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SOIL MICROMORPHOLOGY Field strategies and sample preparation

Soil science applies standard methods to describe soil profiles, following directions in field handbooks. This paper presents a summary of a standard description complemented with a field descriptive method from sedimentology. Using these methods in a personalized, pragmatic way during field work, collecting as much information as possible about the soil, gives rise to possibilities for relating further laboratory analysis to the field situation. This is a very important aspect of the soil micromorphological method, a continuation of the field-descriptive method, except for sample preparation and the use of microscopic techniques. The second part of this paper describes a method to impregnate soil samples with a polyester resin, as the first step towards the production of thin sections.

Introduction

Soil micromorphology is the examination of soils and sediments by studying the constituents and their arrangement in undisturbed samples using microscopic techniques (Brewer 1976; Courty et al. 1989; Fitzpatrick 1993). This is done by impregnating soil and sediment samples with polyester resin, to make polished blocks and/or thin sections. In order to gain as much as possible from this method, it is necessary that there be a strong correlation between field description, sampling and microscopic analysis. This paper will discuss field description and impregnation technique. Readers further interested in the production of polished blocks and thin sections are recommended to read Courty et al. 1989, Murphy 1986 and Jongerius & Heintzberger 1963. Different ways to describe thin sections can be found in Brewer 1976, Courty et al. 1989, Fitzpatrick 1993 and Bullock et al. 1985.

Field strategies

When studying a soil-pit profile it is usual to divide this profile into horizons or layers. Layers refer to sedimentary layering and horizons to the results of soil processes. Soil horizons have more diffuse boundaries than does sedimentary layering, and often run parallel to the ground surface, which is not always the case with sedimentary layering.

In soil science a notational system for soil-horizon description is applied, producing a sort of shorthand (table 1) wherein numbers and letters stand for the different

characteristics of each horizon. In the field situation, it is not always easy to distinguish to what extent certain features are due to primary sedimentary properties (the geological material), or due to post-depositional or soil-forming processes. In addition to this there is the anthropogenic activity to take into account, which has a strong influence on the soil profile – human activity can be responsible for the formation of both horizons and layers.

In figs. 1 and 2, somewhat complementary ways to describe a soil profile are shown. Fig. 1 follows the more traditional method as used in soil science, whereby each horizon is described in accordance with a field-description handbook. Table 2 shows an example of a reminder sheet for soil-profile description. There are many different handbooks available (Hodgson 1976; FitzPatrick 1977; Milne et al. 1991), and it can be of value to study some of these to gather different views on, and hints to, new approaches for the description of soil features and properties.

Fig. 2 shows a columnar section of a soil profile, following the approach used in sedimentology/palaeopedology (Retallack 1988). Here symbols are used to show features and properties of the profile and this kind of drawing can provide quite extensive information.

In order to clarify one's notion of a stratigraphy already in the field, the soil profile can be treated in three ways, according to: (1) lithostratigraphy – referring to the geological material, (2) soil stratigraphy – referring to the pedological, the soil-forming, processes and (3) archaeostratigraphy – the stratigraphy based on archaeological features and artefacts (Courty et al. 1989). This

Stenstorp, Slöinge par., Halland. Thick accumulation of top-soil material in downslope position, forming a field terrace of suspected medieval age. Former pastureland, with grass and mosses. An F-horizon is forming, and there are signs of E-horizon formation in the uppermost part of the profile. The B2 horizon includes a buried A-horizon (2A_b), which has been covered slowly during the formation of the cumulative horizon (A, B1, B2) which is why the boundary is blurred. The B2 might be divided by micromorphology.

