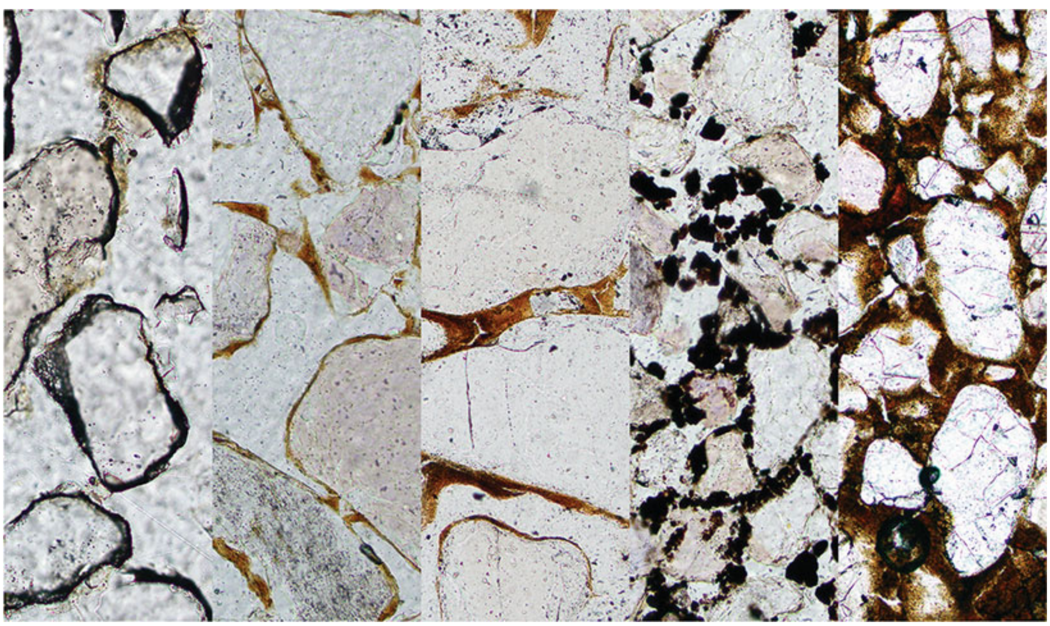
Chapter 2

The Organization of Soil Fragments

File 10: Concept of Fabric

Kubiëna (1938) was the first to introduce the concept of fabric in soil micromorphology, so this term has been used in soil micromorphology for a long time. The term "fabric" was initially applied to rocks by geologists and petrologists. This type of fabric is defined as the "factor of the texture of a crystalline rock which depends on the relative sizes, the shapes, and the arrangement of the component crystals" (Matthews and Boyer 1976). This definition has been adapted for soil micromorphology and its latest definition has been given by Bullock et al. (1985) as: "soil fabric deals with the total organization of a soil, expressed by the spatial arrangement of the soil constituents (solid, liquid, and gaseous), their shape, size, and frequency, considered from a configurational, functional and genetic view-point". In conclusion, the soil micromorphologist should consider the fabric as an arrangement and/or organization of soil constituents.

Fabrics can be very complex and this concept can be encountered in many different circumstances. For instance, the concept of fabric is mainly related to soil microstructure (see "File 9", "File 20", and "File 21"), but also associated to the c/f related distribution (see "File 13" and "File 14"), b-fabric (see "File 45" and "File 46"), as well as pedofeatures (see "File 9" and Chap. 4). Generally speaking, the fabric is related to the type of light used, as well as the scale of observation, i.e. the magnification of the microscope lens (see "File 11").



Examples of various fabrics related to the main c/f distributions (see "File 13"). All microphotographs are in PPL.

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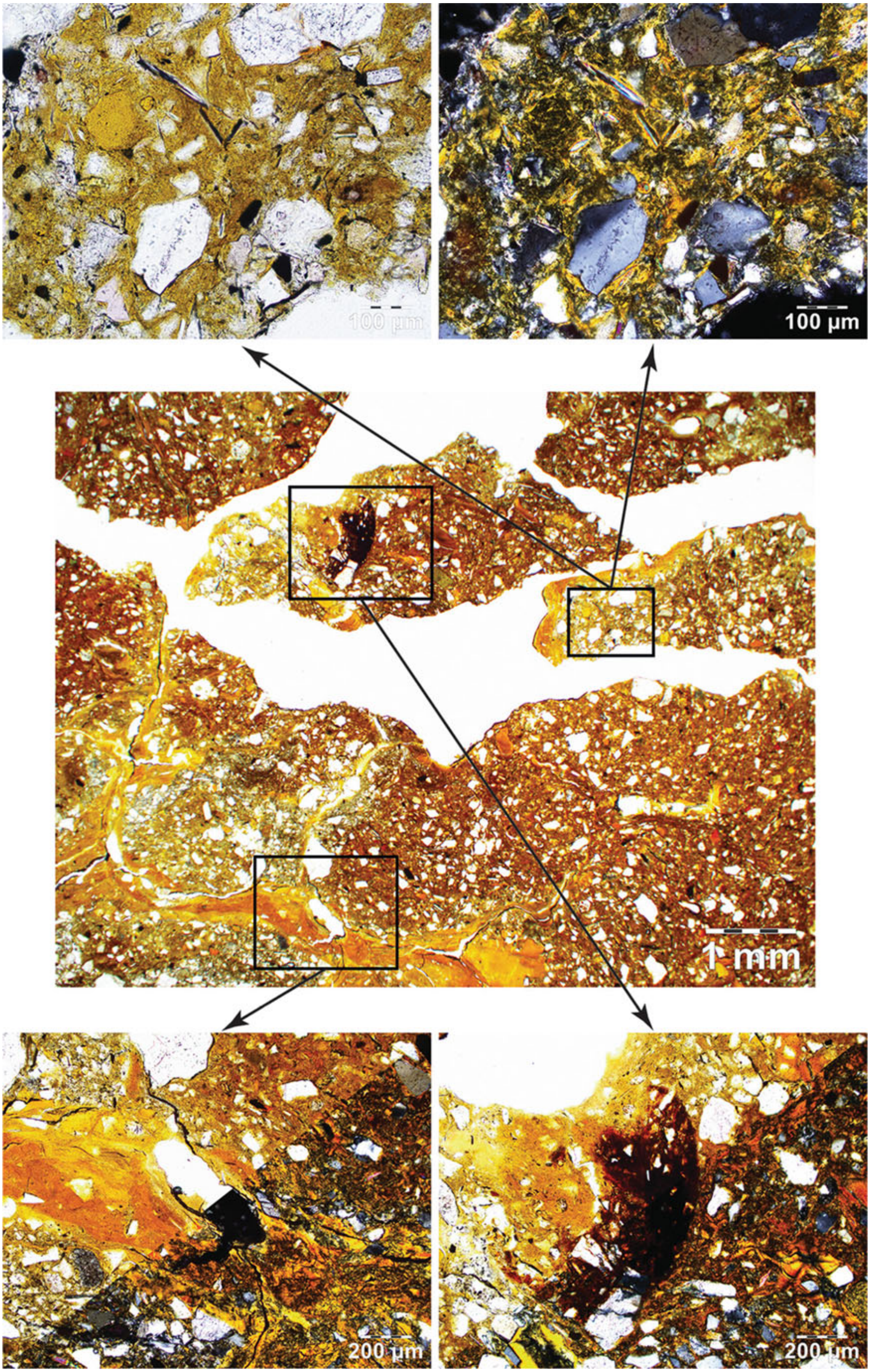

100 µm
100 µm
1 mm
200 µm
200 µm

File 11: Multiscalar Approach to Fabric

Fabric is a multiscalar concept that is used to describe homogeneous and heterogeneous units. The example given in this section shows fabrics observed at various magnifications with different soil components and features. Fabric units are units delimited by natural boundaries, visually homogeneous at the scale of observation and distinct from other fabric units (Bullock et al. 1985; Stoops 2003). However, increasing the magnification leads to an increase in either homogeneity or heterogeneity, depending on the fabric and feature involved.

