 mash grain size and causes highly lustrous and reflective surfaces. The rule is: A good polish can be achieved with grain sizes less than 10 μm.
The necessary polishing steps are listed further below. The dimensional and geometrical accuracy is not improved. Instead, when using soft polishing wheels the relief on the surface of the sample develops significantly, with relative differences in hardness to be increased.

1.8.1 Cleaning the sample between the individual polishing steps

Very thorough cleaning of the sample will be discussed when changing from coarser to finer

abrasives. By far the best results in the mechanical cleaning achieve today the indispensable ultrasonic cleaning equipment with a cleaning effect of approximately 99%. This is a stainless steel tanks, which is equipped on its underside with sounders. The sounders staggered suitable liquids (water, etc.) in the tank in ultrasonic vibrations, which spontaneously produce tiny vibrating bubbles. These act as countless microscopic brushes in micro seconds and penetrate even the farthest corners of open pores or cracks of a sample. All loosely adhering particles such as abrasives and possibly loose material of the sample can be reliably removed.
Attention! Health!
The sample must not be immersed with fingers but only with a clamp or gripper in the ultrasonic bath, because the ultrasonic waves may cause injury in your hands!

1.8.2 Polishing: 'soft skin' deformation effect, 'Beilby-skin'

During polishing of very soft crystals or semi- and non-metals the surface layer is usually coated by the so-called 'Beilby' soft skin. Because of the cold deformation, this layer accesses significantly into the interior of the material depending on the material and polishing method. Crystalline substances are significantly affected by the following processes:
⇒ decrease in grain size
⇒ formation of lattice sliding
⇒ generating pressure twins
⇒ preferred orientation of grains
⇒ phase transformations
The solidification and hardening of the surface layer increases, their deformability decreases. Therefore the once formed Beilby-skin cannot be removed despite repeated polishing steps. The formation of the soft skin or Beilby-skin is confirmed by various studies (by Sir George Beilby):

⇒ Microscopic inspection of the polishing progress (cutting furrows and old scratches be smeared during subsequently fine-grained polishing steps).
⇒ Structural etching makes visible that the substances of cutting grooves and old scratches are easier to be solved and removed, as the non-deformed material.
⇒ Absorption behavior on polished surfaces: A polished marble surface in contrast to an etched surface can adsorb iodine from passing iodine vapors.
⇒ Decreased reflectivity of polished surfaces compared to cleavage planes. The reflectivity of a polished cleavage plane is always lower compared with a freshly produced cleavage plane (of stibnite, Sb_2S_3 to about 10%). The thicker the Bailby-skin, the lower is the reflectivity. The thickest Beilby-skins are found on metals, medium on sulfides and lowest on oxides.

1.8.3 Polishing suspensions: lubricants and polishing compounds, particle size and particle shape

The mixture of lubricant and polishing agent forms the polishing suspension. Depending on the nature of the specimen common lubricants are water, petroleum, paraffin oil or special alcohol-based liquids. Classic polishing agents are "Polishing red" (iron oxide, hematite), chromium oxide, aluminum trioxide and magnesium oxide. More recently, polishing agents like diamond and cerium oxide have largely prevailed in connection with metal disks or chemo textiles as a polishing agent carrier. For microprobe preparations only diamond should be used in principle. Using other polishing agents the preparation may be contaminated with incalculable minor and trace elements.

Polishing agent of mean particle size larger than 1 μm, is referred to as 'coarsely disperse',
between 1/10th and 1/100th of a μm (≡ 100-1000 Å) as 'colloidal disperse',
and less than 1/1000th of a μm (≡ 10 Å) is referred to as 'molecular disperse'.

During the use of coarser grain sizes of polishing agent from 10 to 1 μm the tear and cutting processes dominate. There occur significant scratches and cutting furrows. No scratches or tearing or cutting furrows occur when using finer grain sizes down to colloidal polishing agents. Irregularities such as pores or old grinding scratches caused by the previous coarser abrasives are smeared. Directly on the surface deformations occur, which result in no more material removal, but cause only smearing, compressing and squeezing the top grain layers below about 5 μm grain. The final polishing is complete when the surface is scratch-free and showing the highest reflectance data.