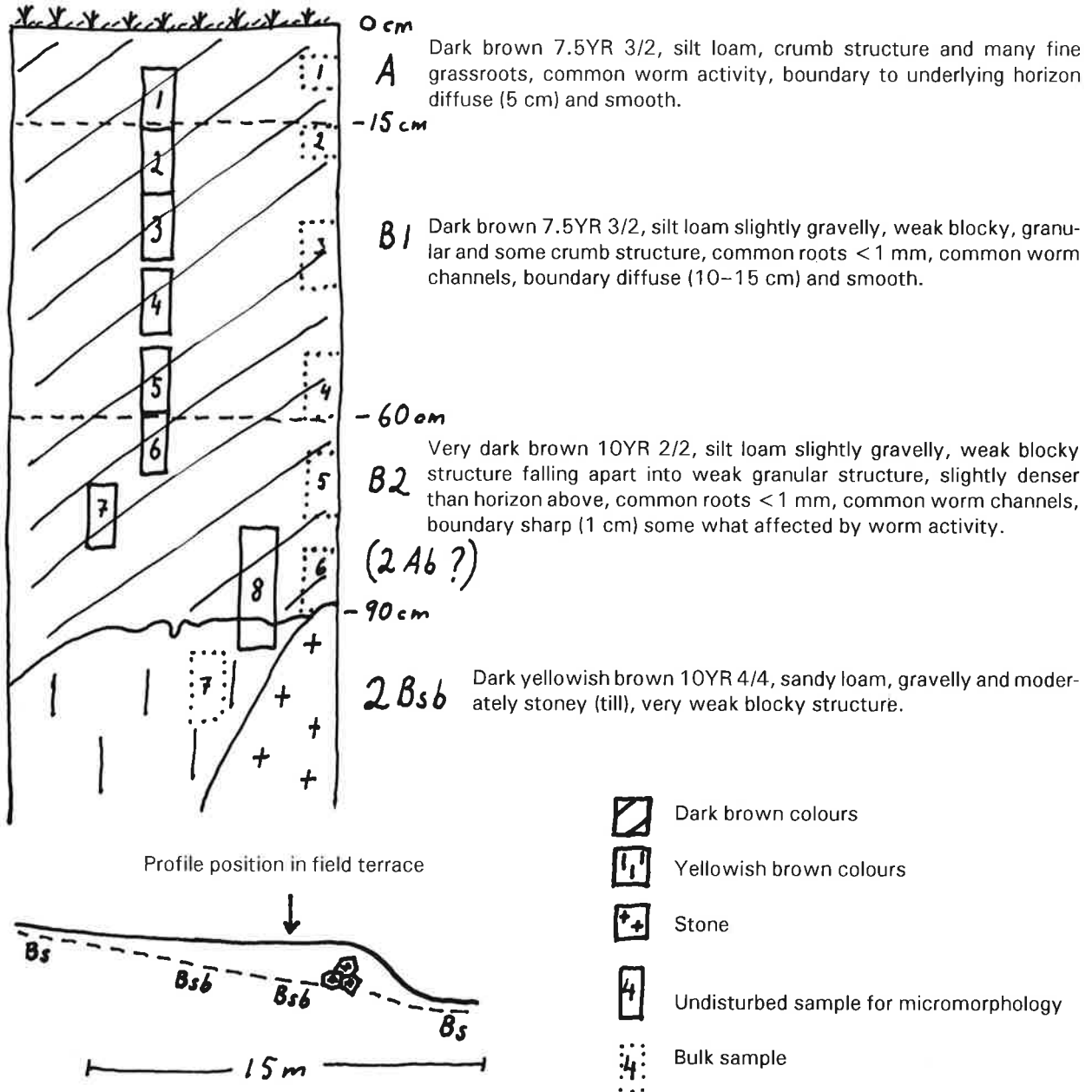


Fig. 1. An example of a field description influenced by standard methods in soil science. Redrawn from the original field description.

is shown in fig. 3, where the soil profile from fig. 2 is subdivided according to field observations and complementary laboratory results.

A columnar section showing stratigraphical subdivision provides a rich summary of the field description. This graphic summary is excellent for interpretative discussion, and can also be complemented after laboratory analysis with soil classification, textural classes, radio-

carbon datings and other analysis results. Sometimes laboratory analysis will show that the stratigraphic interpretation in the field needs to be adjusted, but nonetheless it is always advisable to record impressions during fieldwork on paper. When using standard description methods, it is advisable to complement this with a free-hand description, a drawing of the profile (with colour pencils if available), and photographs.

Table 1. Horizon notation for soil-profile description. A descriptive shorthand for labelling soil horizons. Compiled from Soil Survey Staff (1990), and Hodgson (1976).

Litter, and Organic horizons or layers:

- L Fresh litter deposited during previous annual cycle. It is normally loose and the original plant structures are little altered. Not saturated with water for prolonged periods.
- F Partly decomposed or comminuted litter remaining from earlier years in which some of the original plant structures are visible to the naked eye. Not saturated with water for prolonged periods.
- H Well decomposed litter, often mixed with mineral matter, in which the original plant structures are indiscernable. Not saturated with water for prolonged periods.
- O Peaty layers accumulated under wet conditions, developed mainly from mosses, rushes and woody materials. Can be artificially drained.

