GUIDELINES FOR STANDARD ABRIDGED MICROMORPHOLOGICAL DESCRIPTION OF THIN SECTIONS

To be used in combination with the
Handbook for Soil thin section description
by Bullock et al. 1985

By

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Introduction

A micromorphological study consists of several phases namely: 1. identification, 2. description and 3. interpretation, generally closed of with a syntheses comparing other available data and conclusions. These guidelines deal with descriptions.

The main purpose of a micromorphological description is the registration of the visually observed objects in written text. A description should contain all essential data required for interpretation of the observations. In this respect the function of the description can be compared with an analytical data sheet compiled after execution of chemical analysis.

Proper micromorphological descriptions however, not only contain data on presence and quantity of observed objects but also information on other aspects as location, shape, size, sorting, distribution and orientation. With these basic data not only processes itself can be reconstructed, also information on their extent, relation to other processes and chronology can often be determined.

In soils and other related materials a wide variety of processes are known, indicated by specific features or combinations of them. Indicative for the determination of processes are often descriptions of details of objects e.g. the roughness of an external boundary is sometimes indicative for precipitation or solution. Consequently the presentation of the essential data is not an easy task and cannot be performed after a simple set of rules.

A micromorphological description can consist of the registration of all aspects of the material studied or be restricted to selected features, resp. indicated as comprehensive and subject-oriented descriptions. Both types of descriptions can vary in detail from brief, abridged to detailed ones. The system presented here forms a first approximation to come to a more rigid framework, based on present knowledge, for uniform characterisation of a complete thin section. In these abridged descriptions all essential information needs to be presented adequately and reproducible. They are intended to serve as basic documentation of the micromorphological study. When more elaborated descriptions or brief ones are required the framework of this system can be used as basis.

The aim of these guidelines is to improve reproducibility and comparison to the level that, when used correctly, the presented data can be interpreted in the same way with confidence by all users.

The terminology used follows those selected and recommended by the International Working-Group on Soil Micromorphology first published in a Glossary of Soil Micromorphology (Jongerius and Rutherford, 1979) and very recently reconsidered in the Handbook for soil thin section description (Bullock et al., 1985). In the latter the introduction of much new terminology has been resisted. The sources of earlier defined terminology included in the Handbook are cited as is done in the Handbook. When inevitable other terms have to be selected. They need to be easy to adapt and defined in the text.

The guidelines consist of 5 sections. In the first three sections the framework for the abridged standard description of one thin section is given. In the fourth section outlines are presented to reduce the data to brief descriptions per thin section or to one combined description per profile when more thin sections are available. These combined descriptions which are abridged ones, can also be reduced to brief ones after the same principles as given for single descriptions. More elaborate descriptions are often subject oriented, serving specific purposes for which a strict set of rules is not functional. In the last section examples of the different types of descriptions are given.

CONTENTS Page:

I. General information and references

In this section essential basic information on the thin section is presented.

a) Information on the thin section

1. Number thin section
2. Profile reference, depth, size, plane of section, number and sequence of sections available of same profile
3. Location, country
4. Classification and landuse
5. Date of sampling.

b) General information of the micromorphological study

1. Project no./title
2. Study purpose
3. Specific methods used, before or during preparation
4. Registration of documentation of the site studied
5. Author(s) of description and date of examination.

Details

a) Information on the thin section

1. Number thin section
   The laboratory number of the thin section is given.

2. Profile reference, depth, size, plane of section, number and sequence of sections available of same profile
   The registration name or code given to the site sampled is recorded. The depth of the top and bottom of the sample boxes is given in cm below the mineral surface. The size of the section is expressed in lengths of the x and y axes when placed in the first quadrant, given in cm. The plane of section is indicated with the letter v for a vertical section and the letter h for a horizontal one. When more thin sections of the same site are available, the sequence number starting from the surface is given, followed by the total number in brackets e.g. 2(4), which means that 4 thin sections are available and the second is being described.

3. Location, country
   For the exact location, reference is made to the profile description. Here only province, county, state, etc. and the country are given.

4. Classification and landuse
   Dealing with soils, a high order classification has to be given. If possible first the classification used in the country in which the soil is sampled is given.
   In addition cross-reference is made to the terminology of the F.A.O. legend for the Soil Map of the World and/or of the U.S.D.A. Soil Taxonomy.
   As many processes in soils are influenced by land use, it is important to state shortly the kind of landuse. In un-

cultivated areas the vegetation is described in simple terms e.g. moorland, shrubs, open woodland. When the soil is under cultivation the nature of land use is given together with important management practises e.g. old pasture; orchard, irrigated; wet rice-field, puddled; rainfed crops.

5. Date of sampling
When the date of sampling is known climate and weather conditions before and during sampling can be traced. They may have influenced the quality of the thin section and be necessary to know for interpretation of features.

b) General information of the micromorphological study

1. Project no./title
If the micromorphological study forms a part of a project, reference is made to the project no., code and/or title.

2. Study purpose
The purpose of the micromorphology is given in a short heading e.g. classification, compaction, genesis, degradation.

3. Specific methods used, before or during preparation
Only treatments and methods not performed after the standard procedure for preparation of thin sections are registered e.g. stained void wall by artificial colouring, fluorescent dye added, freeze-dried samples.

4. Registration of documentation of the site studied
All references to important information available are registered here. In the first place reference to profile description and analytical data are given, but also to other related data e.g. rooting measurements, hydraulic conductivities.

5. Author(s) of description and date of examination
Self explanatory.

Note

- When large numbers of standard micromorphological descriptions are to be produced, a registration system for individual descriptions is advisable.

c) Example general information and references

- Thin section no. G. 4291, Profile III, 8 b. C horizon depth: 52-67 cm (v), 3 (4).
- Locality: Goeree Overflakkee, The Netherlands.
- Classification: Poldervaaggrond Mn15A (NL). Typic Fluvaquent (Soil Survey Staff, 1975).
- Land use: arable land, potatoes.
- Project no. 271.17 Stiboka, loosening of compacted layers in southwest Netherland.
  Study purpose: effects of subsoiling in arable land.
  Documentation: profile description, analytical data, image analyses of porosity.
  Author and date of examination: O.H. Boersma; 8-3-1983.

II. Macroscopic characteristics of thin sections

In this section an outline is given of the essential macroscopic characteristics, as observed in thin sections with the naked eye or a handlens with magnification up to 5x. This information forms a link between the field description and the micromorphological description proper. It includes the following items:

a) Uniformity
b) Colour
c) Texture
d) Structural aspects
e) Striking features

Details

a) Uniformity

Indicate the zones in the thin section where soil material occurs in which the characteristics are relatively constant. When the characteristics are uniform over the whole thin section the material is homogeneous. When different zones occur the material is heterogeneous. The distribution of each zone is indicated and the zones are numbered. The following information is given of each of the zones.

b) Colour

Indicate dominant colour of the soil material using as close as possible the standard colour names as given in the Munsell Soil Colour Charts.
The thickness of the thin section has to be taken into account as it influences the colour.

c) Texture

The texture of the particles smaller than 2 mm is estimated in the same three classes as recognized in the legend of the Soil Map of the World, 1 : 5000 000 FAO/UNESCO (1974), namely coarse, medium and fine textured material (Fig. 1).
The coarser particles (>2 mm long) are described according to the Guidelines for Soil Profile Description (FAO, 1977) as follows:

- slightly gravelly: 2-15% of the area covered by solid material is occupied by coarser particles
- gravelly: 15-50% of the area covered by solid material is occupied by coarser particles
- very gravelly: 50-90% of the area covered by solid material is occupied by coarser particles.

When more than 90% of the area is occupied by coarser particles the texture is given as gravel. Stony material rarely occurs in thin sections.

- Coarse textured: sands, loamy sands and sandy loams with less than 18 percent clay, and more than 65 percent sand.
- Medium textured: sandy loams, loams, sandy clay loams, silt loams, silt, silty clay loams and clay loams with less than 35 percent clay and less than 65 percent sand; the sand fraction may be as high as 82 percent if a minimum of 18 percent clay is present.
- Fine textured: clays, silty clays, sandy clays, clay loams and silty clay loams with more than 35 percent clay.

Figure 1. Textural classes of the particles smaller than 2 mm after the legend of the Soil Map of the World 1 : 5000 000 FAO/UNESCO (1974).

d) Structural aspects

The structural aspects refer to the presence of peds in natural horizons or to fragments and clods in disturbed horizons or zones. Here the grade of stucture is given in four classes; the first term refers to peds, the second to fragments and clods.