1.8.4 Polishing discs: chemo-textiles ("Kent", GB / Hartfelt & Co., DK)

For polishing more or less elastic discs of felt, leather, wood or special chemo-textiles are used, as well as metal discs such as copper or lead-tin-antimony alloys. Suitable polishing agents and lubricants are prepared depending on the system on the surfaces of these polishing discs. In exceptional cases, it can also be polished dry. Water-soluble lubricants or oil-soluble liquids are used as needed. A mixture of lubricants and polishing agent gives a polishing suspension.

Polishing wheels consisting of chemo-textile can be glued on to commercial carrier discs (cast iron, aluminum or plastic). This type of a chemo-textile polishing pad, for example, consisting of Perlon, shows a wide-meshed network of filaments that form countless loops and turns in particular on the surface. With the application of the polishing suspension small parts of the polishing agent are bound in grooves of the fibers and act as cutting grains. The bulk of the suspension is pressed into the depths of the chemo-textile. Only the top level of the polishing pad is now directly involved in the polishing process. The fibers of the chemo-textile are "hardened", and the sharp loops of the fibers ongoing polish the sample surface. Decreases the sharpness of the top active areas of the polishing pad, it must be added continuously the polishing compound. In the case of opaque materials, the removal of material is noticeable on the white polishing wheel as spotty distributed film of black dirt. Depending on the hardness of the samples, the polishing pad is worn out after 20 to 30 hours of operation and should be replaced with a new one. The main advantage of this method lies in the ease of use even for inexperienced as well as the low cost of the equipment and consumables.

Examples of commercial names of polishing discs consisting of chemo-textiles:

Company: Ernst Winter & Sohn, Hamburg, D: "Winter Pellon Disc"
Company: Joisten & Kettenbaum, Bergisch-Gladbach, D: "PAN-W-Pellon chemo-textile"
Company: Heraeus / Kulzer GmbH, Wehrheim: "New Lam formula"
Company: Hartfelt & Co., Allerod, Denmark

1.8.5 Polishing hardness, relief, 'KALBSCHE' light-line

Samples that were polished on chemo-textiles show always at the grain boundaries of different hardness a clear relief with higher and deeper surfaces, which are due to the resiliently yielding system of polishing discs. The soft material is more eroded and / or

compressed to form depressions. The hard components form protruding steps or plateaus. This relief has proven to be advantageous because hereby, directly at the grain boundaries, the relative polishing hardness are to be determined in polished sections, similar to the determination of refraction differences in thin sections (BECKE-line of light. When focusing the polished surface in reflected light microscope the so called 'KALBSCHE' light line is visible at the grain boundary of two phases of different hardness. To increase the contrast, the aperture has to be partially drawn. Here applies the 'Two-H-rule'. When lifting the stage the KALBSCHE-line moves into the harder grain.
A strong polishing relief especially in the study of grain boundaries affects negative, since not only the depth of field is affected, but secondly, the nature of the grain boundaries can be distorted by deformation.

1.8.6 The 'REHWALD - VANDERWILT' grinding and polishing method

The highest possible surface quality of polished sections can only be achieved with the special method developed by JW VANDERWILT in 1928 (FREUND, 1966). It is by far superior to any other method. The special qualities of the thin or polished sections made by this method can be identified by the following characteristics:

⇒ extremely low relief differences even with greatest hardness differences
⇒ tiny inclusions are properly recognized and analyzed;
⇒ the grain boundaries are absolutely sharp;
⇒ most components are absolutely flat polished and free of scratches;
⇒ cold deformation on the surface (soft skins, Beilby Layer)) can be largely avoided.
⇒ The polished surfaces (micro hardness, reflectivity) are ideally suited for all test methods.

This polishing method is described in detail in the book 'Applied Ore Microscopy - Theory and Technique' edited by HUGO FREUND (1966). Despite the convincing advantages of this method and the superior quality of the polished sections there are also a few disadvantages:

⇒ the costs of the equipment are extremely high with a price of around EUR 80,000 .--.
⇒ The polishing process makes often serious problems: repeated sudden destruction of the surface of the polishing wheels and cuts during polishing. In this case, mostly the soft metal (alloy of lead, antimony) pushed into cracks and pores of the preparation.
⇒ Therefore, this polishing method is not suitable for products where uranium / lead isotope analysis to be made, or Pb-content to be measured (Pb-Sb-contamination!).

