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Trampling, Poaching and the Effect of Traffic

Philippe Rentzel[1], Cristiano Nicosia[2], Anne Gebhardt[3], David Brönnimann[1], Christine Pümpin[1] and Kristin Ismail-Meyer[1]

[1] *IPAS – Integrative Prehistory and Archaeological Science, University of Basel, Switzerland*
[2] *Centre de Recherches en Archéologie et Patrimoine, Université Libre de Bruxelles, Belgium*
[3] *UMR 7362, LIVE, Équipe Dynamique des Paysages, Université de Strasbourg, INRAP, France*

30.1 Introduction

Micromorphologists are often interested in identifying surfaces intercalated within stratified sequences, and in analysing the activities that took place on them. Humans and animals walking on a surface bring about modifications that can be seen under the microscope and that can be broadly defined as 'trampling' (see Miller 2017). Trampling can be also a depositional formation process where sediment is deposited, particularly in doorways of structures in temperate zones, leading to the accumulation of 'trample' (Banerjea 2015a, b; see also Matthews 1995; Matthews & French 2005). This depositional outcome of the trampling process is discussed in sections 30.2.3 and 30.5. Trampling in thin section is most often inferred on the base of the postdepositional alterations that it causes (see Table 30.1). In this chapter, we will focus more on this aspect of the process, by differentiating:

- Trampling *stricto sensu*, i.e. taking place on dry or prevalently dry conditions, as for example in roofed spaces, on both constructed or nonconstructed floors.
- Poaching (occasionally referred to as 'puddling' – see for example Gebhardt & Langohr 1999, p. 607), which indicates trampling on very wet, preferentially water-saturated sediments.
- Traffic, i.e. the effect of the passage of wheels (e.g., of carts).

The present chapter aims at illustrating the micromorphological features deriving from trampling, poaching and traffic through a series of examples from archaeological contexts. A last section will be devoted to experimental situations.

30.2 Trampling

An analysis of the conspicuous body of micromorphological literature mentioning trampling (see Table 30.1) allowed us to identify three main classes of modifications attributed to this process:

- Microstructural modifications. These include compaction, giving rise to massive microstructures, and the horizontal alignment of planar voids, resulting in a platy or laminar microstructure.
- Development of laminations, bedding or layering (also defined as 'fine layering' or 'microlayering'). The terms are used interchangeably but basically indicate: (i) the strong horizontal orientation and close packing of plant fragments (including grass, peat or turf), phytoliths (as in mats), dung, charcoal and inorganic components; or (ii) alternating sequences of fine layers with different compositions, such as for example turf layers interdigitated with layers of charcoal and ash (Milek 2012 – see Table 30.1), or superimposed thin layers of ash.
- Effects on coarser components such as charcoal, bone, chipped stone, ceramic material, shell, eggshell, etc. Such effects include: (i) integration or embedding in the groundmass; (ii) snapping or crushing of bone material and shell fragments, formation of microcharcoal; (iii) horizontal orientation and parallel distribution.

30.2.1 Trampling on Nonconstructed Floors

The group of nonconstructed floors includes trampled minerogenic deposits. A typical feature of such hardened surfaces consisting of local material is that they are generally no more than a few millimetres thick and are

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Table 30.1 Literature review on micromorphological publications where authors mention 'trampling' or 'traffic' processes. Contexts are all archaeological except where otherwise specified.

Ref.	Context	Microstructure	Lamination/fine layering	Coarse components
1, 2	Herbivore stabling in cave	Compact fabric	Laminated fabric; microlayering of organic litter	
3	Beaten earth floor	Laminar structure		Concentration of fine particulate material (resulting from sweeping away of coarser components)
	Byre		Laminated plant fragments and phytoliths	
4, 5	Constructed floors of tells	Subhorizontal orientation of larger voids, fine vertical cracks (passive zone)	Laminated microfabric with a well-developed subhorizontal fissural porosity, articulated lenses of phytoliths (active zone)	
		Densely packed aggregates of various sizes, porosity dominantly fissural, Subhorizontal orientation of voids (reactive zone)	Dense fine undulating fibrous, organic rich microfabric, a relic of matting	
		Compaction, densely packed subrounded to rounded aggregates mixed with anthropogenic constituents, Weakly developed subhorizontal fissures porosity (active zone)	Micro-lamination related to matting (sieve for human debris)	
	Nonconstructed occupation surfaces of tells	Compaction (active zone)	Regular laminated fabric; densely packed articulated phytoliths (bedding) (active zone)	
5	Mats or rugs made with plant material		Strongly layered lenses of articulated plant remains, Compacted irregular silty clay lenses (percolation through the apertures and compacted in moist conditions) and unoriented sandy deposits	
6	House floor, ethnoarchaeological		Well layered due to successive spreads of layers of fine and coarse material	
	Nonconstructed occupation surface, experimental	Compaction		
	Nonconstructed occupation surface	Compaction		
7	Possible stables		Dung pellets/plant remains/ spherulites with strong parallel referred and related orientation and linear parallel referred and related distribution	
	Accumulating refuse in open area	Complex packing voids	Plant remains with strong parallel orientation and linear parallel distribution	
8	Occupation deposits on floors	Dense microstructure with embedded or bridged related distributions		Moderately linear orientations and parallel distribution
	Plaster floors	Subhorizontal cracks		

Table 30.1 (Continued)