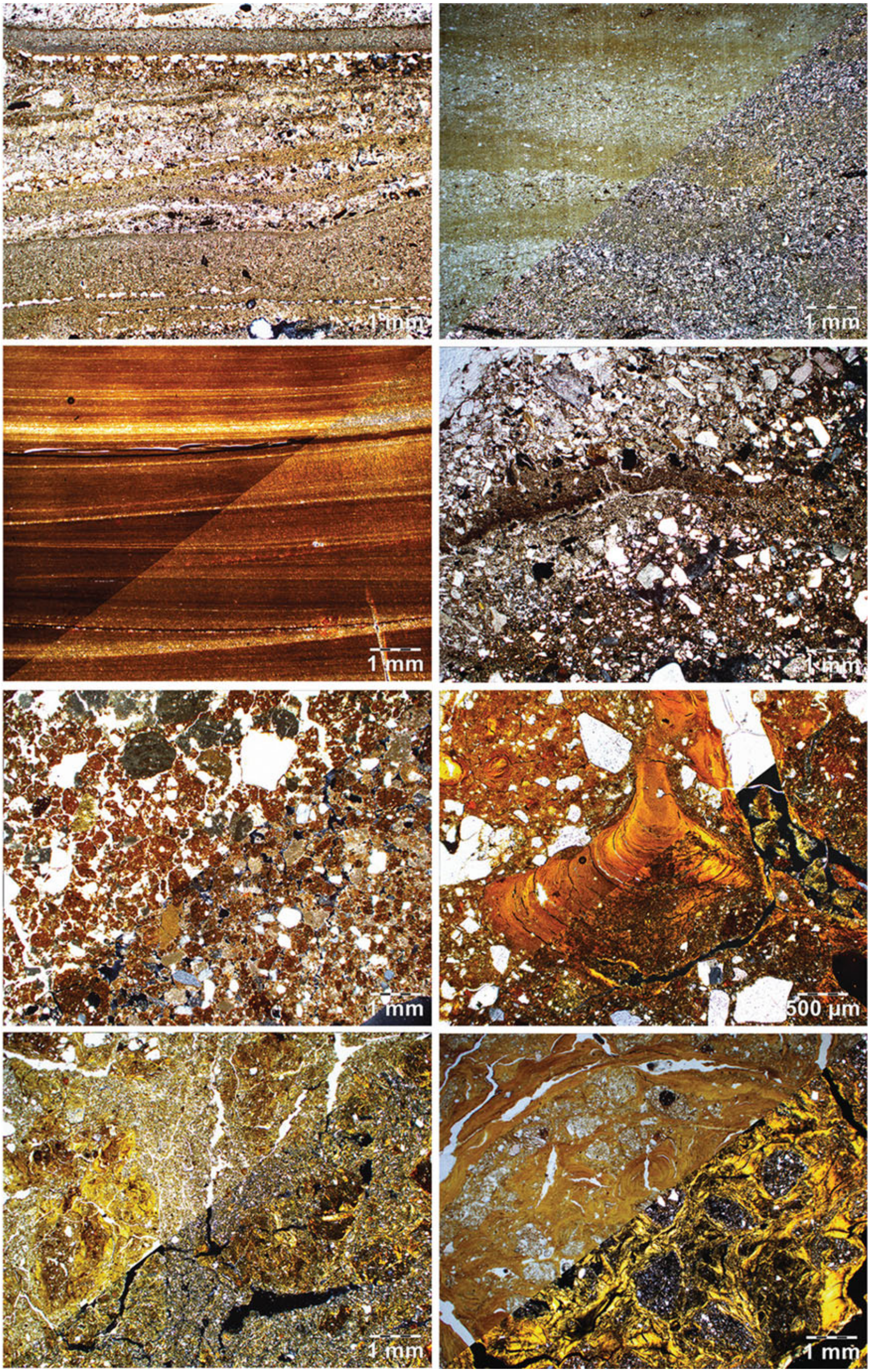
1., central view; 2.–3., upper views; 4.–5., lower views.

1. Central picture: general view at low magnification of a soil thin section (in PPL) showing a mottled soil groundmass with large elongated voids (in white). The arrows point to magnified details of the fabric displayed in the microphotographs.

2.–3. Close-up view showing the presence of quartz grains (each of them being a fabric unit) in a clayey and fine silty micromass (left: PPL; right: XPL). This arrangement constitutes the base material of the soil.

4. Left: a specific pedofeature called "clay coating" (see "File 56" and "File 57"), formed by clay layers associated with iron oxyhydroxides. These coatings display a specific fabric, also called "partial fabric" by Bullock et al. (1985) and Stoops (2003) at the given magnification.

5. Right: a specific pedofeature called a "matrix nodule" formed by the concentration of oxyhydroxides in the groundmass (see "File 48"). This nodule is characterized by a specific fabric at the given magnification.