1.8.7 Re-polishing

Polished surfaces of many materials become contaminated over time with dust particles, gases and liquids of air to form tarnish and crusts. Further sets with light-sensitive substances (eg. silver-containing compounds, arsenic sulphides) when exposed to light, the so-called light etching, and can result in complete decomposition. Accordingly polished sections must be protected against dust and light, and be polished before each microscopic examination. A simple polishing pad lying on a solid basis is sufficient. As a polishing suspension of aluminum trioxide or magnesium oxide in combination with water are proven many times. Layers of carbon or gold, which were deposited on sections for electron microscopy, have to be removed with the last two to three polishing steps (pre-polishing, fine polishing, final polishing - see above). The final polishing alone is not enough in most cases.

2a. Basic steps for producing a petrographic thin section

1) Oriented cutting of an approximately 1 cm thick slice from the hand specimen.
(Attention Health: safety glasses and hearing protection required)

2) The thin section cut must be marked (for example 28 x 48 mm) including the focus on one of the two cutting surfaces (front or back) of the specimen.

3) Formatting the sample. Brittle samples must be at least 1 cm thick.
If necessary, three-dimensional orientation accordingly to the field data should be added.

4) Marking on the back of the specimen with the sample number (waterproof pencil).

5) Ultrasonic cleaning of the sample to remove the dirt material from the sawing pores and fractures of the sample.

6) Embedding or impregnating brittle material. Overhanging mounting resin to be removed.

7) First coarse surface grinding of the cut specimen (minimum grain size 200 SiC powder, or sandpaper. Ultrasonic cleaning of the sample to remove the material dirt and the abrasive from the pores and fractures of the sample.

8) Lapping the surface in steps of 400, 600 and 800 SiC abrasive powder. Complete removal of the surface roughness and the cracks of the previous grinding step. Ultrasonic cleaning of the sample after each change of the grain size, to remove the loose dirt of the material and the abrasive from pores and fractures.

9) Specimen surface to be mounted on a satin finished object-slide (ground with 600 SiC on one side only) have to be grease- oil- and dust-free. The distance between the slide and the specimen must be parallel and minimized.

10) Scoring the sample number on the crystal-clear bottom at one corner of the object-slide with a diamond pen.

11) Cutting off the specimen depending on the material to a thickness of 0.5 to 1 mm, depending on the sensitivity of the material. The cut has to be plane-parallel, vibration-free using a torsion-fine diamond saw blade.

12) Removing the thick section in steps, machine or by hand to a minimum of 0.1 mm. Ultrasonic cleaning of the sample to remove the material dirt and the abrasive from the pores and fractures of the sample after each change of the grain size.

13) Final grinding gently and uniformly by hand down to a thickness of minimal 0.03 to 0.02 mm with 800 SiC. Constant checking of the thickness due to the interference colors of quartz and /or feldspar (if present) down to the white and gray of the first order.

14) Covering the cut surface with a thermoplastic resin and a microscopic coverslip glass specially made for petrographic thin sections.

15) Removing the excess resin. Clean with acetone or alcohol under the fume hood.

16) Self-adhesive labels attach to either side of the coverslip glass.

17) Final labeling of the thin section preparation.

2b. Differences in the production of paleontological carbonate and sandstone thin sections

The production of thin sections and their evaluation especially from the paleontological and / or sedimentological viewpoints, differs in some crucial points from the production of petrographic thin sections as follows:

The standard size of petrographic thin sections (28 x 48 mm) is for the determination of organisms remains often too small, as you need for the identification of foraminifera as many different cutting positions as possible. Therefore serve 50 x 50 mm large slides as the standard format. Sometimes it will even be necessary, such as in the study of reef rocks to produce even larger thin sections.
The thickness (0.02 to 0.03 mm) of a standard petrographic thin section proves in the determination of residues of organisms and sedimentary structures often to thin due to the lack of contrast. Often thin sections of carbonates with thicknesses 0.05 mm are already thin enough to detect all the details and show also even sufficient contrast. Since it is often not necessary to determine the mineral species in thin sections of carbonates, it is also not necessary to maintain a standard thickness. It is the untold rule that a thin section of carbonate is ready when it is sufficiently rich in contrast in the overview, and you still see all the details well, which you want to detect. The ideal thickness depends strongly on the contained fossils and of the enlargements that are needed at their determination. Are, for example, corallinaceae or calpionellides detectable in thin section area, the ground thickness must be less than for bryozoans or crinoidea.
Even with the choice of adhesives and mounting resins one has significantly more choices than in the production of standard petrographic thin sections. Since it does not require adhesives and mounting resins with standardized refractive indices, cheaper and easier to process materials may be used. Cheap polyester resins are proven to be useful as an adhesive.
Considering these differences follow steps 1 to 17 as the standard thin section.