Mineral horizons:

- A Mineral horizon formed at the surface, and characterized by incorporation of humified organic matter as a result of biological activity or artificial mixing.
- E Mineral horizon characterized by the eluviation of clay, iron, aluminium, either alone or in combination.
- B Subsurface mineral horizon characterized by enrichment in organic matter, iron, aluminium or clay, either alone or in combination, and/or by the development of soil structure.
- C This is a unconsolidated or weakly consolidated mineral horizon unaffected by the pedogenic processes operative in A and B horizons, except gleying.
- R This is a consolidated bedrock layer that is too hard to break with the hands or to dig with a spade.

Transitional horizons:

- AE, AB, BC, etc. Horizons dominated by properties of one horizon but having subordinate properties of another. The dominating horizon is written first.
- A/E, A/B, B/C, etc. Horizons in which distinct parts of two horizons are present and not mixed.

Lowercase suffixes:

- a Highly decomposed organic material (Oa)
- b Buried horizon
- c Concretions or nodules
- e Organic material of intermediate decomposition (Oe)
- g Strong gleying due to variation in reduction and oxidation
- h Illuvial accumulation of organic matter
- i Slightly decomposed organic matter (Oi)
- p Tillage or other disturbance
- s Illuvial accumulation of iron, aluminium and organic matter
- w Development of colour or structure

Subdivision:

Sometimes there is a need to subdivide horizons and this is done with numbers, e.g. A, E, B1, B2, B3, C. If a soil profile consists of contrasting material the subdivision can take the form of e.g. A, E, B, 2B, 2C, where number 2 stands for the different soil material (number 1 is always omitted).

Sampling

Depending on the type of soil material – loose or hard, sandy or stony, etc. – different methods to take undisturbed samples should be followed. Metal frames, about 10×7 cm and 5 cm high, can be pushed into the soil after which the frame and enclosed sample is cut out, labelled with its orientation and covered with lids (Courty et al. 1989). This type of sampling box is called a “Kubiens box”. The method is not useful if there are small stones, gravel, or large objects in the soil.

If the soil is coherent enough, a more straightforward method is to use milk-cartons. The milk-carton being slightly flexible, can be adapted to accommodate protruding objects. A column of the soil is prepared to the size of the milk-carton. Then the carton is placed over the column which is carefully cut loose from the soil profile. This is then wrapped with tape, labelled, and carefully transported to the laboratory.

If the soil material is coarse, a column of the soil can be

covered with plaster of Paris before being cut loose. During sampling, the position of all samples must be clearly marked on the field-description drawing, to enable later relating of the sample to the field setting. Before cutting the samples loose, it is advisable to take a photograph of the profile with sampling boxes in place, recording their position and the profile.

Sample treatment

The impregnation of undisturbed soil and sediment samples allows them to be studied as polished blocks or thin sections, enabling a description of the constituents and their arrangement in the sample to be made (Brewer 1976; Courty et al. 1989). Impregnation makes it possible to produce thin sections of loose unconsolidated soils and sediments in much the same way as in petrography, with the difference that in soil micromorphology, thin sections are usually made larger (7×7 cm, 7×10 cm) compared to the standard petrographic thin sections

(2×3 cm). This larger size makes it easier to correlate the thin section with the field description, and to study larger structures and objects in the sample.

Here will follow a description of the way samples are impregnated with polyester resin, using standard laboratory equipment, at the Department of Quaternary Research, Stockholm University.

Preparation

Finding a polyester resin that has the correct quality for impregnation of soil material and is available at a reasonable price, can be time consuming. Thus, it is most effective to use not only the same polyester but also the same recipe for the resin mixture as another laboratory. Because the available polyester resins very often vary as to brand and type in different countries, this might not be possible. A list of polyester resins used for impregnation, together with the names of researchers and also the recipe they follow for mixing the resin, is given in Murphy (1986). One disadvantage of the impregnation method is the use of hazardous chemicals, and the importance of safety precautions during the impregnation process can not be stressed too often. The impregnation process is described in Fox et al. 1993, Murphy 1986, and Jongerius & Heintzberger 1963.

Drying

Equipment:

- Plastic containers
- Acetone
- Oven

Before samples can be impregnated they have to be dried. This is usually done either with acetone replacement or by air drying; it is also possible to use freeze drying. Which one of these drying methods that should be used, will depend on the character of the material. As a general rule one can say that all materials that will shrink upon air drying are better dried with acetone replacement or freeze drying. Air drying is by far the easiest way: samples are left to dry in a room for some weeks, if necessary an oven can be used to speed up the drying process but temperatures should not exceed 60°C. Too rapid drying might cause structural changes. If samples are to be dried with acetone replacement, they are immersed in acetone for about four to six weeks, changing the acetone weekly (Murphy 1986).