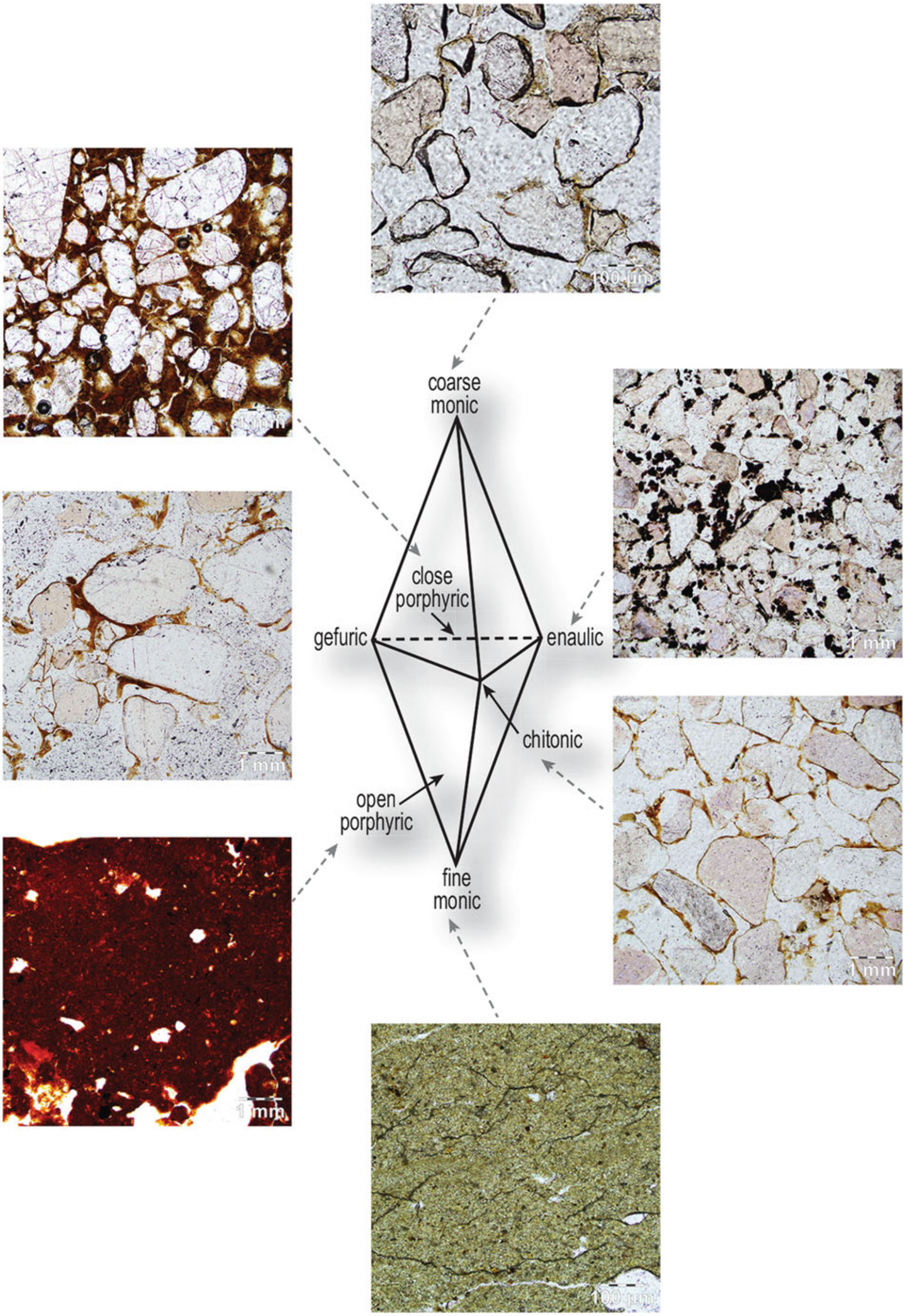

1 mm
1 mm
1 mm
1 mm
1 mm
500 µm
1 mm
1 mm

File 12: Basic Distribution Patterns

A pattern is the spatial arrangement of fabric units (Stoops 2003). Two types of patterns are usually defined: the distribution patterns and the orientation patterns. This section illustrates the basic distribution patterns commonly observed in thin sections, which are the distribution of fabric units of the same type with regard to each other (Stoops 2003).

Captions from upper left corner to lower right corner.

1.–3. Three examples of banded patterns formed by alternating layers of different grain size. (1) Alternating clayey, silty, and coarse layers (PPL); (2) Alternating coarse and silty layers; (3) Alternating very fine and fine clayey layers.
4. Linear pattern illustrated by a fabric unit organized along a line.
5. Random pattern characterized by a random distribution of the fabric units.
6. Fan-like pattern constituted by multiple clay infillings, organized in a fan-like morphology. In this case, the fabric units create a fan-like pattern at a specific scale.
7. Clustered pattern defined by a grouping of fabric units emphasized by both their colour and the void distribution in this example.
8. Interlaced pattern showing interlaced fabric units constituted by clay coatings and infillings in this example.


100 µm
1 mm
coarse
monic
close
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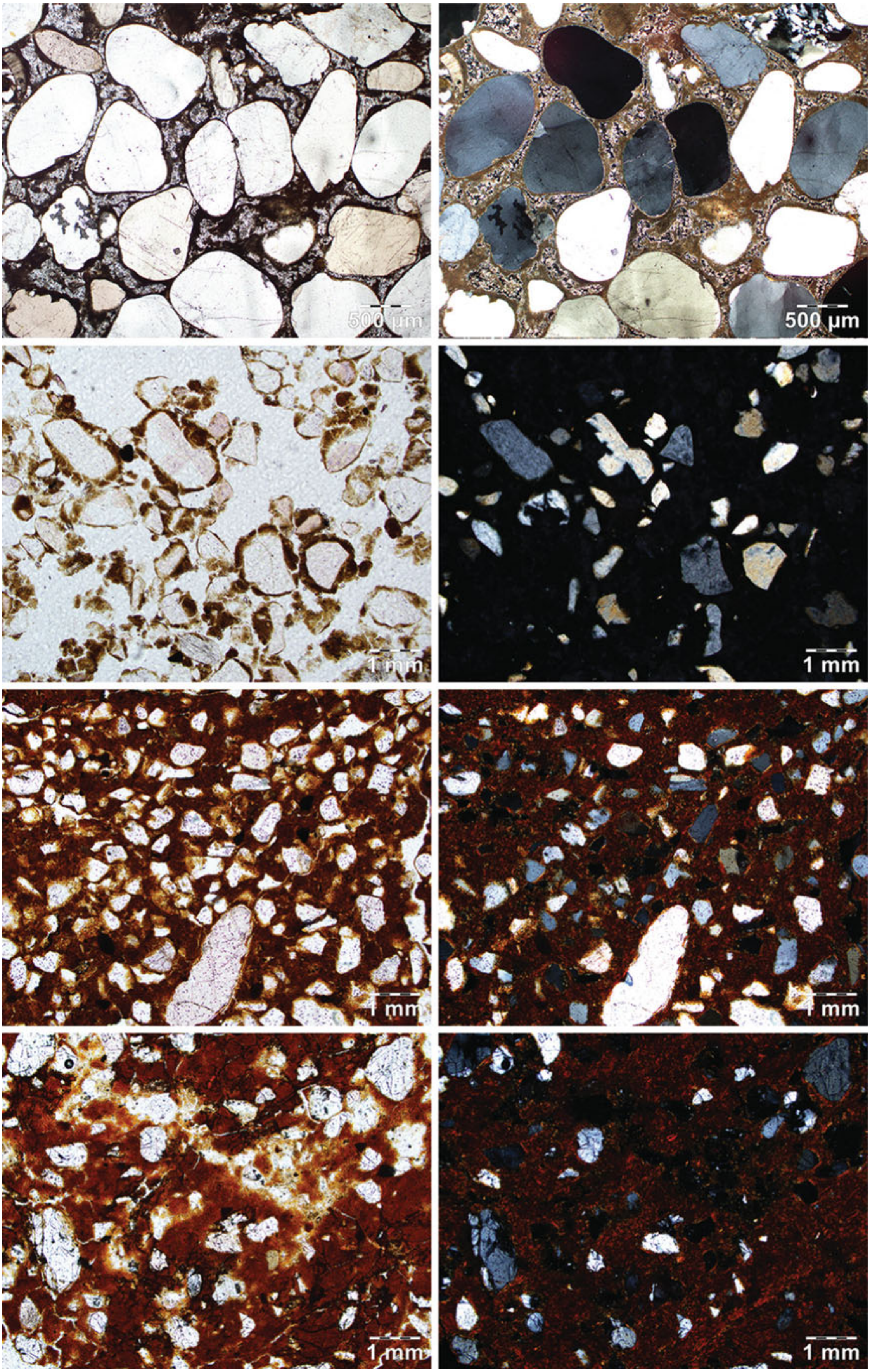
enaulic
1 mm
1 mm
chitonic
open
porphyric
1 mm
fine
monic
1 mm
100 µm

File 13: c/f Related Distributions I

The c/f related distribution refers to the distribution of coarse fabric units compared to fine fabric units and, if applicable, their associated pores. It has to be emphasized that this concept is purely descriptive and does not consider the interpretation of such fabric units. Stoops and Jongerius (1975) proposed a bipyramid of tetrahedra to summarize the basic c/f related distribution. This geometrical shape is modified and used in this section to illustrate the main c/f patterns.

Captions given clockwise from the upper top picture. All microphotographs in PPL.

1. Coarse monic: there is only one size of fabric unit, in this case, which is coarser than the given c/f limit chosen by the observer. Quartz grains are loosely arranged with a quasi-absence of fine material.
2. Enaulic: fine fabric units form small aggregates (i.e. micro-aggregates) inside the space between the coarse fabric units. Organic micro-aggregates spread inside the space between quartz grains.
3. Chitonic: coarse fabric units are coated by fine fabric units. Quartz grains are surrounded by brownish clay and oxyhydroxide thin layers.
4. Fine monic: there is only one size of fabric unit, in this case, which is finer than the given c/f limit chosen by the observer. A very fine silty and clayey mixture with a quasi-absence of coarse material.
5. Open porphyric: the coarse fabric units are scattered in a dense micromass of fine fabric units, and the distance between the coarse fabric units is more than twice their average size. Rare quartz grains are floating in a reddish clayey micromass.
6. Gefuric: coarse fabric units are connected by bridges of fine fabric units. Quartz grains are bound by brownish clay and oxyhydroxide material.
7. Close porphyric: the coarse fabric units are dispersed in a dense micromass of fine fabric units, and have many points of contact. Quartz grains are embedded in a reddish clayey micromass.