3. Basic steps for producing a polished thin section.

Steps 1 to 12 as performing a standard thin section.

13) Fine grinding by hand with 800 SiC gently and uniformly down to 0.04 mm thickness. Constantly checking the interference colors as the light yellow of the 1st order of quartz / feldspar is reached corresponding to a thickness of 0.04 mm.

14) Fine grinding down to the mesh numbers 1000 and 1200 SiC minimum 0.03 mm thickness. The ground surface must be planar.

15) Pre-polishing with diamond 6 μm (removing the roughness of the 1200 mesh abrasive).

16) Pre-polishing with diamond 3 μm (completely removing the remaining rawness of the 1200 mesh abrasive and removing the remaining scratches of the 6 μm diamond medium).

17) Fine polishing with diamond compound 1 μm (removing the residual scratches of the 6 μm and 3 μm diamond compound).

18) Final polishing with diamond compound 1/10 μm or other polishing media (removal of fine scratches of the 1 μm diamond compound).

19) Removing the excess resin. Clean with acetone or alcohol under the fume hood.

4. Basic steps for producing a polished thick section.

1) Oriented cutting of the hand specimen. (Health Warning: Wear safety glasses and hearing protection)

2) Select the desired section (15 x 15 mm), including orientation on one of the section surfaces.

3) Prepare the annular molds made of aluminum, brass or polyethylene. If necessary, grinding of the contact surface of the ring. Surfaces of the mold and the planar surface of the subjacent slide that come in contact with the mounting resin has to be sealed with a special release agent.

4) Inserting the sample into the mold. Filling the mold with resin together with sample. Remove any air bubbles with a needle.

5) Formatting of the hardened resin, if necessary grinding and polishing the surface and the back side parallel and carving the sample number. If necessary, polishing the back side, when translucent or transparent objects such as glasses or crystals should be viewed in transmitted light.

6) Manually lapping of the sample surface in steps of 400, 600, 800, 1000 and 1200 SiC abrasive powder, or machine made with 400, 800 and 1200 SiC. Complete removal of the surface roughness and the cracks of the previous grinding step. Ultrasonic cleaning of the sample to remove the material dirt and the abrasive from pores and fractures of the sample after each change of the grain size. If necessary, re-opened outbreaks, pores or fissures to be sealed again with resin.

7) Pre-polishing with diamond ccompound 6 μm (removing the roughness of the 1200s abrasive or removing coarser scretches; possibly repeat fine grrinding with 1200 SiC).

8) Pre-polishing with diamond compound 3 μm (removing the roughness of the 1200s abrasive and reducing and removing the remaining coarser scratches).

9) Fine polishing with diamond compound 1 μm (removing the residual scratches of the diamond compounds 6 and 3 μm).

10) Final polishing with diamond compound 1/10 μm or other polishing media (removal of fine scratches from the 1 μm diamond ccompound).

5. Basic steps for producing polished hand samples and foil prints

The question of whether, a thin section should be made from a rock sample or not is generally only then to decide if you cut a hand sample, grind it and look over with a stereomicroscope. Although grinded and polished rock surfaces already show many details, a thin section is of course still much more meaningful. On the other hand, the production of thin sections is very time consuming, especially when it comes to large formats. Applied to carbonate rocks the so-called peeling can be an alternative, especially if you want to work with high magnifications not needing the determination of microfossils, but rather want to study sedimentary structures. Easily and with relatively little time to produce peels of rock surfaces from DIN A6 to DIN A4 format that can be even studied under the microscope at low magnifications. The peels surprisingly reproduce even with Alizarin S stained calcite surfaces (see below!). Prerequisite for the production of a peel from carbonate rock is a finely ground but not polished cut surface. For the preparation of an acetate peel the following equipment are required:

a) about 1-3 liters of 1: 10 to 1: 100 diluted concentrated acetic acid or 1: 50 diluted hydrochloric acid conc. (37%)

b) in acetone-soluble films (for example, acetate films, 0.08-0.12 mm thick, or any other film that is dissoluble by acetone;

c) about 100 cc of acetone.