Samples are placed in acetone-resistant plastic containers with a height of about 1.5 times the sample itself, to provide enough volume for the acetone in the case of acetone replacement drying, and polyester resin during impregnation.

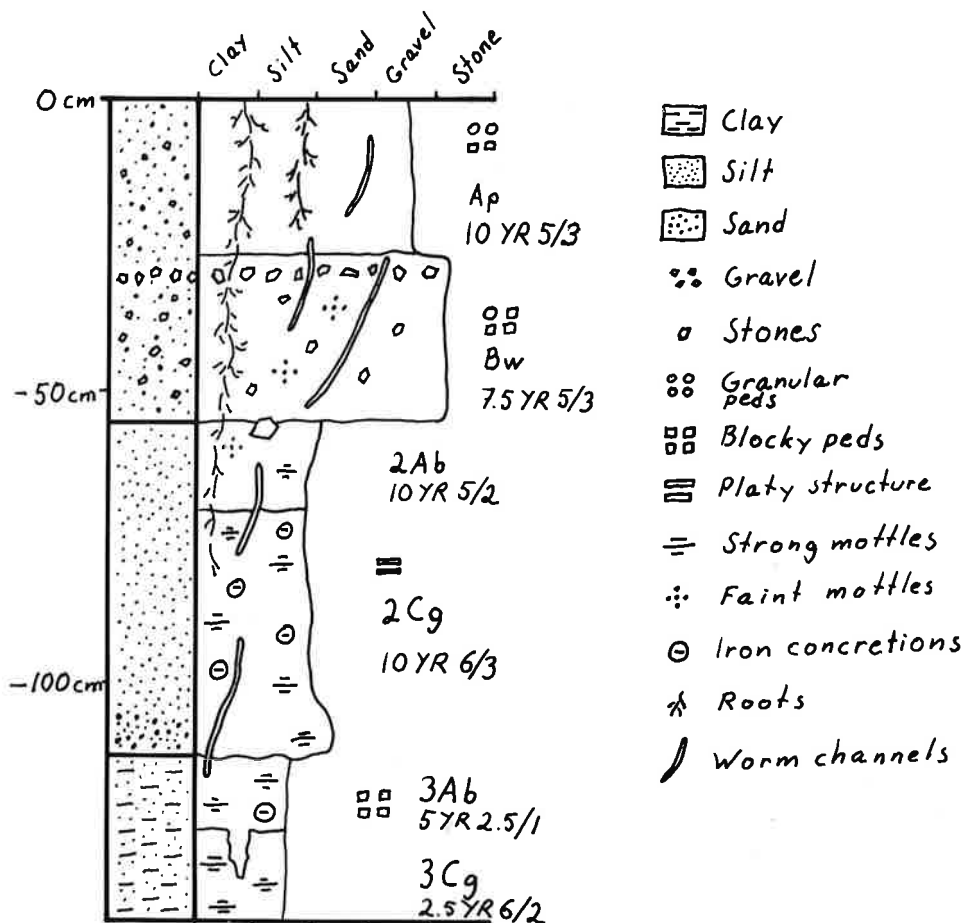


Fig. 2. A columnar section of a soil profile, from Frotorp, Närke.

Polyester resin mixture

The resin mixture is made from polyester resin, dilutant (acetone), and catalyst. It is recommended that resins which are not pre-accelerated be used, since pre-accelerated resins have a shorter shelf life than other resins, and are more restrictive if changes to the recipe are needed. Before commencing to impregnate samples for the first time, it is advisable to test a few different mixtures with the resin, to control if the resin when hardened has the desired quality, if the polymerization process is slow enough, and if the test samples become fully impregnated. The recipe provides general advice, to be changed and tested as required. The amount of acetone varies among laboratories, and in accordance to the kind of sample that is to be impregnated, in the range of 10–50 % of the resin mixture. High amounts of acetone in the resin mixture will cause the volume of the resin to decrease during impregnation and necessitate that more resin be poured on the sample. Often laboratories find a recipe that works with the type of resin they are using and the kind of samples they have, and then continue to use that recipe only with minor changes.