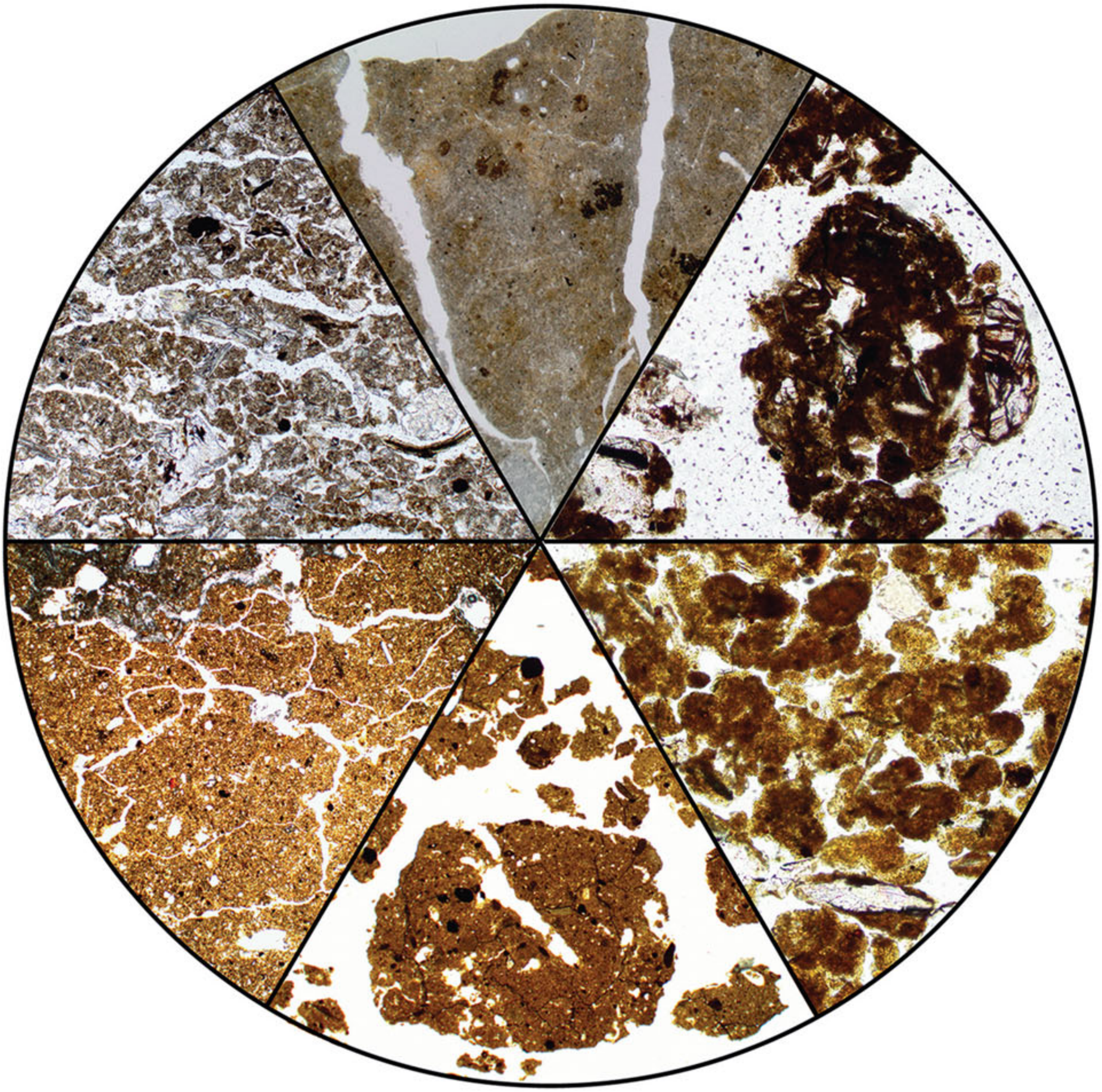

500 µm
500 µm
1 mm
1 mm
1 mm
1 mm
1 mm
1 mm

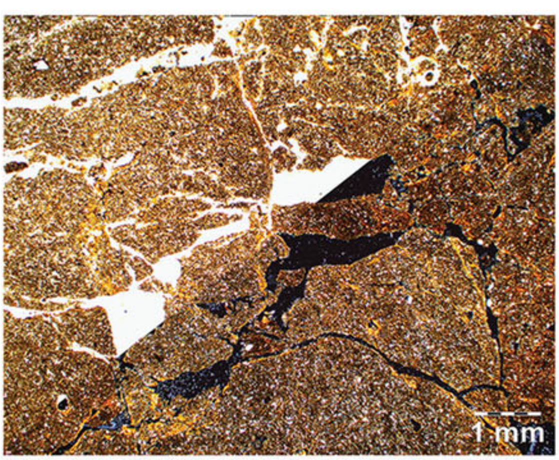
File 14: c/f Related Distributions II

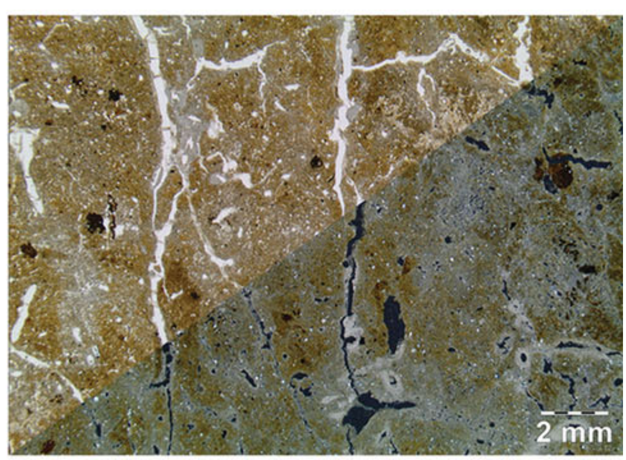
The c/f related distribution refers to the distribution of coarse fabric units compared to fine fabric units and, if applicable, their associated pores. It has to be emphasized that this concept is purely descriptive and does not consider the interpretation of these fabric units. This section shows different variations in chitonic, gefuric, and porphyric c/f related distributions.

Captions from upper left corner to lower right corner.

1.–2. Chitonic: coarse fabric units are coated by fine fabric units. In the picture, quartz grains are surrounded by thin layers of micritic calcite. The space between the grains is secondarily filled by a cement made of microsparitic calcite (left: PPL; right: XPL).
3.–4. Chito-gefuric: the coarse fabric units are both coated and connected by bridges of fine fabric units. Quartz grains are surrounded and bounded by brownish clay and fine material rich in oxyhydroxides (left: PPL; right: XPL).
5.–6. Single-spaced porphyric: scattered coarse fabric units float in a dense micromass of fine fabric units. However, the distance between the coarse fabric units is less than their average size. Quartz grains are dispersed in a reddish clayey micromass (left: PPL; right: XPL).
7.–8. Double-spaced porphyric: the coarse fabric units are floating in a dense micromass of fine fabric units, and the distance between them is more than one and less than twice their average size. Quartz grains are embedded in a reddish clayey micromass (left: PPL; right: XPL).