Necessary steps for the production of an acetate film have been described generally already above (under 2a):

1. Oriented cutting the hand sample. Establishing a possible large and smooth cut surface; Excision of approximately 1 to 2 cm thick slice (Caution health protection: Wear safety glasses and hearing protection).

2. Label the sections with pencil, ink or waterproof markers (Caution: Acetone dissolves to certain inks, or making them unrecognizable).

3. Ultrasonic cleaning of the sample to remove the material of the sawing out of the pores and fractures of the sample.

4. First coarse grinding of the cut surface with 220 or 320 SiC powder, sandpaper etc. Ultrasonic cleaning of the sample to remove the material removal and the abrasive from the pores and fractures of the sample.

5. Lapping the surface in steps of 400, 600 and 800, possibly with 1000 SiC abrasive powder. Complete removal of the surface roughness and the cracks of the previous grinding step. Ultrasonic cleaning of the sample to remove the material dirt and the abrasive from pores and fractures of the sample after each change of the grain size.
   Of course you can at this point also decide not to create a peel, but polishing instead. In this case continue grinding the surface with 1200 SiC powder, then polish on a felt pad). If you really want to make an acetate peel, continue by 6.

6. Keep the finely ground rock surface grease-free and dust-free. The surface of the rock

sample directed upwards is placed in an acid bath, so that the specimen is at least 1 cm above the acid surface. It is important to ensure that the ground surface of the sample is absolutely horizontal (possibly wooden blocks or bricks are laid). Mainly dilute acetic or highly diluted hydrochloric acid are suitable (see below).

7. The pieces are etched until the color contrast on the ground face noticeably increases. It is important to ensure that the gas bubbles do not start moving the slope of the ground face upwards, following the side to hike (optionally surface straighten). With multiple cautious dousing with water remove the bubbles. The following acid concentrations and etching times have proved effective: 1-3 minutes at 1: 10 diluted conc. Acetic acid, for 1 hour at 1: 100 dilute acetic acid conc. and 1-5 minutes at 1: 50-diluted hydrochloric acid conc. In fact, every rock requires other acid concentrations and other etching times. You just have to try to deliver the best results which acid concentrations and which etching times.

8. Then, you insert the sample gently 1/2 hour in water to remove residual acid. If the carbonate rock sample in the following should be stained, use desalinated water.

9. Thorough drying of the sample. Caution: Do not touch the finger at the etched surface, do not wipe it! After drying the sample the structures are often much easier to recognize than on rough-polished surfaces. In many cases, the piece does not need further treatment.

10. The piece is again laid perfectly horizontal with the ground face upwards (works best in a bed of sand). Then, carefully and abundant acetone poured onto the surface until the liquid is about 1 mm in height on the ground face (health: use acetone only after deduction!) Create
11. Put the peel at one edge of the ground surface and press down firmly with a squeegee progressively in one direction so that the excess liquid is squeezed out laterally. Then push the peel with a cloth onto the sample surface and rub firmly.

12. It is to try whether you can pull off the peel shortly after the press down or it needs to dry for at least 10 minutes. The peeled films can be immediately examined microscopically or stained. It is advisable to keep them after drying between sheets of glass for protection.

6. Selective staining methods for thin sections, polished samples and foil prints

To determine the amount and / or the spatial distribution of certain mineral phases in grinded hand samples, thin sections and grain preparations selective staining methods are suitable. Using these methods, certain carbonates, sulfates or feldspars can be detected on a cut surface of the sample. For the procedure for carbonates see MANN (1955) and SCHNITZER (1958), for sulfates see FRIEDMANN (1954) for feldspars see BAILEY (1960). In the following the recipe for the staining of feldspars and carbonates, is described:

6.1 The distinction between alkali feldspar and plagioclase (Method by BAILEY, 1960)

Reagents:

-- 48% hydrofluoric acid (HF) (Note: Extremely corrosive! Note Rules!
-- (Goggles, gloves, gowns, laboratory fume hood!)
-- 5% $BaCl_2$ solution

-- sodium cobalt nitrite solution saturated
-- Potassium rhodizonat solution (solution is stable only limited, prepare freshly).