- apedal or unaggregated: no pattern of planar voids occurs
- weakly pedal or weakly aggregated: weakly developed pattern of planar voids. The voids are isolated.
- moderately pedal or moderately aggregated: moderately developed pattern of planar voids, which partly are intersected
- strongly pedal or strongly aggregated: strongly developed pattern of intersected planar voids, forming nearly or completely a continuous system.

When the soil material is moderate or strong pedal the type of structure can be given after the Guidelines for Soil Profile Description, FAO (1977).

e) Striking features

Striking macroscopic features, not given above, are registered e.g. distinct iron mottles, large carbonate nodules, coarse root fragments. An indication of frequency (few, common, many), size (range actual diameters) and distribution (random, clustered, banded, etc.) is added.

Examples macroscopic characteristics

- Homogeneous, olive brown, fine textured apedal soil material, containing few brown and black nodules up to 5 mm in diameter, randomly distributed.
- Dark brown, medium textured moderate pedal (upper 1/3 of the section) and weak pedal (lower 2/3 of the section) soil material.
- Homogeneous, light reddish brown, slightly gravelly, fine textured weakly aggregated soil material.

III Micromorphological characteristics for abridged descriptions of individual thin sections

The micromorphological description of a thin section consists of three parts: structure, groundmass and pedofeatures, i.e. all features distinguishable from the groundmass by any difference in composition and/or arrangement.

Each separate group of objects is characterized by a number of items. Some items and detail of information can be dealt with in the same way for many groups of objects. These items are given seperately as general criteria. More specific items and detailed information are given in the successive paragraphs dealing with the above distinguished parts.

The information of the distinguished individual aspects is noted in telegraphese-like sentences.

In general the following order of noting is used:
quantity; size; colour, composition and kind of feature; shape; orientation; distribution.

Examples:
- Few (< 1% surface area), large (3-4 mm ∅) darkbrown sesquioxidic nodules, with irregular sharp external boundaries, containing a few mineral grains; randomly distributed;
- Common (ca. 5% surface area), regular, straight sometimes curves elongated voids (channels), widths up to 2 mm, lengths less than a few cm, voids sometimes branched, vertically oriented, randomly distributed.

Abundant examples of this type of noting are present in: Micromorphological analyses and characterization of 70 Benchmark soils of India (Kooistra, 1982).
The length of a standard abridged micromorphological description rarely exceeds 1½ page A4.

a) General criteria for description

The main objective of a description is to characterize the objects in an accurate and consistent way. The main line of description is to characterize the kind of object, its position and relation to other objects, and its frequency. These principles are translated into the following list of main headings:

1. Nature and/or composition
2. Colour
3. Shape
4. Size
5. Orientation
6. Distribution
7. Frequency

General criteria of these main headings can often be used in the same way for many groups. They are given below.

1. Nature and/or composition

The term nature is used in the sense of sort or kind of object, referrring to origin or high level units. No general criteria can be given for these items.

2. Colour

Indicate the dominant colour in transmitted light, which either may be plain light or plane polarised light, using the standard colour names as given in the Munsell Soil Colour Charts, without colour notations. The colour is influenced by the thickness of the thin section and the light source used, which has to be taken into account.

3. Shape

Some objects have specific shapes with own terminology e.g. channels as special group of voids and euhedral minerals as a constituent. They will be considered in the subsections b, c and d. When no specific terms are available shapes of objects, inclusive voids, are morphologically characterized by the following properties (Fig. 2).

i. Length/width ratios
   - equant or round : ratio of short to long axis is >0.4 ($\frac{1}{2.5}$)
   - elongated: ratio of short to long axis is <0.4

ii. Course (restricted to elongated shapes)
   The course presents the overall direction throughout its length. Three types are discerned.
   - straight: shape in which more or less the same direction throughout its lengths is maintained.
   - curved: shape in which distinct deviations in bends, without angles, from a straight line throughout its length is occur.
   - angled: shape in which distinct deviations with angles from a straight line throughout its length is occur.

iii. Regularity
   The regularity refers to the degree to which reentrant or acute angles or curves occur in successive parts of the walls in the course of a shape, which are not identical for opposite boundary. This aspect includes the variation in diameter or width. When valid information is obtained by a more adequate characterization of the kind of irregularity, this is done after the rules set out in Bullock et al. (1985).
   - regular: virtually no reentrant or acute angles curves occur, whereby the diameter or width of the main course remains of the same magnitude, or increases/decreases regularly.
   - irregular: the void walls show significant reentrant or acute angles/curves, whereby the diameter or width of the main course varies significantly in magnitude.

Figure 2. Survey of parameters used to characterize shape

Note

- The regularity of planar voids forming a pedal structure is not given as this information is included in the accommodation of peds. In fact accommodated peds correspond with regular planar voids which may be straight, curved or angled and unaccommodated and partly accommodated peds with irregular planar voids.

iv. Surface smoothness
Surface smoothness refers to the degree and length to which a surface has a continuously even surface.
- smooth: even surfaces without protuding particles over more than half their lengths.
- rough: uneven surfaces due to protuding particles or clusters of a few particles over more than half their length.

4. Size

Sizes are given in actual measurements, referred to as diameters when more or less round or simple elongated shapes are concerned, or lengths and widths for other shapes, expressed in µm or mm. Coatings, hypocoatings and quasicoatings (Section III d1i) distinguished are characterized by their thickness and presented in the same way. When the size varies too much, size ranges can be given and/or dominant occurrence in which

75-80% of the cases fits. As general indication for the coatings, hypo- and quasicoatings the terms thin, moderately thick can be used in addition. In all other cases the terms small, medium and large can be used. Instead of actual measurements size classes can be given as presented in Bullock et al. (1985).

5. Orientation

Two general aspects are considered namely the direction of orientation with regard to the soil surface and the degree of orientation.

i. Direction of orientation (adapted after the Guidelines for soil profile description FAO, 1977).
- Vertical: Most individuals are oriented vertically, or more nearly vertically than diagonally.
- Horizontal: Most individuals are oriented horizontally, or more nearly horizontally than diagonally.
- Oblique: Most individuals are oriented at the angle of 45° to the vertical, or more nearly diagonally than horizontally or vertically.
- Random: Individuals are oriented in all directions and it is impossible to say that vertical, horizontal, or oblique orientation predominates.

ii. Degree of orientation
- Strongly oriented: More than 60 percent of the individuals are oriented with their principal axes within 30 degrees of each other.
- Moderately oriented: Between 40 and 60 percent of the individuals are oriented with their principal axes within 30 degrees of each other.
- Weakly oriented: Between 20 and 40 percent of the individuals are oriented with their principal axes within 30 degrees of each other.
- Unoriented: There is no preferred orientation.

Notes
- The degree of orientation is described only when it offers relevant information.
- Orientation does not concern the planar voids belonging to the pedal structure.

6. Distribution

Two types of distribution patterns are important.

i. Basic distributions (concerning the arrangements of individuals with regard to each other).

Patterns distinguished:
- Random: the individuals are distributed randomly throughout the soil material; there is no recognizable specific pattern of distribution.
- Clustered: the individuals are concentrated in clusters of groups.

- Banded: the individuals are concentrated in bands or sheets.
- Others: to be given in descriptive terms.

ii. Referred distributions (concerning the arrangements of individuals with regard to specific features e.g. planar voids).

Patterns distinguished:
- Unreferred: the pattern of distribution is unrelated to any reference feature.
- Perpendicular: individuals, or groups of them, are arranged perpendicular to the specific reference feature.
- Parallel: individuals, or groups of them, are arranged parallel to the specific reference feature.
- Inclined: individuals, or groups of them, are arranged at roughly a constant angle to the specific reference feature; this angle should be measured and stated.
- Radial: Individuals are grouped along radiating lines.
- Concentric: Individuals are grouped along approximately concentric lines or surfaces.

7. Frequency

The following two aspects are recommended:

i. The total area occupied by the special feature in the thin section, estimated in % surface area covered.
ii. The number of individuals of the different types of the special features is indicated in the general terms few, common or many. Because of the wide variety in size and thickness no further specification can be given.

b) Microstructure

Soil structure is one of the basic items described during field surveys. It is therefore necessary to present the micromorphological data of this subject in such a way that it fits the field description. Several soil structure concepts are in use. They differ in specificity and physical attributes that are considered. Basically, all these concepts deal with the voids present in the soil. Voids are the spaces not occupied by solid organic or inorganic materials. Three groups of voids can be distinguished in thin sections (Fig. 3): 1. voids forming a part of the pedal structure including clods and fragments; 2. packing voids between the basic soil constituents and 3. other voids present in apedal soil material or in peds, clods or fragments. The packing voids between the basic soil constituents are a function of size, shape and arrangement of these constituents and are considered as aspect of the groundmass dealt with in Section III, c. The other two groups of voids form the microstructure, with exception of voids being a part of pedofeatures. These voids are described as such in Section III, d.