1 mm

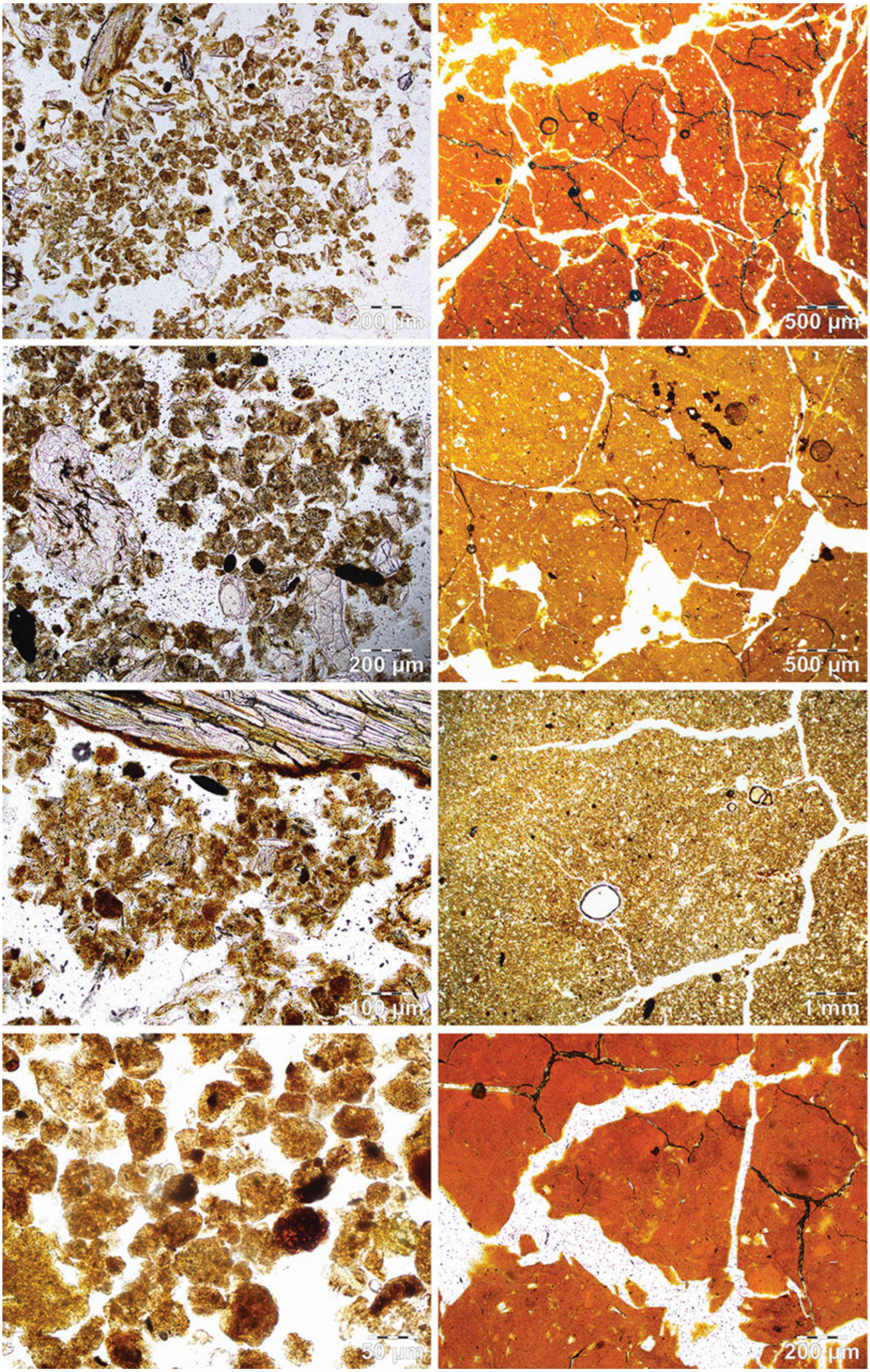

2 mm

File 15: Aggregates and Aggregation

Aggregation and aggregates (also called peds) are directly related to the soil structure. Their role is fundamental in defining soil properties, as aggregates are typically a product of pedogenesis. Aggregates are bodies separate from the soil groundmass, clearly delimited from each other and/or the surrounding soil material. In soil microscopy, they are first defined by their morphology.

Captions from top circle clockwise to lower right corner.

1. Captions are given clockwise starting from the uppermost slice. Photographs are in PPL. *Prisms*: they are vertically elongate aggregates, usually bounded by planar voids; prisms are only clearly visible if the thin section is big enough to contain them (see item 3., this plate). *Crumbs*: variously rounded peds appearing porous at the microscopic scale. *Granules*: variously rounded peds appearing non-porous at the microscopic scale. *Subangular blocky peds*: peds of more or less equant size with a subangular shape; they often correspond to a macroscopic subangular blocky structure. *Angular blocky peds*: peds of more or less equant size with angular edges; they mostly correspond to a macroscopic polyhedral structure. *Plates*: plates form generally elongate and sub-horizontal aggregates; in the picture, plates have a lenticular shape, but it is also possible to observe simple straight plates.
2. Angular blocky aggregates: at this low magnification, it is possible to see the general shape of the angular large peds.
3. Prisms at low magnification: the network of vertical and horizontal planar voids clearly separates the prismatic aggregates.

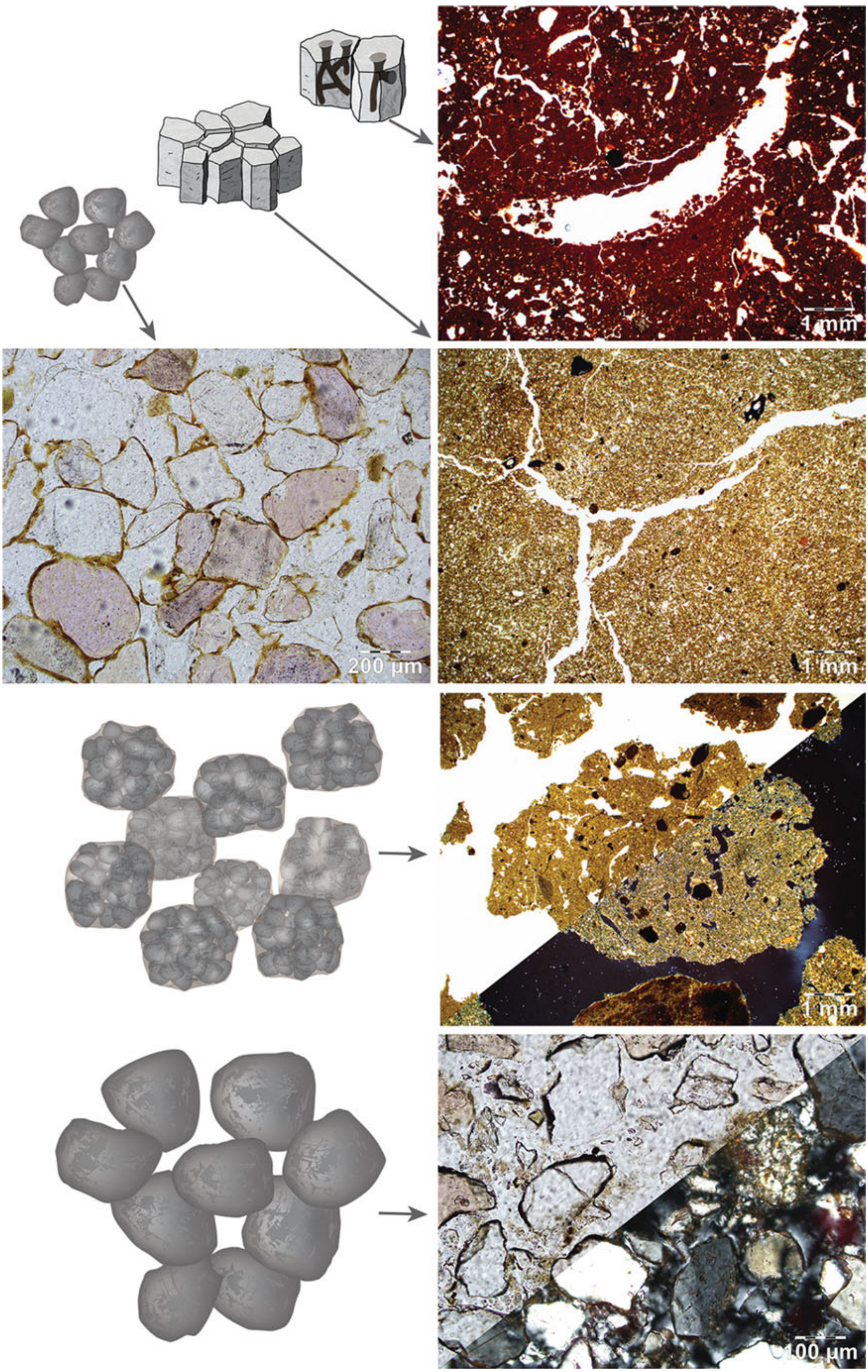

200 µm
500 µm
200 µm
500 µm
100 µm
1 mm
50 µm
200 µm

File 16: Degree of Separation and Accommodation of Aggregates

Aggregation and aggregates (also called peds) are directly related to the soil structure. Their role is fundamental in defining soil properties, as aggregates are typically a product of pedogenesis. Aggregates are bodies separate from the soil groundmass, clearly delimited from each other and/or the surrounding soil material. In addition to their morphology, they are also defined by their degree of separation and accommodation. The degree of separation refers to preferential zones of weakness illustrated by voids in soil microscopy. The accommodation is the degree to which adjacent ped faces coincide in a complementary way.