Equipment:

- Acetone.** Technical grade. Used for water replacement and for diluting the resin.
- Polyester resin.** Synolite 1077-N-1 (DSM, Landskrona).
- Catalyst.** MEK peroxide.
- Glass beaker.** Minimum 2000 ml.
- Mixer.** Propeller mixer or similar.
- Fume-cupboard.** A good fume-cupboard is necessary when working with polyester resin, for health reasons.
- Safety equipment.** It is essential to use plastic gloves and other protection equipment during work with polyester resin.

Procedure

The resin is poured into a glass beaker, and acetone is added and mixed in. When resin and acetone are fully mixed, the catalyst is added and mixing is continued for c. 5 minutes.

Resin mixture:

- Polyester resin 1500 ml
- Acetone 200 ml
- Catalyst 15 ml

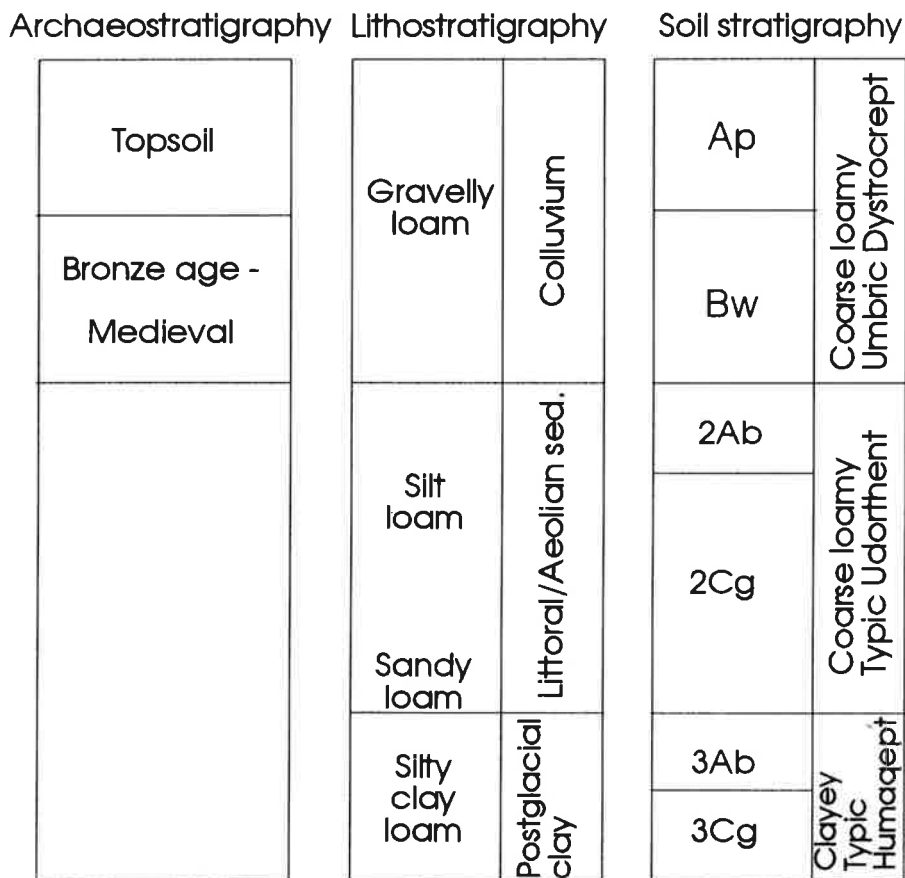


Fig. 3. Stratigraphical subdivision of the Frotorp profile shown in fig. 2.

Table 2. Reminder sheet for soil profile description. Compiled mainly from FitzPatrick 1977, Hodgson 1976.