It has to be kept in mind that the pedal structure is not always detectable from thin sections depending the size of each. The description includes the following aspects:

1. Nature
2. Shape
3. Size
4. Orientation
5. Distribution
6. Frequency.

Details

1. Nature

The microstructure is determined by the voids occurring. On the basis of the voids two groups are distinguished.

i. Voids forming the pedal structure, defined after the structure they form as given in standard soil profile descriptions (see Soil Survey Staff SCS, USDA, 1975), inclusive artificially formed soil aggregates due to cultivation or management.

ii. Voids present in apedal soil material, peds, clods and fragments.

2. Shape

The same two groups are distinguished :

i. Shape characteristics of pedal structures.
- Type
- The type is given after the Guidelines for soil profile description FAO (1977), viz. platy, prismatic, columnar, angular blocky, subangular blocky, granular and crumb, of which the last two may be composed or include artificial aggregates due to cultivation or management.

- Accommodation of the peds
Accommodation is measure of the degree to which opposite ped faces mold each other.
Three subdivisions are used:
. accommodated: opposite walls show identical outline over more than 70% of the surface
. partly accommodated: between 30-70% of the opposite walls show identical outlines
. unaccommodated: less than 30% of the opposite walls show identical outlines.

- Grade of structure
The grade of structure is expressed by the degree of intersection of planar voids surrounding the peds. Intersecting voids are crossing planar voids. Three subdivisions are distinguished, identical with the last three classes of the pedality given in Section II, d.
. weak: isolated planar voids, which are rarely intersecting (idem weak pedal/aggregated)
. moderate: common planar voids surrounding the peds are intersecting (idem moderate pedal/aggregated)

. strong: the planar voids surrounding peds are nearly all or all intersecting, forming a nearly completely or completely continuous system (idem strong pedal/ aggregated).

Note:

The degree of accommodation may be due to local modifications of the faces of peds. These modifications are formed afterwards by other agents. In some of these cases it is advisable to use the word modified instead of accommodated to indicate superposition of processes.

ii. Shape characteristics of voids present in apedal soil material, peds, clods and fragments. A few types of voids are distinguished based on characteristic shapes. These are:
- channels: elongated voids with rather constant diameters over the main course of their length, which can be straight or curved, and with rounded eds. They never show acute angles and generally have rahter regular and smooth walls. Cross-sections are rounded, often circular, regular smooth-walled equant voids. Channels may be branched. In large thin sections often enough sections through channels occur to identify their type.
- chambers: near spherical voids connected to channels, generally with smooth walls. Maximum diameters larger than those of the connected channels.
- planes/planar voids: elongated voids, which either may be straight or angled, with diameters which may vary regularly and have sharp ends. Surfaces can be either regular or irregular, smooth or rough. Cross-sections are also elongated voids with the same characteristics. Planar voids can be intersecting.
- vesicles: circular to ellipsoidal, regular, smooth, equant voids which occur as individuals, with identical cross-sections. Vesicles are spheroidal voids.
- packing voids: equant to elongated voids with varying diameters, generally interconnected, due to random packing of individuals which are not accommodated. Several subtypes of packing voids can be distinguished (Bullock et al., 1985). Here, two subdivisions are recognized, viz. single packing voids dealt with in next paragraph as aspect of the groundmass and compound packing voids. Compound packing voids are voids between unaccommodated individuals which have a compound composition e.g. soil aggregates, peds, excrements.
- vughs: equant to elongated, irregular voids, other than the above mentioned types. In fact the term vugh can be used for all other voids and includes a large group of compound voids. Compound voids are the result of different processes which often acted after each other. Examples are: root channels modified by faunal activity; planar voids with root channels etc. (see Fig. 4). Dealing with vughs a morphometical characterization using

the four shape parameters as outlined in the general criteria for description has to be given (III a3).

Figure 4. Compound void (c) developed from a void between welded shaped earthworm excrements (a). In one end (1) a root found its way; on the other end (2) small mites modified the void. The resulting void can be described as a smooth, irregular, elongated compound void/vugh.

Notes:

Two main groups based on shape of the above mentioned types of voids can be distinguished, of which the sub-divisions of the second group are commonly used in the descriptions.

- simple shaped voids
- complex shaped voids, divided into:
  . branched voids: voids with lateral extentions
  . interconnected voids: concurrent voids of different systems
  . intersected voids: crossing planar voids.

3. Size

   i. Size peds

      The range of the main thickness (for plates) or diameters (for other types of peds) are given in mm.

   ii. Sizes other voids, see general criteria (III a4).

4. Orientation (only applicable for voids in apedal soil material, peds, clods, fragments. See general criteria (III a5).

5. Distribution

   i. Basic distribution, only applicable for voids in apedal soil material, peds, clods and fragments. See general criteria (III a6i).

   ii. Referred distribution after general criteria (III a6ii) or after Brewer, 1964:
   - interpedal: Voids occurring between peds, clods and fragments.
   - intrapedal: Voids occurring in the groundmass of peds, clods and fragments as well as in apedal soil material.
   - transpedal: Voids traversing the soil material without any specific relationship to the occurrence of peds, clods or fragments; they usually extend beyond the limits of a single ped, clod or fragment.

6. Frequency
See general criteria (III a7). In addition the part of the surface area occupied by voids forming the pedal structure is given too.

c) Groundmass

The term "groundmass" is used to characterize the solid constituents (and their arrangement), other than in the special features, which together form the base material of the soil. Only when a special feature occurs throughout the base material in a way that it seems to form (forms) an essential part of this material this feature is included in the description of the groundmass.
The solid soil constituents of the groundmass are referred to as the basic components of the soil. They are considered to be the simplest fabric units, which may be of mineral or organic composition.

For each homogeneous part of soil material (partial fabric, as distinguished in section II a), occurring in thin sections the following information is given, when applicable.

In laminated soil material homogeneous zones with the same type of layering are described as one partial fabric. The alternation and thickness of laminae are characterized and the different compositions noted after the rules set out below.

1. Texture and grain-size range
2. Size limit coarse/fine material
3. Related distribution coarse/fine material
4. Coarse mineral components
   - nature
   - mineralogy
   - shape (roundness, sphericity)
   - size
   - alteration
   - sorting
   - orientation
   - distribution
5. Fine mineral components
   - colour
   - nature
   - mineralogy
   - alteration
   - birefringence fabric
6. Coarse and fine organic components
   - nature
   - colour
   - shape and sizes
   - decomposition
   - orientation
   - distribution

Details

1. Texture and grain-size range

The texture is described according to the rules as given in Section II,c. In addition the grain size range of the constituents is given in actual diameters (µm or mm). The percentage area covered by particles >2 mm is indicated.

2. Size limit coarse/fine material

Before 1975, the pasma-skeleton concept, as developed by Kubiëna (1938) and Brewer and Sleeman (1960) had gained general acceptance to describe the great variation of grain size of soil constituents.
Recently, Stoops and Jongerius (1975) and FitzPatrick (1977) introduced the coarse/fine concept to allow a more precise description.
In these concepts the size limit between the two fractions is not fixed. The concept developed by Stoops and Jongerius (1975) is followed here. The limit between the two fractions is given in actual size expressed in µm diameter, rounded off to a multiple of 5, e.g. 5, 15, 60 µm 0. If possible, the same limits as used in the USDA textural classification are followed. The relative proportions of the coarse and fine fraction are roughly indicated in percentages, e.g. c : f = 60 : 40. When a considerable amount of organic matter is included, the quantity is indicated as fraction of the coarse c.q. fine material. In some cases all material is organic.

3. Related distribution coarse/fine material

Five basic types are distinguished in the concept developed by Stoops and Jongerius (1975):

i. Monic c/f related distribution: only particles of one size group or amorphous material is present.

ii. Gefuric c/f related distribution: the coarser particles are linked by braces of finer material.

iii. Chitonic c/f related distribution: a skeleton of coarser particles which are wholly or partly surrounded by a cover of finer material.

iv. Enaulic c/f related distribution: a skeleton of coarser particles with aggregates of finer material in the intergranular spaces.

v. Porphyric c/f related distribution: the coarser particles occur in a dense groundmass of finer material (Fig. 5).

Figure 5. Survey of coarse/fine related distributions of the basic components (adapted from Stoops and Jongerius, 1975). a. dense porphyric, b. wide porphyric.

Figure 6. Examples of humusforms:

a. moder, O-horizon;
b. moder, A-horizon;
c. raw humus, O-horizon;
d. mull, A-horizon.