Captions from upper left corner to lower right corner. All microphotographs in PPL.

1. Granular aggregates showing a high degree of separation.
2. Angular blocky peds with a high degree of separation.
3. Crumb aggregates with a moderate degree of separation.
4. Angular blocky peds with a moderate degree of separation.
5. Crumb aggregates with a weak degree of separation.
6. Weakly separated angular blocky peds.
7. Rounded aggregates cannot be accommodated.
8. Example of accommodated blocky aggregates.

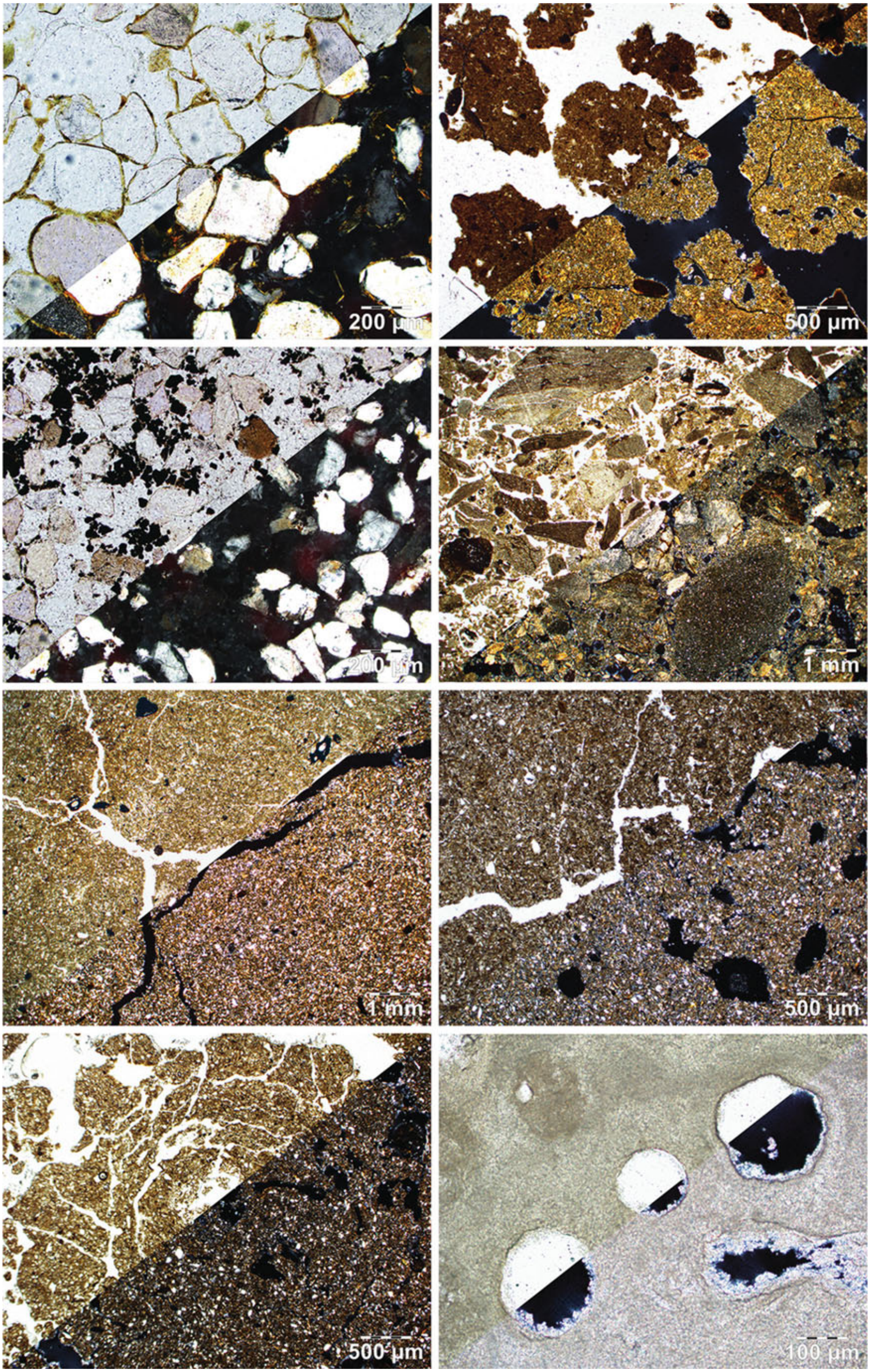

1 mm
200 µm
1 mm
1 mm
100 µm

File 17: The Nature of Voids

Voids are spaces unoccupied by soil material. Soil micromorphologists distinguish between various types of voids, according to their shape and arrangement. Moreover, in soil microscopy, voids between clay particles are not taken into account as they are below the resolution of the optical microscope.

Captions from upper left corner to lower right corner.

1. Soil scientists usually describe the nature of pores using a typology based on their origin, i.e. resulting from (a) packing of primary soil particles (bottom left), (b) cracks separating structural peds (centre), and (c) biological activity (upper right corner). Sketch modified from Weil and Brady (2017).
2. Example of a biological pore: this type of pore is called a “channel” (PPL).
3. Simple packing voids between quartz grains coated by fine material (PPL).
4. Planes, i.e. planar voids between angular peds (PPL).
5. In some soil aggregates, two types of pores have to be recognized: the intrapedal and the interpedal pores. Sketch modified from Weil and Brady (2017).
6. Subangular blocky ped with intrapedal pores surrounded by compound packing voids.
7. When the soil material is mainly composed by individual mineral particles, voids are only composed by the space between the particles themselves. Sketch modified from Weil and Brady (2017).
8. Quartz grains surrounded by simple packing voids.