Procedure:

1) 0.05 grams Potassium-rhodizonat dissolve in 20 ml distilled water.

2) Under the hood is an unassailable vessel with 48% HF filled.

3) The product / mineral / rock is placed with the sharpened side in the vessel.

4) Cover the container with a plastic lid and leave it for 3 minutes.

5) Object rinse with distilled water and briefly dip 2 times into the $BaCl_2$ solution.

6) Object rinse well with distilled water and dip for 1 minute into the Na-Co-nitrite solution.

7) Object carefully rinse in distilled water, without touching the surface. The alkali feldspar should appear golden yellow. If not, then the etched locations rubbed with distilled water repeate the operation at point (3) again.

8) Object rinse again with distilled water and cover it with the Potassium rhodizinat solution.

9) If the red of the plagioclase is sufficiently intense, again rinse with distilled water. The alkali feldspar should now be golden yellow, the plagioclase should be red.

6.2 Staining of calcite with Alizarin-Red S (method by SCHNITZER, 1958)

Reagents:

1% hydrochloric acid
(Note: slightly corrosive! Observe regulations! Gloves, goggles, hood, coat!)
Alizarin-S powder

Procedure:

1) Dissolve 1 g of alizarin red S in 1000 ml of 1% hydrochloric acid.

2) Cut surface of the sample with 800 SiC powder. Grind planar surface and clean.

3) Preparation of the surface for about 1 minute in the staining solution and swirl gently so any air bubbles are removed.

4) Surface thoroughly Rinse with a mild beam of distilled water. Avoid any surface damage, since after a light touch, the wafer-thin layer of paint could flake off partially.

5) Allow surface to dry.

6.3 Staining of dolomite with p-Nitrobenzolazoresorcin (method by MANN, 1955)

Reagents:

7% hydrochloric acid (Note: use gloves, hood, goggles, gowns)
2 normal NaOH
p-Nitrobenzolazoresorcin

Procedure:

1) Cut surface of the sample with 800 SiC powder. Grind planar and clean.

2) After blistering of CO_2 swirl gently in a very dilute alkaline p-Nitrobenzol-azoresorcin solution (prepared by dissolving 0.02 g p-Nitrobenzolazoresorcin in 100 ml of 2 normal NaOH).

Depending on the Magnesium-concentration on the sample surface a more or less intense blue to violet coloration will develop. The color formation must be determined within the first minute by adding the color solution. Otherwise by evaporation, the concentration (and thus the color intensity) can be varied. Since almost all pure lime stones contain at least traces of magnesium, a weak blue coloration will be observed here as well in most cases. According to FUECHTBAUER in G. MUELLER (1964) much better results can be achieved with the coloration test by MANN (1955) if the coloring was not obtained on a rock face itself, but on the bottom line of an unglazed porcelain plate. If the sample contains more than 5% dolomite (or ankerite), so the bottom line of the sample after 5 -10 seconds turns bluish after acid treatment and application of the staining solution.

B) ELUTRIATION ANALYSIS OF ROCKS

1. Basics for the preparation of elutriation samples.

Occasionally it turns out to be necessary to separate small particles from the sand fractions of fine-grained sediments, such as microfossils or heavy mineral grains. This in general is only achieved if the surrounding sediment is rich in clay minerals. The separation of the particles is achieved by elutriating and sieving the sample. Good results can be obtained with not to weakly consolidated clays, marl and loam. Strong solidified samples as mudstone or shale are difficult to elutriate. Slate, most sandstones or even carbonate rocks are not applicable.
Certain microfossils in carbonate rocks (radiolarians, sponge spicules, or conodonts) can only be separated if they are less soluble in acids than the surrounding sediment.
For the elutriation process itself a 30% hydrogen peroxide (H_2O_2) solution is needed and the largest possible aluminum or plastic containers. The etching of echinoderms to be carried out usually with 10% acetic acid; siliceous skeletons (radiolarian or siliceous spicules of sponges) need to be etched in 37% concentrated hydrochloric acid. In the recovery of conodonts the monochloroacetic acid has been proven. All etching and elutriation work must be done under the laboratory hood!