In view of the great variation of the coarse/fine ratio, in the case of porphyric c/f related distribution, four subdivisions have been proposed in the original concept. In practice, however, a description according to these four groups offers difficulties, especially if the coarse grains vary greatly in size. In this text two subdivisions are recommended.

- Dense porphyric: the distance between the coarser grains is less than two times their mean diameter
- Wide porphyric: the distance between the coarser grains is more than twice their mean diameter.

The terms dense and wide can also be used in relation with other basic types.

Intergrades are defined by joining the basic terms, mentioning the dominant one last. From the first term the siffix 'ic' and the last consonant are dropped e.g. gefuchitonic. If both types are present in about equal amounts both terms are given fully e.g. enaulic-chitonic. When mixtures of different types are observed the c/f related distributions are indicated by full terms joined by the word and e.g. chitonic and enaulic. These related distributions are used irrespective of the composition of the materials, which can be mineral, organic or mixtures.

The same related distribution concept is applied to describe the coarse/fine distribution of organic material only or organic and mineral material in humus forms (term used in the sense of Kubiëna, 1955). As illustration the basic description of a few main humus forms occurring in soils is given below (Fig. 6). More information on humus forms can be found in Babel, 1974, 1985; Bal, 1973, Barat, 1969; Jongerius and Schelling, 1960 and Kubiëna, 1955).

- Raw Humus: A terrestrial humus form consisting predominantly of well preserved often fragmented plant residues as coarse material, with clear evidence of decomposition by fungal attack, hyphae and amorphous humus, and sparse shaped organic excrements of soil fauna as fine material. The coarse/fine related distribution is enaulic and the relative proportion of the coarse material varies between 30% and 70%. The coarse as well as the fine material are dominantly organic.
- Moder: A terrestrial humus form in which the organic matter becomes conversed into shaped organic excrements produced by small soil fauna, chiefly microarthropods, which are present in open or close packed or slightly welded clusters between larger material. In the O-horizon this coarse material consists of fragments of plant residues; in the A-horizon of mineral particles. The related distribution is enaulic and the relative proportion of the coarse material varies between 30% and 70% in an O-horizon; in the A-horizon relative proportion of the fine material varies between 20% and 40%. The coarse material is essential organic or mineral, the fine material always dominantly organic.

- Mull: A terrestrial humus form in which the organic material is intimately mixed with the mineral material forming a clay-humus complex, causing a darker coloured groundmass, with a few embedded, often rounded, organic fragments lacking a distinct internal structure. The related distribution is porphyric and the quantity of recognizable organic matter is generally < 5%. The mixture of organic and mineral material is a result of animal activity.

In the following the distinguished coarse and fine fractions forming the groundmass are described in more detail.

4. Coarse mineral components

i. Nature

Three main groups can be distinguished according to their composition.

- single mineral grains
- compound mineral grains or rock fragments
- inorganic residues of biological origin

When more than one group is present the area covered by the not dominant groups are given in percentage of the coarse mineral material.

Notes

- Contrary to the Handbook for soil thin section description artefacts are considered as special features and not as part of the groundmass.
- It doubtfull whether a constituent should be considered as part of the groundmass or a special feature/part of a special feature, the description can be made here, or in subsection d as special feature with reference to the other possible place.

ii. Mineralogy

The mineralogy of each group is given. Only single mineral grains belonging to the parent material are listed. Newformed minerals are dealt with as special features. If doubtfull whether a special feature or a constituent should be considered as part of the groundmass the description is given at the most obvious place with reference to the other possible place. In most cases the mineralogy of the bulk part of the coarse single minerals is given; trace minerals are omitted. Compound mineral grains and rock fragments should be indicated after their main petrographic name, e.g. granite, basalt, gneiss, quartzite, limestone and the main components listed. Only the inorganic residues of organic origin forming a part of the parent material are listed here. They can be derived from plants e.g. diatoms or be internal or external skeleton remnants of animals e.g. bones, shell fragments.

iii. Shape (roundness, sphericity)

The shape of coarse mineral components, except for the inorganic residues, can adequately be described according to roundness and sphericity. Roundness refers to the relative sharpness of particle corners and can be given in three classes combined from the 5 classes defined by Pettijohn (1957).

Weakly rounded	Strongly developed faces with sharp to somewhat rounded edges and corners; secondary corners* are numerous
Moderately rounded	The edges and corners are rounded and the area of flat faces is comparatively small; secondary corners are much rounded and reduced in number
Strongly rounded	Flat faces are practically to completely absent; all edges and corners are (rather) broad curves, and there may be broad re-entrant angles; secondary corners have disappeared

* Secondary corners are "the many minor convexities seen in the grain profile. Primary corners are the principal interfacial edges and are few in number" (Pettijohn, 1957).

The sphericity gives the overall form of the particle irrespective of the sharpness of its edges. Two classes are distinguished. Elongated particles have a low sphericity, whereas more equidimensional ones have higher sphericities. A chart for visual estimation of roundness and sphericity after Powers (1953) is given in Brewer (1964). The shape of single mineral grains can also be described after their crystal morphology. The following terms are recommended:

- euhedral: mineral grains are bounded by crystal faces
- subhedral: mineral grains are only partly bounded by crystal faces
- anhedral: mineral grains are not bounded by crystal faces.

The shapes of inorganic residues are indicated in simple descriptive terms or refer to orginal shapes.

iv. Size (only when useful information is obtained).
See general criteria (III a4).

v. Alteration
The term alteration covers all transformations of mineral material resulting from weathering and alteration sensu stricto, as well as diagenesis (Stoops et al., 1979) In descriptions the degree of alteration is given in three classes based on percentages of the area of the original material that has been altered.

- weakly altered: less than 25% of the material has been altered;
- moderately altered: 25-75% of the material has been altered;
- very altered: more than 75% of the material has been altered.

For different minerals, compound minerals or rock fragments the classes can be given separately. When more details on alteration are required one is referred to the above mentioned literature and Bullock et al. (1985).

vi. Sorting
Sorting, often expressed as sorting coefficients, is a measure of the evenness of grain sizes or spread of the size frequency distribution. Many sorting coefficients are proposed in literature of which a number are collected by Brewer (1964), but no one is generally used. For general characterization three classes are proposed:

- sorted: 75% or more of the grain sizes belongs to one fraction
- limitedly sorted: particles of more fractions occur of which about 40-75% belongs to one fraction
- unsorted: particles of more size classes occur in which no fraction is more sorted than others.
When the mineral material is sorted or limitedly sorted the dominant fraction is given too.

vii. Orientation
Only applicable to elongated particles and described when relevant information is obtained. For description see general criteria (III a5).

viii. Distribution
See general criteria (III a6).

5. Fine mineral components

i. Colour
See general criteria (III a2).

ii. Nature
The fine material present below the size limit stated as limit between the coarse and fine mineral material can be subdivided into clay-sized material and particles up to the stated size limit. The following groups are distinguished:
- only clay-sized material (beyond the resolving power of the optical microscope).
- clay-sized material containing particles up to the stated size limit, subdivided into few, common or many particles. The area covered by the small particles can be given in percentage of the fine material
- only small particles of which the range of diameters is given.

iii. Mineralogy
The mineralogy of the small particles is given, when detectable. Only in exeptional cases the clay mineralogy can be determined optically.

iv. Alteration
When detectable, the alteration of the particles is given in the same way as for the coarse mineral components.

v. Birefringence fabric
In Bullock et al. (1984) the concept of birefringence fabrics is introduced, which is adopted here. The birefringence fabric or b-fabric of the fine material refers to the orientation and distribution of interference colours between crossed polarizers and their nature. This fabric is related to the plasmic fabrics of Brewer (1964). It differs from the latter in being applicable to fine materials in which individual particles can be larger than 2 μm. Three main groups are distinguished:
- Undifferentiated b-fabric, characterized by an absence of interference colours in the fine mass, due to isotropic or opaque properties or masking by other materials.
- Crystallitic b-fabric, characterized by the presence of small birefringent crystallites, microlites or mineral fragments which cause interference colours in the fine mass.

- Striated, speckled and strial b-fabrics. These fabrics refer to anisotropy of clayey material. Only when individual clay minerals form larger units whith parallel orientations their are anisotropy can be detected in thin sections. These units are indicated as domains (Aylmore and Quirk, 1959).
  . Striated b-fabrics are characterised by the presence of elongated birefringent zones or streaks which show a more or less simultaneous extinction. The interference colours in the streaks are not continuous but have a striated pattern. They are subdivided into two groups of patterns of which the first is associated with natural surfaces of which two types are recognised:
    .. porostriated b-fabric: clay domains are oriented parallel to the surface of a pore. This b-fabric corresponds with Brewer's vosepic plasmic fabric (Figure 7, a).
    .. granostriated b-fabric: clay domains are oriented parallel to the walls of resistant fabric units (grains, nodules). This b-fabric can be compared with Brewer's skelsepic type (Figure 7, b).