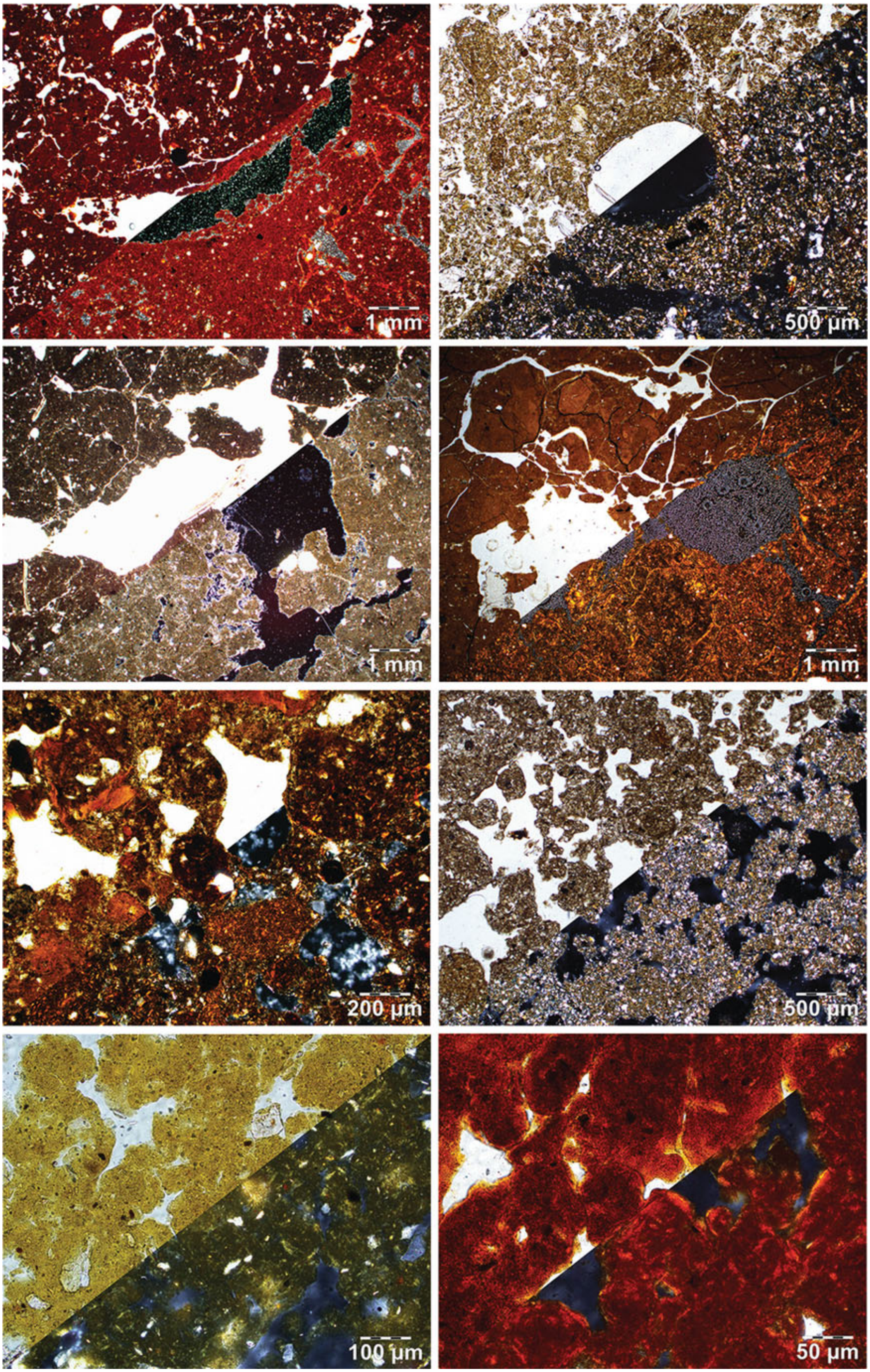

200 µm
500 µm
200 µm
1 mm
1 mm
500 µm
500 µm
100 µm

File 18: Morphology of Voids I

Voids are spaces unoccupied by soil material. Soil micromorphologists distinguish between various types of voids according to their shape and arrangement. Once their nature is identified, voids can be classified according to their morphology.

Captions from upper left corner to lower right corner.

1. Simple packing voids separating quartz grains coated by fine material.
2. Compound packing voids between non-accommodated crumb to subangular peds.
3. Complex packing voids separating quartz grains and organic micro-aggregates.
4. Complex packing voids between coarse rock fragments and soil aggregates of different sizes.
5. Straight planes are flat voids, accommodated with sharp pointy ends.
6. Zigzag planes are cracks abruptly changing directions throughout their length.
7. Curved planes are curved to circular voids, sometimes occurring as an onion skin with multiple layers.
8. Vesicles are round voids often observed in groups. They commonly indicate the presence of air bubbles in the soil material.


1 mm
500 µm
1 mm
1 mm
200 µm
500 µm
100 µm
50 µm

File 19: The Morphology of Voids II

Voids are spaces unoccupied by soil material. Soil micromorphologists distinguish between various types of voids, according to their shape and arrangement. Once their nature is identified, voids can be categorized according to their morphology.

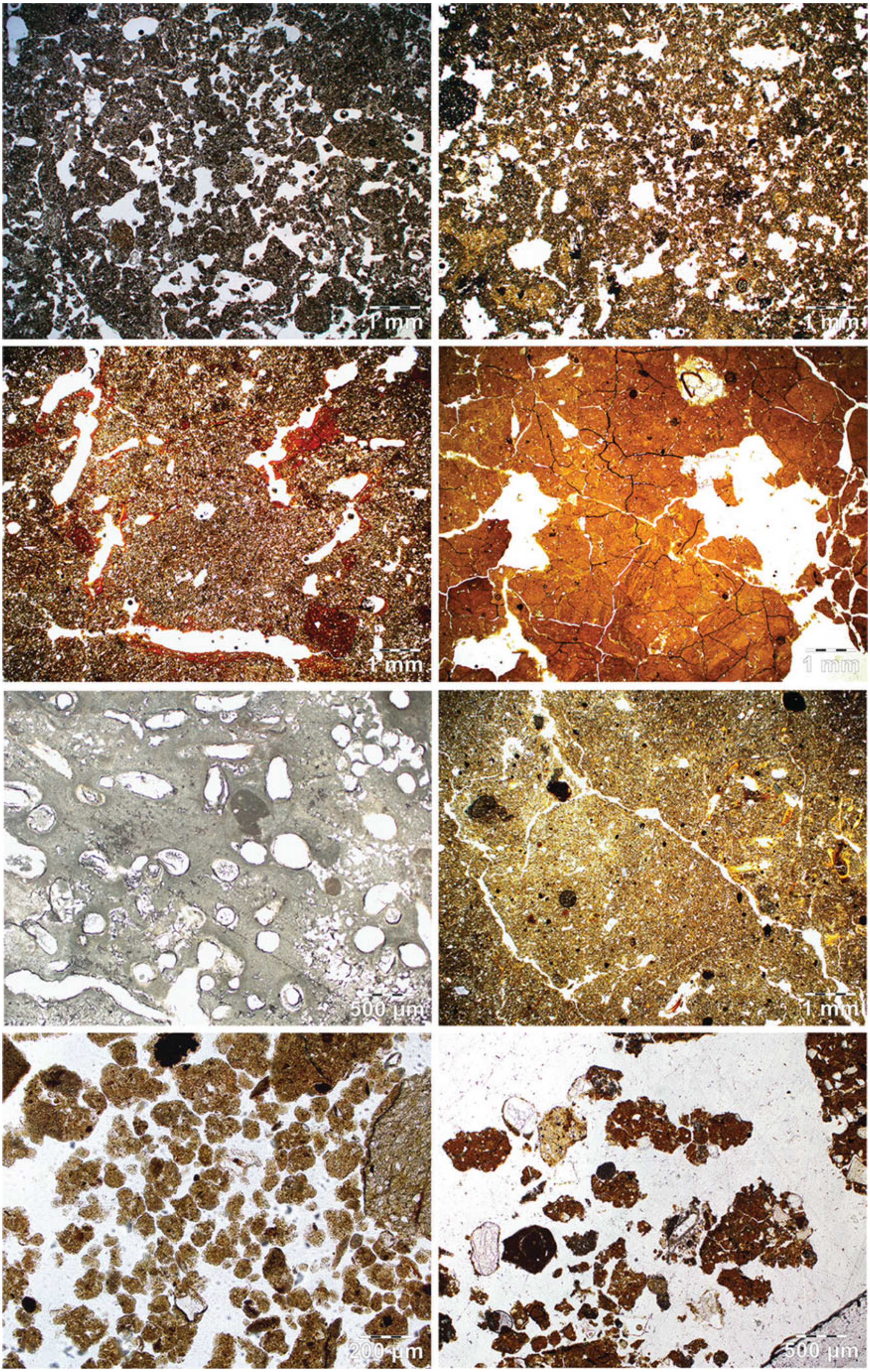
Captions from upper left corner to lower right corner.

1. Longitudinal section of a channel: such voids are tubular and smooth and cylindrical or arch-shaped in section. They are fairly uniform all along their length.
2. Transversal section of a channel: similar to the void described above, the section is usually round and smooth and may show some evidence of compacted soil material around the edges.