2. Basic steps for the elutriation analysis of rocks.

Occasionally it turns out to be necessary to separate small particles from the sand fractions of fine-grained sediments, such as microfossils or heavy mineral grains. This in general is only achieved if the surrounding sediment is rich in clay minerals.

1. The marl or clay sample (100 to 300 g, not more than 1 kg) is thoroughly dried.

2. The completely dry sample is broken with your fingers or a hammer in thumbnail-sized pieces.

The broken material is placed in the widest possible vessel or a container made of plastic, aluminum, ceramic or glass. The receptacles shall be much (10-20 times) to be greater than the amount of sample (not use high glass cylinder, otherwise the sample may glued to the ceiling!)

3. Pour over the sample with 30% hydrogen peroxide (H2O2) in the hood. The amount of liquid should be at least twice the volume of the sample (be sure to use protective goggles).

4. Let the hydrogen peroxide act until a significant reaction takes place (vigorous expansion of gas!). The reaction can already go off a few minutes after pouring, sometimes many hours nothing happens before it starts suddenly. Never left the sample out of control, the gas release can easily be explosive! If necessary, pour large amounts of water, to prevent drying out of the sample and to slow down the reaction (be sure to use protective goggles). If no recognizable reaction occurs even after many hours of treatment, the process can pushed on by carefully heating the vessel (if it is not made of plastic) in a sand bath. The process is complete when no more gas is formed or the sample has disintegrated into mush.

5. The material is tilted by a pile of sieves: coarse sieves on the top (use safety goggles!) fine sieves on the bottom. The filters must be previously washed and cleaned with compressed air. The mesh size of the screens depends on the size of the objects. For foraminifera usually you need a 90 or 125 µ sieve. Characeae-oogonia or ostracods can often be separated with mesh sizes of 0.3-0.5 mm. At least one pile of two sieves is used, with the coarser mesh size of about 1 mm serves to retain the coarser impurities.

6. Flush with plenty of tap water. Not ruined sediment lumps should be carefully crushed with a soft brush. The residue is gently rinsed with deionized water from the sieve into a beaker. It is recommended to treat the beaker 5 minutes by ultrasonic to clean the microfossils and even destroy existing sediment lumps. Then the sieving should be repeated. Remaining sediment lumps to be dried in the desiccator and the elutriation to be repeated.

7. The purified residue is dried in the desiccator and carefully selected by hand picking under the stereo micro microscope. The microfossils are best kept in black plastic cells with transparent lid of 5 mm to 10 mm chamber width.

3. Separation methods in gravity (heavy liquid) solutions.

With the dissolution of carbonates an insoluble residue often remains left (dolomite, clay minerals, pyrite, quartz, etc.). The few determinable fossils are then not so easy to find. Since conodonts consisting of the relatively heavy apatite (or phosphorite), they can be enriched by gravity separation.

C) EQUIPMENT, HARDWARE AND SUPPLIES FOR THE PREPARATION

(In bold: must be present; normal font: may be present)

1. Machinery and hardware equipment

Rock saws
Automatic Machine with clamping, cutting depths up to 15 cm, Diamond saw 40 - 50 cm ∅

Feeder by hand, cutting-depths of up to 10 cm, 25 cm ∅ diamond saw blade, parallel swinging arm and hand feeder, cutting-depths of up to 5 cm, 15 cm ∅ diamond saw blade.

Grinders
Semi-automatic thin section machine (precision surface grinder) lapping machine (type: Logitech)

2 grinding machines, 2 grinding discs made of cast iron between 15 cm and 30 cm ∅; 2 grinding discs (magnetic exchangeable) hard-faced with diamonds (grain sizes: 360, 600, 1200 mesh) about 15 cm ∅.

Polishing Machines
3-4 Semi-automatic polishing machines, polishing discs 20 - 25 cm ∅, can be used with polishing pads and chemo textiles hard faced with diamond polishing compound (water-soluble or oil soluble, Diamond grain sizes 6, 3, 1, ∅ 0.1 micron).

Thickness Tester, measuring tool with measuring stand, 1/100 mm can be read;

Straightedge / bracket (hardened steel) for overviews of bumps on surfaces.