<p><u>Profile No.:</u></p> <p><u>Date:</u></p> <p><u>Location:</u> (with map reference)</p> <p><u>Geomorphological setting:</u> (elevation, aspect, angle of slope, form of slope, microrelief, exposure)</p> <p><u>Land use and land use history:</u></p> <p><u>Archaeological context:</u></p> <p><u>Vegetation:</u></p> <p><u>Erosion:</u></p> <p><u>Geology:</u> (frequency of rock outcrops, bedrock type, quaternary geology)</p> <p><u>Parent material:</u></p> <p><u>Surface drainage:</u> (ponded, slow run-off, medium run-off, rapid run-off)</p> <p><u>Photographs:</u></p> <p><u>Drawing of profile:</u> (preferably in colour)</p> <p><u>Stoniness:</u> (> 20 mm: frequency, size, lithology, variation in profile)</p> <p><u>Surface of the upper horizon:</u></p>	<p>The following for each horizon</p> <p><u>Depth:</u> (in cm to upper boundary of horizon; variation; thickness variation)</p> <p><u>Symbol:</u></p> <p><u>Lower boundary:</u> (transition zone width in cm, smooth, wavy irregular, or broken outline)</p> <p><u>Colour:</u> (wet or dry, uniform, spotted, mottled, etc., size and colour of motiles)</p> <p><u>Texture:</u> (< 20 mm: content of gravel, sand, silt and clay)</p> <p><u>Stoniness:</u> (if applicable)</p> <p><u>Structure type:</u> (blocky, crumb, granular, platy, compound, single grain)</p> <p><u>Structure degree:</u> (none, weak, moderate, strong)</p> <p><u>Porosity:</u> (frequency, size, origin)</p> <p><u>Consistence (handling properties):</u> (loose, soft, friable, firm, compact, hard, sticky, plastic)</p> <p><u>Organic matter:</u> (state of decomposition, origin)</p> <p><u>Roots:</u> (frequency, size, origin)</p> <p><u>Soil fauna:</u> (earthworms, etc.)</p> <p><u>Soil water state:</u> (dry, moist, wet, saturated)</p> <p><u>Soil drainage:</u> (well drained, imperfectly drained, poorly drained)</p> <p><u>Archaeological artefacts:</u></p> <p><u>Other:</u></p>
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Impregnation

Equipment (fig. 4):

Resin mixture. See above.

Vacuum pump. A small sized pump to fit in the fume-cupboard.

Manometer. Showing pressures from 0 to -760 mm Hg (0 to -100 kPa, 0 to -1 bar).

Vapour trap. The vapour trap is a condenser in a "Dewar" flask, filled with crushed dry ice during evacuation. The vapour trap protects the pump from acetone and styrene.

Vacuum desiccator. Diameter 250 mm, with vacuum connection, and placed in a protective case during evacuation in case of implosion. The material must be solvent resistant (glass).

Neoprene tubing. Solvent resistant tube to connect vacuum pump with vacuum gauge, vapour trap and vacuum desiccator. Size 8 mm in diameter.

Tube valve. A short piece of tube, with a tubing clamp, is connected to the vacuum tube with a T-connection to control the pressure.

Oven. Placed in the fume-cupboard.

Procedure

The sample, placed in a plastic container labelled with sample number and orientation, is slowly saturated with the resin mixture by pouring the mixture into the container but not on top of the sample. Initially, only a small volume is poured into the container, adding more as the resin rises in the sample. When the sample becomes saturated, its surface will appear wet. Now the sample can be covered with resin mixture. The volume of resin will decrease during impregnation when the acetone evaporates, so enough resin has to be poured into the container to compensate this. Samples are placed in the vacuum desiccator, and the pressure is lowered to -500 mm Hg. This pressure is maintained for half an hour before being further lowered to -720 mm Hg. Small bubbles will occur in the resin during evacuation, but if these grow too large and the resin starts to boil, the pressure must be adjusted. Samples are evacuated for at least six hours. After evacuation, samples are left in the fume-cupboard for six weeks. During this time the level of the resin must not

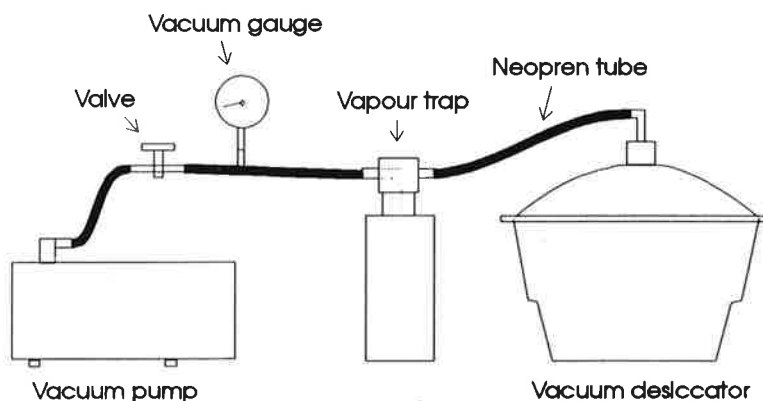


Fig. 4. Vacuum impregnation line.

fall below the surface of the sample. If resin has to be added, no acetone is mixed into the resin mixture. When the resin begins to set hard after about six weeks, the samples are put into the oven at 60°C for two days. The oven should be placed in the fume-cupboard. After the samples have cooled, they are knocked out of their containers, and carefully labelled. The impregnated and hardened samples are now ready for the production of polished blocks and/or thin sections.

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