  The second group is not associated with natural surfaces. Several types are recognised. The main ones are:
    .. monostriated: birefringent streaks occur isolated and independant in the groundmass.
    .. parallel striated: birefringent streaks occur in parallel or subparallel sets (Figure 7, c).
    .. reticulate striated: two sets of birefringent streaks intersect at right angles.
    .. cross striated: two intersecting sets of birefringent streaks, which are not perpendicular to each other.
    .. random striated: an irregular pattern of interwoven fine streaks, which successively extinguish when the microscope stage is rotated.
    .. circular striated: birefringent streaks are arranged in more or less circular features or rings. When concentric rings are observed the pattern is a concentric striated b-fabric.
    .. crescent striated: infilled channel-like features with a cresent-like internal fabric of birefringent streaks (ref. stress striotubules of Stoops, 1968).
  . Speckled b-fabrics are characterised by the occurrence in the fine mass of randomly arranged equidimensional or slightly prolate speckles of optically oriented clay. A subdivision in two types is proposed:
    .. stipple-speckled, consisting of individual and isolated speckles. This b-fabric corresponds to Brewer's insepic and asepic plasmic fabrics.
    .. mosaic-speckled: birefringent speckles are in contact with each other, resulting in a mosaic-like pattern. This b-fabric can be compared with Brewer's mosepic type.

Ruchur 113-128 cm
Porostriated b-fabric
along planor void with
inclined horizontal axis.
Crossed polarizers.

x 4.

Barsi 75-90 cm
Carbonate nodule (light colour)
with a granostriated b-fabric
in adjoining groundmass.
A horizon crossed polarizers.

x 4.

Figure 7

. Strial b-fabrics are characterised by a birefringence pattern occurring over the whole zone in preferred parallel orientations. This concept is introduced to describe the fabric of unconsolidated clayey sediments. Two subtypes are distinguished:
.. unistrial: characterised by one preferred direction.
.. bistrial: characterised by two preferred directions.
Brewer's concept of strial plasmic fabric is equivalent to the strial b-fabrics.

Notes

Birefringence fabrics of the fine material have to be studied between crossed polarisers in circular polarized light at high magnifications with a high light intensity.

Be sure that the anisotropic clay domains studied, do not belong to features due to proper clay illuviation.

6. Coarse and fine organic components

Organic material may be present in soils as plant remains in all stages of decomposition, as precipitations of secondary products, as excrements or incorporated in these and other forms e.g. charcoal. The organic material considered as part of the groundmass is principally restricted to the plant remains and decomposition stages in situ. Only when one of the other types of organic material occurs throughout the base material in a way that it seems to be one of its constituent, e.g. in humus forms, this type is described as part of the groundmass. Other types are special features.

i. Nature and, when possible, origin
First a subdivision is made in floral or faunal organic matter. The latter is rare in thin sections. In the following reference is made only to floral matter. When faunal material occurs, the same outline can be followed. The following groups are distinguished based on recognizable structure of original state.
- complete organs and organ fragments (composed of different types of tissues)
- tissue fragments, which can be subdivided after type (parenchymatic, lignified, etc.)
- cells and cell wall residues
- excrements, subdivided into organic, organo-mineral and mineral.
- others e.g. sklerotia, fungal hyphae and organic matter with unrecognizable structure of original state.

When possible, in case of complete organs and of organ fragments of which parts of original contours are recognizable, the origin is given e.g. residues of leaves, needles, wood, roots.

When more information is required one is referred to the contribution of Babel in the Handbook for soil thin section description and the literature cited there.
When the soil fauna which produced the excrements is known, the species are mentioned.

Next information is given of the main groups distinguished.

ii. Colour

The colour of organic matter can be indicative for the kind and stage of decomposition, especially the chemical altering. When the colour distinctly differs from fresh sections the dominant colour in transmitted light, which either may be plain light or plane polorized light, is given in simple colour names, as much as possible related to the standard colour names of the Munsell Soil Colour Charts. Opaque organic matter is also mentioned.

iii. Shape

Of the plant and animal remains with mainly intact original contours the original shapes are given. In other cases the fragments are described after the guidelines for the description of shape as given in the general criteria (III a3). Regularity and smoothness of the external boundaries are given, when characteristic. Basically five groups are distinguished to describe the shape of excrements, i.e.: spheres, ellipsoids and conoids, cylinders, plates and threadlike ones (Bal, 1973, Bullock et al., 1985). The cylindrical excrements may have straight, rounded or pointed ends (Kooistra, 1978). When required the composition, internal structure, regularity and smoothness of the shaped or not-shaped excrements are given in the same way as outlined above. Shaped excrements occur as discrete entities, are coagulated or show desintegration due to ageing. The following types are distinguished:

- packed: individual aggregates occur as discrete entities. Subdivided into:
  . open packed: the aggregates occupy less then 60% of the whole area occupied by the infilled part of the void/zone.
  . close packed: the aggregates occupy more than 60% of the whole area occupied by the infilled part of the void/zone.

Three grades of coalescence and desintegration are distinguished:

. weak: 30% of the excrements are coalesced or desintegrated.
. moderate: 30-70% of the excrements are coalesced or desintegrated.
. strong: 70% or more of the excrements are coalesced or desintegrated.

In a number of cases it is more functional to mention only the presence of excrements here and to give a detailed description as special feature.

iv. Size

In all cases the sizes are given in actual measurements, referred to as diameters, widths or lengths, expressed in µm or mm.
Size ranges are given or the dominant occurrence, which includes 75-80% of the cases.

Note

Reference is given whether the material concerned belongs to the coarse and/or fine material of the groundmass.

v. Decomposition

Alteration of plant material is based on two main characteristics namely size and internal structure. Communition and internal alteration, decomposition, often do not develop parallel to each other. In the description these aspects are given separately. Communition can be detected from nature, size, orientation and distribution. Decomposition is described as follows.

Decomposition refers to the level of recognition of the internal structure of the organic matter. The original internal structure consists of cell walls, cel contents and often of inter or intra cellular voids. Decomposition of organic matter occurs by various processes and to different degrees. Consequently only a few broad classes can be distinguished:

- slightly decomposed: loss of some cell structure (<30%) and interference colours of the first order. Relative increase of fine organic material, which may be coloured
- moderately decomposed: considerable loss of internal structure (30-70%); interference colours are hardly observable. About twice as much fine organic material as in fresh organic matter
- strongly decomposed: most of the internal structure is lost (>70%) and became amorphous. The quantity of fine organic material is large.
- very strongly decomposed: the internal structure is lost and became amorphous. More than 3/4 of the area consists of fine organic material.

Decomposition generally refers to effects of processes in plant and animal remains and not to excrements. When applied for excrements, it has to be stated clearly.

vi. Orientation

Only appliable to elongated components and described when relevant information is obtained. For description see general criteria (III a5).

vii. Distribution

See general criteria (III a6).

d) Pedó features

In the groundmass units that differ can be depictured: the special features. ~~These are distinguished from the groundmass by any difference~~ in composition and/or ~~arrangement~~. These features need not solely to be a result of soil forming processes, also material of other origin incorporated by exogenic processes or human activities or their effects are included. There are many different kinds of pedo features showing a large variaty in habit. In the Hndbook the term pedofeatures is used. Here more kinds of features, not resulting from soil forming processes, are included. Therefore the term special feature is preferred. Several groups of pedo features can be distinguished, according ~~to~~ the effects of processes. ~~They fllow as closely as possible the groups as recognized in the Handbook~~. Each type of ~~special~~ feature is described separately in the same way as done for microstructure and groundmass.

internal fabric

Groups of special features:

- Features with different quantities of groundmass components, as compared with the surrounding groundmass, inclusive accumulations of one or more groundmass components.
  Clay illuviation features and most of the mineral excrements are listed here.
  This group includes the textural pedofeatures and a part of the excrement pedofeatures of Bullock et al. (1985).
- Features associated with the loss of one or more chemical components compared with adjacent groundmass.
  This group is identical to the depletion pedofeatures of Bullock et al. (1985).
- Features due to neoformations past or present, whether crystalline or amorphous, mineral or organic.
  This group combines the groups of the crystalline pedofeatures and of the amorphous and cryptocrystalline pedofeatures of Bullock et al. (1985).
- Other bodies of different composition, which can be allochtoneous. Included are lithorelicts, charcoal fragments, phytoliths, potsherts, snails, etc. . part of faunal features belong to this group.
- Features due to different arrangement(s) of the constituents. Changes in packing, orientation of elongated particles or deformations of any kind are included.
  This group includes the fabric pedofeatures of Bullock et al. (1985).
- Features consisting of shaped units other than peds c.s. with the same composition as the groundmass. A number of faunal features belong to this group, as well as soil aggregates.
- Any other features.