3.–4. Chambers are specific voids characterized by interconnecting channels and planes. Generally speaking, they are often larger than other voids in the same thin section.

5.–6. Vughs are irregular and non-elongated voids.

7.–8. Star-shaped vughs refer to voids having a triangular to polygonal shape due to the welding of rounded aggregates.

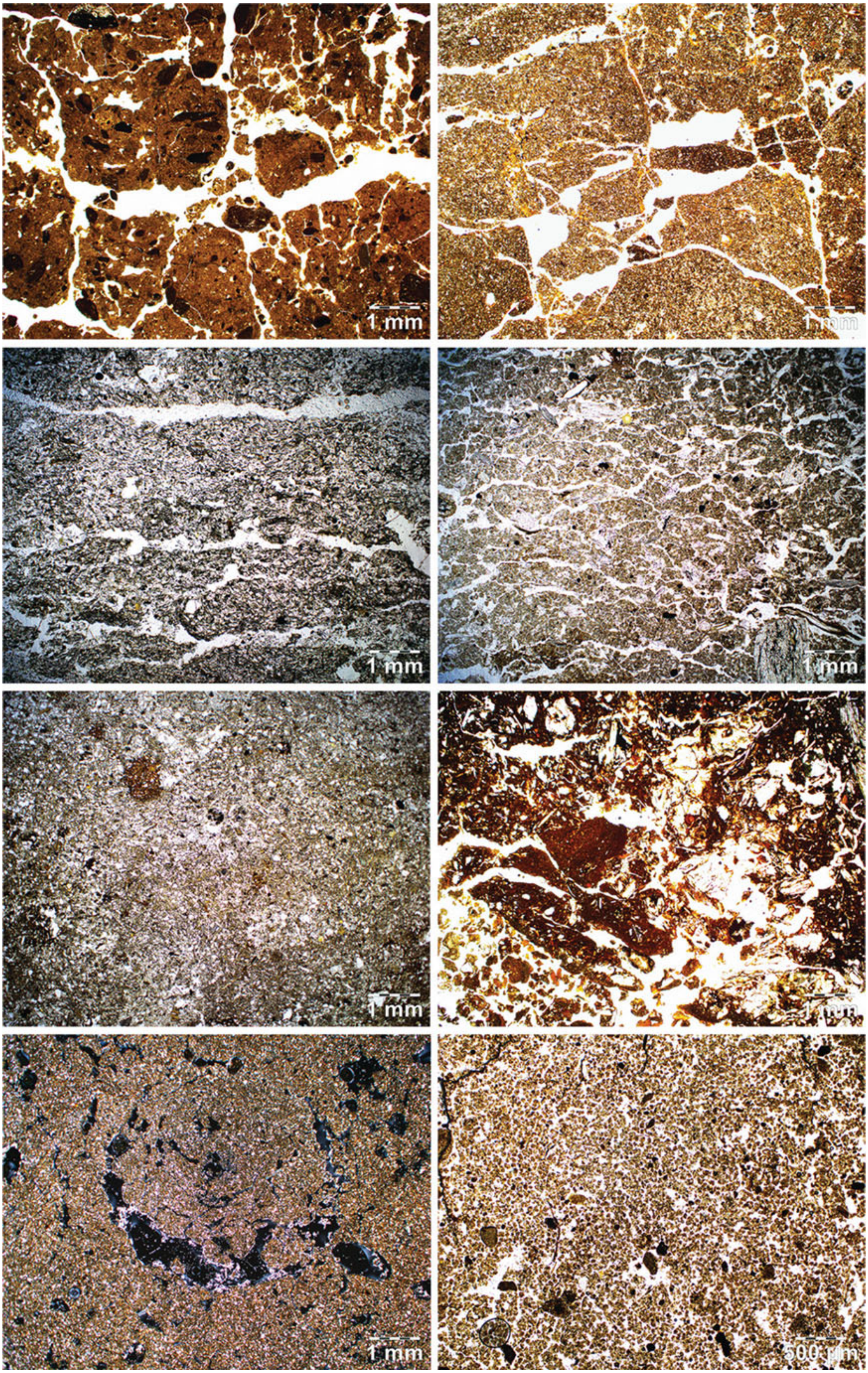

1 mm
1 mm
1 mm
1 mm
500 µm
1 mm
200 µm
500 µm

File 20: Microstructure I

Microstructure is a term used to describe the relationship between the solid and the non-solid phases of the soil. It is defined using the morphologies of aggregates and voids, degree of separation of aggregates, as well as the relationships between voids, aggregates, and mineral grains. It is obvious that soils display different types of microstructure according to the magnification used during observation. Therefore, a choice must be made for the description, as this concept is supported by a comprehensive approach to the thin section.

Captions from upper left corner to lower right corner. All microphotographs in PPL.

1. Vughy microstructure: dominant vughs disrupt the continuity of soil fine material.
2. Spongy microstructure: whatever the type of voids, they are numerous and often interconnected, interrupting the continuity of soil material.
3. Channel microstructure: an abundance of channels is present inside the soil groundmass.
4. Chamber microstructure: an abundance of chambers is present inside the soil groundmass.
5. Vesicular microstructure: an abundance of vesicles is present inside the soil groundmass. Some of the pores are also channels in the given example.
6. Fissure/crack (Bullock et al. 1985) microstructure: blocky aggregates are not fully separated. Generally, the groundmass is dense except for a few planes and possibly some channels, as shown in the picture.
7. Granules: small, rounded, non-accommodating aggregates, with no noticeable internal porosity. They are separated by compound packing voids and, in this case, the microstructure is termed as granular.
8. Crumbs: aggregates made of small, even tiny, clusters of groundmass, unevenly welded together, often more or less rounded, and incorporating some small pores. Put together, crumbs form a crumb microstructure.


1 mm
1 mm
1 mm
1 mm
1 mm
1 mm
1 mm
500 µm

File 21: Microstructure II

Microstructure is a term used to describe the relationship between the solid and the non-solid phases of the soil. It is defined using the morphologies of aggregates and voids, degree of separation of aggregates, as well as the relationships between voids, aggregates, and mineral grains. It is obvious that soils display different types of microstructure according to the magnification used during observation. Therefore, a choice must be made for the description, as this concept is supported by a comprehensive approach to the thin section.

Captions from upper left corner to lower right corner. All microphotographs in PPL if not otherwise specified.

1. Subangular blocky microstructure: short planar voids separate subangular blocky peds on all or most of their sides. Some other voids, such as small channels or vughs, can also be present inside or between aggregates. Finally, the faces of aggregates accommodate each other well.
2. Angular blocky microstructure: aggregates with sharp angular edges. Aggregates are separated by a network of planar voids and accommodate each other well. Other types of voids are rare.
3. Platy microstructure: when elongated and horizontal aggregates are stacked together, they are usually separated by planar voids.
4. Lenticular microstructure: elongated but lenticular aggregates (plates) are stacked and isolated from each other by sub-horizontal, wavy, and/or zigzag planar voids.
5. Massive microstructure: an abundant solid phase in which it is impossible to isolate aggregates or peds. Some small voids can be observed, but in the picture, white spots are quartz grains and not voids.
6. Complex microstructure: a mixture of two or more microstructural types. In this case, the microstructure can be named using a combination of terms defining the various microstructures observed in the soil thin section.
7. Spheroidal microstructure, or onion skin microstructure (FitzPatrick 1993): a specific microstructure recognized in the nomenclature adopted by Stoops (2003). The shape is given by discontinuous and concentric curved planar voids developed in a groundmass, XPL view.
8. Vermicular microstructure: it resembles an intertwining mass of worm shapes. It is a complex network of dense complete infillings lined by continuous or discontinuous wormlike voids. Introduced by FitzPatrick (1993), it is a specific microstructure also recognized in the nomenclature used by Stoops (2003).