Ultrasonic cleaning tank with timer and continuous operation.

Electronic Scale with tare key, loadable up to 3000 grams, 0.01 grams of precision.

Heating plate, 25 x 25 cm, infinitely adjustable and readable up 200° C.

Table Lamp shielded upwards.

1 Bunsen burner with pilot flame, lighter, matches

Drying oven with Vacuum Equipment, infinitely adjustable and readable up 200° C.

Polarization microscope combination for transmitted and reflected light with opaque illuminator and three objective lenses (5, 10, 25 times, or 5, 10, 20 times).

Magnifying lens 5 to 10 times. POL-thin section viewer ("Petro-Thin", Fa. Buehler).

Stereo microscope ("binocular") with stand (or "technoscope"), zoom or single lenses exchangeable (5 to 40 times magnification).

Planar hand press for the plane-parallel setting of polished thick sections in incident light (plasticine on slides).

Fume hood, (for working with hazardous substances).

Roller press or glass rod (2 to 3 cm in diameter, for the production of peels).

Laboratory sand bath (horizontal adjustment of hand samples, manufacturing peels).

2. Small sized equipment and articles of consumption

Tweezers (fine and coarse), crucible tongs, pliers, side cutter, flat nose pliers, hammer and small chisel, shaving blades, cutter blades, scalpels, preparation needles, glass rods, wooden sticks, wedges, scissors, clips, clamps.

Slides and slide-mounts, slide holders for "Giessen format" 28 x 48 mm (white glass 1 - 1.3mm thick) and slide format 48 x 48 mm (1 mm thick).

Coverslips 24 x 24 mm, 24 x 32 mm, 24 x 48 mm, 45 x 45 mm (0.17 to 0, 2 mm thickness).

Cleaning Accessories
Towels, linen cloth, "Kleenex" or similar, absorbent paper (lint), brushes, compressed air supply, brush, sponge, etc.

Vessels
Aluminum foil (extra strong), glass beakers, Erlenmeyer flasks, spray bottles, diverse plastic beaker, aluminum or brass rings for casting molds, diverse sample vessels, "Franke cells" agate mortar, plastic tubs, aluminum bowl for elutriation.

Labeling and storage boxes for thin sections; diamond pen, felt-tin pens (waterproof), pencils, fineliners, adhesive labels, adhesive tape, masking tape, double-sided tape, cold laminating foil, thin section box for 50 pcs. Or 100 pcs. 28 x 48 mm.

Solvents, caustics
Acetone, ethanol, trichlorethylene, xylene, 1-7% HCl for calcite / dolomite test, HF conc., hydrochloric acid conc. and acetic acid-conc.

Dye stuff, coloring
Blue Paste for "Araldite", "Alizarin Red S" for calcite, "Prussian blue" for dolomite, "potassiumhexanitrocobaltat" for staining alkali feldspar; Acetate (0.3 mm thickness) for film prints.

Abrasives
Silicon carbide (gray or green) in grits 120, 200, 400, 600, 800, 1000, 1200 mesh
Boron carbide, corundum**, diamond,** spinel, garnet, quartz.

Embedding - thermoplastics (without stress birefringence, isotropic)
Canada balsam (in xylene); "Meltmount"; "Mountex" (in toluene);); "70C Lakeside Cement" (from Hugh Court Ride, USA.) "Venetian turpentine resin - viscous"; Glycerin, immersion oils, castor oil, paraffin oil.

Embedding, mounting
Thermoplastic plastic mounting resins (free of stress birefringence; vacuum suitability!) "Araldite D epoxy with hardener HY 956 " (CIBA), "Technovit 2000 LC" (KULZER / HERAEUS), polyester casting resins.

Polishing agents
Chromium oxide, **aluminum oxide**, magnesium oxide, cerium oxide = "Tecepol", "polishing red" (hematite clay)
Diamond compound 6, 3, 1, 1/10 micron particle size (water- or oil-soluble).

Planar glass plates as an abrasive pad
(transparent or milky white) 20 x 20 x 1 cm for SiC abrasives.

Acetate films or other acetone-soluble films

Health Accessories
Rubber gloves, goggles, overalls, eye wash, ear protection, and others.

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