Features of compound nature e.g. infillings partly consisting of shaped mineral excrements and partly of carbonate crystals can be described as soon as one of the characteristics fits. Compound features are firstly characterized as a whole, whereafter the different units are described in the same way. When the origin of a feature is identified this information is used, e.g. mineral aggregates can be described as soil fragments or mineral excrements.

Notes

- The aim of this list is to describe all relevant features. The order of description of the individual features is of minor importance.
- Birefringence fabrics of the groundmass are excluded from the special features.

The following aspects of each of the special features are described:

1. Nature
2. Composition/arrangement
3. Colour
4. Shape
5. Boundary
6. Size
7. Position
8. Orientation
9. Distribution
10. Frequency

Details

1. Nature

At highest level the special features are separated in two groups which can be subdivided in a few subgroups (Kooistra, 1982; Bullock et al. 1985).

i. Special features related to voids, grains and aggregates, subdivided into:
   - Coatings: special features that coat surfaces of voids, grains and aggregates (cf. cutan Brewer, 1964).
   - Hypocoatings: special features occurring immediately adjoining rather than on the surface with which they are associated (cf. neocutan, Brewer, 1964).
   - Quasicoatings: special features related to surfaces of voids, grains and aggregates, but not immediately adjoining them (cf. quasicutan, Brewer, 1964).

   Hypocoatings and quasicoatings may occur external and internal. The neocutan and quasicutan of Brewer (1964 cit.) refer only to external types.
   - Infillings: Special features in which materials either completely fill a void or essentially are not lined along the walls or when lined along the walls cover more than 75% of the former void area (Figure 8).

Figure 8. Schematic examples of infillings: a. close packed complete infilling, b. open packed partly infilled void, c. laminated not coated partly infilled void, d. laminated coated (complete) infilling, e. laminated coated and not coated partly infilled void.

Voids containing material not lined along the walls need not to be filled completely (partly infilled voids). To the infillings belong the pedotubules and part of the crystallaria of Brewer (1964). Not tubular infillings e.g. in planar voids and vughs are also included and external boundaries need not to be sharp.

ii. Special features unrelated to voids, grains and aggregates. All special features not consistently related to voids, grains and aggregates are listed here, irrespective of size.

The main subdivisions after Bullock et al. (1985) are:

- Crystals and crystal intergrowths: special features formed in situ, which consist of a single crystal and/or crystal intergrowths, normally >20 µm diameter , embedded in the groundmass.
- Nodules: special features unrelated to voids or surfaces of grains or aggregates that do not consist of single crystals or crystal intergrowths.

This concept of nodules is similar to the one of glaebules of Brewer (1964).

- Intercalations: special features unrelated to voids or surfaces of grains or aggregates with elongate, undulating shape, not consisting of single crystals or crystal intergrowths.

Besides glaebules also intercalary crystals and part of the lithorelicts, pedorelicts or biorelicts mentioned in Brewer (op. cit.) belong to this main group of features. Deformed and fragmented special features e.g. papules (Brewer, 1964) are also included. More information of the subgroups can be found in Bullock et al. (1985).

When relevant the following information is given.

2. Composition/arrangement

The composition is given by characterization of the organic and/or mineral material or by clear reference to already described materials e.g. the groundmass. When specific minerals are identified their mineralogy is given. In other cases broad classification occurs e.g. sesquioxidic, carbonate. Special features mainly composed of fine clay are characterized in the same way as the fine mineral components of the groundmass (III c5). Special features of compound nature are firstly characterized as a whole, whereafter the different units are described following the same system, e.g. laminated infillings composed of alternating unoriented fine clay and fine silt layers and sequioxidic nodules containing a few silt-sized mineral grains. The internal arrangement of the constituents of a special feature is described after the concept developed by Stoops and Jongerius (1975), given in Section III c3. Changes in arrangement(s) are indicated in descriptive terms e.g. compaction or orientation of elongated particles, when relevant more specified after their basic type of related distribution given after the above mentioned concept.
When the internal arrangement is not homogeneous over the feature their characteristics are given in simple terms e.g. laminated cutans, concentric nodules, when relevant further specified after the above mentioned concept.
A special group of the latter forms the infillings composed of aggregates. The internal arrangement of these aggregates as well as those of the whole infilling are indicated. The arrangement of the aggregates present in the infilling as a whole is characterized as follows:

- Packed: Individual aggregates occur as discrete entities. Subdivided into:
  . open packed: the aggregates occupy less than 60% of the whole area occupied by the infilled part of the void/zone
  . close packed: the aggregates occupy more than 60% of the whole area occupied by the infilled part of the void/zone.

- Individual aggregates occur coalesced or desintegrating. Three grades are distinguished:
  . weak: 30% of the aggregates are coalesced or desintegrated.
  . moderate: 30-70% of the aggregates are coalesced or desintegrated.
  . strong: 70% or more of the aggregates are coalesced or desintegrated.

  The degree of infilling is indicated in general terms e.g. partly, nearly completely. The void area which is infilled can also be given as percentage of the whole void. When the degree of infilling varies too much to be characterized by one percentage a range can be given covering 75-80% of the cases.

3. Colour

See general criteria (III a2).

4. Shape

For the coatings, hypocoatings and quasicoatings the shape is characterized by the thickness and continuity of the feature. The thickness of these features is considered as size and dealt with under heading 6. The continuity is given in three classes referring to the surface of the related void, grain or aggregate:

- continuous: more than 90% of the perimeter is occupied by the feature
- discontinuous: between 45-90% of the perimeter is occupied by the feature
- patchy: less than 45% of the perimeter is occupied by the feature.

In all other cases the shape can be characterized morphologically with a few parameters. Shapes of single mineral grains can be described after their crystal morphology in euhedral, subhedral and anhedral (see section III c4iii and those of excrements after the system given in section III c6iii). When no specific shapes are recognized, the shape is described after the rules set out as general criteria.

5. Boundary

The following information of the boundaries of the feature can be given.

- Sharpness
  The following three classes are recommended:
  . diffuse: the transition occurs over a distance greater than one-quarter of the shortest dimension of the feature
  . clear: the transition occurs between one-quarter and one-tenth of the shortest dimension of the feature
  . sharp: the transition is less than one-tenth of the shortest dimension of the feature.
- Contrast
  Three degrees are distinguished (based on FAO, 1977):
  . faint: indistinct difference of feature and adjoining groundmass or other features in terms of colour, particle-size distribution, b-fabric etc.
  . distinct: although not striking the materials can clearly be seen based on difference in colour, particle-size distribution etc.
  . prominent: the individuals are conspicuous and outstanding compared with adjoining groundmass or other features.

6. Size

See general criteria (III a4).

7. Position

Of the special features related to voids the nature and/or shape of the voids concerned are given. When relevant, the position of infillings is described in the same way.

8. Orientation

See general criteria (III a5).

Note
The orientation of the special features related to voids of which the position is given, is not described, as this subject is dealt with in section III b4).

9. Distribution

See general criteria (III a6).

10. Frequency

See general criteria (III a7).

SECTION IV

Brief and combined micromorphological descriptions of thin sections

The standard abridged micromorphological description gives the registration of the visually observed objects to such an extent that the essential data required for interpretation of the observations are presented. In short micromorphological descriptions this information is, in one way or another, reduced. Three types are distinguished:

a) Brief micromorphological description per thin section

b) Combined standard abridged micromorphological description per pedon

c) Brief combined micromorphological description per pedon

Details

a) Brief micromorphological description per thin section

The brief micromorphological description per thin section consists of an outline of the standard micromorphological description. The information to be given is reduced to the main important items summarized after the following principles: what (feature/group of features, size), where (location or distribution) and how much (quantity). The same subdivisions, namely: structure and porosity, groundmass and special features, as for the standard descriptions are used and the same rules followed. The information to be given for each of the subdivisions is reduced to the following topics.

Structure

1) Nature:

   i. pedal structure:
      - shape of peds, clods or fragments
      - grade of structure
   ii. other voids:
      - type of voids, based on length, width ratios or after characteristics shapes

2) Regularity

3) Size

4) Distribution, only when relevant

5) Quantity

Example: Weak subangular blocky with common (ca. 3% surface area) regular channels, 0 up to 3 mm, and a few (< 1% s.a.) interconnected vughs, 0 up to 2 mm.

Groundmass

1) Texture and grain size range
2) Size limit coarse/fine material
3) Related distribution coarse/fine material. When more types occur the one of minor importance are omitted.
4) Coarse mineral material, restricted to:
   i. nature
   ii. indication of mineralogy; only dominant minerals are given
   iii. general degree of alteration
   iv. only when relevant: sorting
   v. only when relevant: distribution
5) Fine mineral material, restricted to:
   - for clay-sized material whether or not containing small particles the colour, nature and b-fabric. When more types of b-fabrics occur the ones of minor importance are omitted
   - for mainly or only small particles the mineralogy and general degree of alteration.
6) Coarse and fine organic matter
   i. nature
   ii. when relevant: size
   iii. general degree of decomposition
   iv. when relevant: distribution

Example: Medium textured soil material including grain sizes up to coarse sand. Size limit coarse/fine material 5 µm, c : f = 60 : 40; related distribution: porphyric. The coarse mineral material consists mainly of quartz grains and some feldspars, which are fresh to slightly altered. The dark brown fine material is largely clay-sized; weak granostriated b-fabric. A few fresh root-fragments, O up to 2 mm, occur.

Special features

1) Nature
2) When relevant: composition/arrangement
3) Size or thickness
4) When relevant: distribution
5) Quantity in general terms; only when relevant surface area covered.

Example of one thin section:
- Common thin calcite coatings (< 20 µm thick), in channels
- A few coatings of pure oriented clay (< 10 µm thick) in channels and vughs of the upper half of the section
- Common channels infilled with fine sand, O up to 3 mm
- Common sesquioxidic nodules, O up to 7 mm
- A few calcite nodules, O up to 5 mm, occurring in the lower part of the section.

A short micromorphological description of one thin section covers about half a page A4.

b) Combined standard abridged micromorphological description per pedon

In principle all information given in the individual standard descriptions is maintained in the combined standard description. The new element introduced is the compact registration of changes in observations with depth. The same objects can occur over the whole micromorphologically studied depth but sizes, shapes, distributions and quantities may vary. Otherwise objects can occur only in one thin section or be present over the whole studied depth without any change. This type of compilation is valuable for interpretation of the data. The extent of individual processes and relation to other processes can be determined easier. The length of compiled standard descriptions rarely exceeds 2½ page A4 and generally covers no more than two pages, irrespective of number of thin sections involved.

Example:

- Individual descriptions of one feature:
  - Section 1. (30-45 cm depth): Few (< 1% surface area) darkbrown sesquioxidic nodules, 0 up to 2 mm, regular clear external boundaries, random oriented, increasing in quantity with depth.
  - Section 2. (55-70 cm depth): Few to common (< 2% s.a.) darkbrown sesquioxidic nodules, 0 up to 3 mm, regular and irregular clear external boundaries, random oriented, increasing in quantity with depth.
  - Section 3. (75-90 cm depth): Common (ca. 4% s.a.) darkbrown sesquioxidic nodules, 0 up to 5 mm, mainly irregular clear external boundaries, random oriented and distributed.
- Combined description of this feature:
  Unoriented darkbrown sesquioxidic nodules occur over the whole studied depth. The diameters increase from 2 mm (section 1) to 5 mm (section 3) and quantities from few (1% s.a.) to common (ca. 4% s.a.) from about 70 cm depth onwards. The regularity of external boundaries changes with depth from regular (1) to mainly irregular (3), the sharpness remains clear.

c) Brief combined micromorphological description per pedon

The same procedure as given for the reduction of the information from standard abridged micromorphological description to brief micromorphological description of one thin section is followed for the reduction of information from the combined standard description of a pedon to a brief one. A brief combined description generally covers about one page A4.

The example given in b) will be reduced to:

Darkbrown sesquioxidic nodules increasing in size, from 2 to 5 mm 0, and quantity, from < 1% s.a. to ca. 4% s.a., over the studied depth.

The brief and brief combined micromorphological descriptions represent only the main characteristics of the observed objects. Consequently, when used as basic documentation, only a general indication of processes and their relations with other processes can be based on this information.

Figure 9. General view thin section no. G4223 of example 1 (A) and two details of main special features: (B) (C)

SECTION V

Examples of micromorphological descriptions

The following descriptions are illustrations of the methods outlined in the previous text. Real thin sections are used as examples.

Example 1, Figure 9.

General information and references

Thin section no. G 4223, Profile II, 10a: 29-44 cm (v), 1 (2).
Locality: Dinteloord, W.-Brabant, The Netherlands.
Classification: poldervaaggrond Mn15A (NL), Typic Haplaquent (Soil Survey Staff, 1975).
Land use: arable land, wheat.
Project no. 247.17 Stiboka, degradation of soil structure.
Study purpose: occurrence of ploughpans.
Documentation: profile description, analytical data, image analyses of porosity.

Macroscopic characteristics

Dark grayish brown (29-37 cm) and dark grayish brown with darkbrown irregular diffuse mottling (37-44 cm) coarse textured apedal soil material, in which between 33½-37 cm depth hardly any voids occur.

Standard abridged micromorphological description

Structure

Apedal soil material of which the porosity pattern can be split up into three zones:
29-33½ cm: Few to common (2½% surface area) irregular, generally rough elongated and equant voids (vughs and channels), Ø / up to 3 mm, with tendency to a horizontal orientation. The quantity of voids increases with depth, random distributed.
33½-37 cm: Few (1% s.a.) regular smooth equant and elongated voids (channels), Ø up to 750 µm, random oriented and distributed.
37-44 cm: Few to common (2,25% s.a.) regular and irregular, smooth and rough equant and elongated voids (channels and vughs), Ø up to 3 mm, lengths up to 1 cm. The elongated regular smooth channels are oriented vertically, others random, distribution random.

Groundmass

The coarse textured soil material includes grain sizes up to and inclusive fine sand. The size limit coarse/fine material is 10 µm, c:f = 85:15; related distribution: close porphyric. The coarse mineral material consists of sorted mineral grains, dominantly quartz with a low number of other minerals viz.

glauconite, hornblende, carbonate, micas, feldspars and black minerals. Minerals are fresh or nearly unaltered, except for glauconite, hornblende and micas which occur up to moderately altered. The bulk of the grains are subangular to subrounded and randomly oriented and distributed. The fine material consists of clay-sized material containing common particles up to 10 µm, partly carbonate grains and has a stipple-speckled b-fabric. A few fragments of plantroots occur, Ø up to 500 µm, which vary from fresh to moderately decomposed. They occur in channels and vughs from 29-33½ cm, below that depth in channels; random distribution.

Special features

- Common infilled voids (channels, vughs) with close packed ineral grains, Ø up to 3 mm, randomly oriented and distributed, decreasing in quantity with depth.
- Few thin (<20 µm thick) coatings of darkbrown clay-sized soil material with black dots. Coatings are present in channels and vughs and most occur just below 37 cm depth, decreasing in quantity with depth, random orientation and distribution.
- Few small voids, Ø <250 µm, infilled with the same clay-sized material as mentioned in the previous group and same occurrence.
- A few fragments of these coatings and infillings occur embedded in the groundmass between 29-33½ cm depth, random orientation and distribution.
- Below 37 cm depth occur common darkbrown ferric hypocoatings and/or ferric-iron nodules, diam. up to 2 mm, boundaries are irregular and diffuse, random orientation and distribution.
- A very few voids are partly infilled with welded shaped mineral excrements, Ø ca. 600 µm, random orientation and distribution below 37 cm depth.
- A very few infilled voids with soil material tending to striotubules, Ø ca. 2 mm, some occurrence as previous group.
- Common fragments of shells and snails embedded in the groundmass, random orientation and distribution and a few biogenic calcite nodules, Ø ca. 2½ mm random oriented and distributed, till 33½ cm depth.
- Till 33½ cm depth occur a few allochthoneous fragments, probably of bricks, Ø up to 2½ mm.

Brief micromorphological description

Structure

Apedal soil material with three different porosity patterns.
29-33½ cm: Few to common (2½% s.a.) irregular vughs and channels, Ø up to 3 mm.
33½-37 cm: Few (1% s.a.) regular channels, Ø up to 750 µm.
37-44 cm: Few to common (2,25% s.a.) regular and irregular channels and vughs, Ø up to 3 mm, lengths up to 1 cm.

Groundmass

The coarse textured soil material includes grain sizes up to and inclusive fine sand. Size limit coarse/fine material 10 µm, c:f = 60:40; related distribution: close porphyric. The coarse mineral grains consist dominantly of quartz and some other minerals e.g. glauconite, hornblende and carbonate of which the first two can be altered to various degrees. The dark grayish brown fine material is mainly clay-sized and has a stipple-speckled b-fabric. A few fragments of plant roots; Ø up to 500 µm, fresh to moderately decomposed.

Special features

- Common infilled voids with close-packed mineral grains, Ø up to 3 mm, decreasing in quantity with depth.
- Few thin (<20 µm thick) coatings of darkbrown clay-sized soil material, highest occurrence just below 37 cm depth.
- Few infilled small (Ø <250 µm) voids with the same clay-sized material and occurrence as the coatings.
- Till 33½ cm depth occur a few embedded fragments of these coatings and infillings.
- Common darkbrown ferric hypocoatings and/or ferric-iron nodules, Ø up to 2 mm, below 37 cm depth.
- A very few partly infilled voids with welded mineral excrements, Ø ca. 600 µm and a very few striotubule-like infillings, Ø ca. 2 mm, below 37 cm depth.
- Common embedded fragments of shells and snails. A few biogenic calcite nodules O ca. 2.5 mm, till 33½ cm depth.
- A few allochthoneous mineral fragments, probably bricks, Ø up to 2½ mm, till 33½ cm depth.

Example 2, Figure 10.

General information and references

Thin section no. G 4547, Profile No. L1 (MOC-2): 60-75 cm (v), 2 (4).
Locality, country: Lichinga, Mozambique.
Classification: ?
Land use: shifting cultivation, maize.
Project no.: 260.47.89 - Backstopping Mozambique.
Study purpose: classification and genesis.
Documentation: profile description, analytical data and a soil monolith at ISRIC, Wageningen.

Macroscopic characteristics

Homogeneous, dark red, fine textured, porous apedal soil material.

Figure 10. General view thin section no. G4547 of example 2 (A) and two details of main special features (B) (C)

Standard abridged micromorphological description

Structure

The soil material is apedal and highly porous. It contains common, generally regular, smooth channels, Ø up to 5 mm, lengths up to a few cm, random oriented and distributed. The high porosity is formed by abundant partly to completely infilled voids with mainly mineral aggregates (excrements), which generally are interconnected and superimposed. All stages of packed and welded excrements occur leaving a system of irregular, smooth and rough, interconnected vughs of all sizes between them. A detailed description of these infillings is given under the heading special features.

Groundmass

The fine textured soil material includes grain sizes up to and inclusive coarse sand. The size limit coarse/fine material is 10 µm, c:f = 35:65. The related c/f distribution is essentially open porphyric. The coarse mineral material consists predominantly of subangular to subrounded quartz grains, a few generally subrounded black and other minerals (biotite, epidote) and rock fragments. Biotites are moderately altered, plates become separated. Other coarse minerals are fresh or nearly unaltered. The coarse mineral material is unsorted, random oriented and distributed. The fine mineral material consists mainly of darkred coloured clay sized material containing a very few particles up to 10 µm. The b-fabric is weak random striated. The organic matter consists of a few coarse root-fragments, when decomposing becoming cell-wall residue tissues, Ø up to 1 mm, random oriented and distributed.

Special features

- Abundant partly to completely infilled voids with mainly mineral aggregates (excrements), which generally are interconnected and superimposed. A few types of mineral excrements occur. About 70% consists of small (40-100 µm Ø) irregular equant excrements composed of nearly only clay-sized material. Of second importance are regular smooth compact bacillocylinders (ca. 150-200 µm Ø, ca. 280-380 µm long; ca. 15%) composed of the same material. All stages of packed and welded excrements occur. The bulk part is weakly welded to welded. A number of coarse mineral grains, often with a thin clay-rich coating form part of the infillings.
- Along voids, whether infilled or not, commonly compacted zones are present, which often are broken and fragments displaced or disappeared. Thickness zones up to 450 µm, random oriented and distributed. Compacted material generally composed of mineral excrements.
- Few complete infillings in regular smooth channels, Ø ca. 3 mm, composed of darkred compact soil material missing most of the coarse sand minerals. In the infillings locally small mammilated vughs occur. Infillings random oriented and distributed in the upper part of the section.

- Common coatings and completely infilled small voids with the oriented clay containing iron occurring in small areas (ca. 15% s.a.) in the groundmass, not completely disturbed by faunal activity, mainly present below 70 cm depth. Thickness cutans up to 40 µm, random oriented and distributed. Few embedded fragments of these oriented clay features, Ø up to 60 µm, occur over the whole depth, random oriented and distributed.
- Few embedded charcoal fragments up to 2,5 mm Ø, random orientation, decreasing in quantity with depth.

Brief micromorphological description

Structure

Apedal soil material containing common, generally regular channels, Ø up to 5 mm and abundant irregular interconnected vughs of many sizes, formed between mineral aggregates (excrements) in abundant interconnected infillings.

Groundmass

Fine textured soil material including grain sizes up to and inclusive coarse sand. Size limit coarse/fine material 10 µm, c:f = 35:65; related distribution: open porphyric. The coarse mineral material consists mainly of quartz and some other minerals (biotite, epidote) and rocj fragments. Biotites are moderately altered, other minerals fresh or nearly unaltered. The dark red fine material is mainly clay-sized; the b-fabric weak random striated. A few root fragments, Ø up to 1 mm, when decomposing cell-wall residue tissues remain.

Special features

- Abundant partly to completely infilled voids with mainly mineral aggregates (excrements), which are interconnected and superimposed. The excrements are mainly small (40-100 µm Ø) irregular equant excrement (ca. 70%) and regular bacillocylinders (ca. 150-200 µm Ø, ca. 15%) composed of nearly only clay sized material. All stages of packed and welded excrements occur.
- Common compacted zones along whether or not infilled voids, which often are broken, thickness up to 450 µm.
- Few complete infillings in channels (Ø ca. 3 m) with compact soil material, missing most coarse sand grains, occurring in upper part of the section.
- Few complete infillings in channels (Ø 2-4 mm), with reddish brown material with dark brown rines; upper part of the section.
- Common coatings (thickness up to 40 µm) and completely infilled small voids with oriented clay containing iron occurring in ca. 15% of relatively undisturbed groundmass below 70 cm depth. Few embedded fragments of these oriented clay features, Ø up to 60 µm, random distributed.
- Few charcoal fragments, Ø up to 2,5 mm.

Brief combined micromorphological description

Profile No. L 1 (MOC-2) Lichinga.

Four thin sections are studied; 1: 20-35 cm (4546); 2: 60-75 cm (4547); 3: 105-120 cm (4548); 4: 160-175 cm (4549) depth.

Structure

The soil material is essential apedal and highly porous. Channels up to 10 mm wide and a few cm long occur over the whole depth; quantities few to common. Abundant irregular interconnected vughs of many sizes, formed between mineral aggregates (mainly excrements) in abundant interconnected infillings.

Groundmass

The fine textured soil material includes grain sizes up to and inclusive coarse sand. In the topsoil incidentally larger grains up to 3 mm are present. The size limit coarse/fine material is 10 µm. The quantities of coarse and fine material are about equal in the top (1), deeper the fine material dominates slightly. Related c/f distribution is essentially porphyric. The coarse mineral material consists predominantly of quartz with a few black and other minerals (biotites, epidotes) and rock fragments. Biotites generally are moderately altered, plates become separated. With depth biotites and rock fragments become more numerous. In the topsoil (1) are a few coarse root fragments present. The fine material consists mainly of clay-sized material containing a very few particles up to 10 µm. The b-fabric is weak monostriated in the upper part of the pedon, becoming slightly stronger developed with depth changing into a random striated b-fabric.

Special features

- Abundant partly to completely infilled voids with mainly mineral aggregates (excrements), which are interconnected and super-imposed occur over the whole studied depth. Most of them are small (40-100 µm) irregular equant excrements (70% or more) and regular bacillocylinders, Ø 150-250 µm, composed of nearly only clay-sized material. All stages of packed and welded excrements occur. Coarse mineral grains are present as admixtures in infillings, occurring as individual grains or embedded in welded aggregates. This type of infillings occupy 70% or more of the groundmass in all thin sections.
- Common compacted zones along, whether or not infilled, voids, which often are broken, thickness up to 450 µm.
- Few to common channels, Ø 2-5 mm, infilled with compact soil material, missing most of the coarse sand grains, occur over the whole studied depth. Locally small mammilated vughs occur in these infillings. Part of them have dark brown rims up to 150 µm thick.
- In the studied pedon clay illuviation features occur. Coatings and completely infilled small voids with the oriented clay containing iron are present in small areas undisturbed

by faunal activity in the thin sections 1 and 2. In these areas their quantities fulfill the requirements for an argillic horizon. Few embedded fragments of these oriented clay features are present over the whole studied depth.

- Few charchoal fragments up to 3 mm in diamter occur till 70 cm depth. Randomly distributed.
- A few black rounded nodules including coarse mineral grains are present from 70 cm depth onwards. Diam. up to 3 mm, randomly distributed.

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