Ref.	Context	Microstructure	Lamination/fine layering	Coarse components
9, 10	Modern horse stable floor	Dominantly laminar structured Organic deposit		
	Domestic beaten floors, experimental	Massive microstructure		Integration of anthropogenic and allochtonous components
	Stable, experimental		Compacted layered crust of plant fragments from grass and hay fodder and bedding, trampled silts	
11	Stable floors		Layered plant fragments that depending on pH can be cemented (e.g., hydroxyapatite) or stained by phosphate	
12	Trampled hearths, experimental	Compaction, less open structure		Burnt bone snapped and crushed, Larger pieces of bone and charcoal pressed in the underlying substrate
13	Beaten/trampled occupation deposits		Laminations	Fine sorting, horizontal orientation of materials (bone, egg shell, mollusc shell)
14	Occupation deposits on floors		Finely comminuted plant remains mixed with subrounded/rounded aggregates of burnt and construction materials in thin compacted lenses	
15	Corridor turf floor, ethnoarchaeological	Massive microstructure, prismatic or platy microstructure	Layering (alternating lenses)	Artefacts are mainly <2 mm and embedded in floor sediments
	Kitchen floor, ethnoarchaeological	Well-developed platy microstructure	Layering (pink and grey ash and charcoal)	
	Fuel storage area, ethnoarchaeological	Well-developed platy microstructure	Horizontally bedded phytoliths within lenses of peat (fuel remains)	
	Pantry, ethnoarchaeological	Platy microstructure (bioturbated)	Peaty turf layers, interdigitated with uneven and discontinuous layers of charcoal and grey ash, Horizontally bedded phytoliths	
	Cattle byre, ethnoarchaeological	Well-developed platy and localised massive microstructure	Multilayered silty organic sediments, longer strands of plant tissues predominantly horizontally or Subhorizontally aligned	
	Sheephouse, ethnoarchaeological	Well-developed platy microstructure	Layers of dung and horizontally bedded grass tissues, as well as soil mixed with partially decomposed plant tissues	
16	Burnt vegetal bedding, experimental and archaeological		Laminations, alternating sequence of laminated fibrous charcoal/laminated fibrous charcoal and laminated phytoliths/laminated phytoliths	Stringers of crushed bone and chipped stone that defined surfaces within the constructed bedding unit (repeated addition of plant material to refresh the bedding surface)

(*Continued*)

Table 30.1 (Continued)

Ref.	Context	Microstructure	Lamination/fine layering	Coarse components
17	Nonconstructed earthen floor, experimental	Occasional subhorizontal fissures	Possible single layers of plant remains	
	Compacted trample, experimental		Frequent superimposed microlaminations	
	Mixed compacted trample and accumulation, experimental		Laminated bedding structures, plant remains with a parallel strong orientation aligned with the basal boundary	Strong parallel orientation and distribution of components
	Repeated / periodic accumulation		Linear and parallel distribution and local orientation of the coarser harder materials (aligned with the basal boundary), Microlaminations (e.g., superimposed fine lenses of calcitic ash)	
18	Surface with knapped artefacts, experimental	Compacted matrix		Clear horizontal disposition of subangular coarse materials, Microfractures of quartz artefacts and bone fragments

References: (1) Wattez *et al.* 1990, p. 437; (2) Macphail *et al.* 1997; (3) Davidson *et al.* 1992, p. 62; (4) Gé *et al.* 1993 pp. 153–159; (5) Matthews 1995 pp. 60–61; (6) Gebhardt 1995, pp. 32–33; (7) Matthews *et al.* 1996, p. 322; (8) Matthews *et al.* 1997 pp. 289, 300; (9) Cruise & Macphail 2001 pp. 185–186; (10) Macphail *et al.* 2004; (11) Goldberg & Macphail 2006, p. 265; (12) Miller *et al.* 2009, pp. 33, 35; (13) Macphail & Goldberg 2010, pp. 595–596; (14) Matthews 2010, p. 102; (15) Milek 2012, pp. 125–131; (16); Miller & Sievers 2012, pp. 3040, 3049; (17) Banerjea *et al.* 2015a pp. 95–8, 102; (18) Driscoll *et al.* 2016, pp. 4–5.

usually only faintly visible in the field (Bresson & Zambaux 1990; Miskovsky 2002, p. 545; Goldberg & Macphail 2006, p. 246; Rentzel 2009, p. 575; Ismail-Meyer *et al.* 2013, p. 327). In the case of the royal tomb of Qatna, which was cut out of Tertiary limestone (Pfälzner 2011), traces of digging were preserved on top of the bedrock by a thin layer of sand and fine gravels originating from the soft lime marl (Figure 30.1). Due to mechanical abrasion by trampling (Banerjea *et al.* 2015a, p. 105), parts of the marl were detached from the bedrock resulting in a continuous 0.5 mm thick planar void. The weakly stratified material showed a porosity of 5–10% and had a granular structure in some parts and a crack structure in others. This layer was overlain by a compacted accumulation of fine lime marl sand and soft sediments characterized by elongated lenses of clay and silt, which had been worked into the floor by trampling. Rare anthropogenic debris such as charcoal and bone splinters was embedded parallel to the basal layer. The deposit showed a massive structure with mainly planar voids (porosity 5–10%). All the encountered features gave the sediment a microlaminated aspect. Similar observations, albeit with more distinct

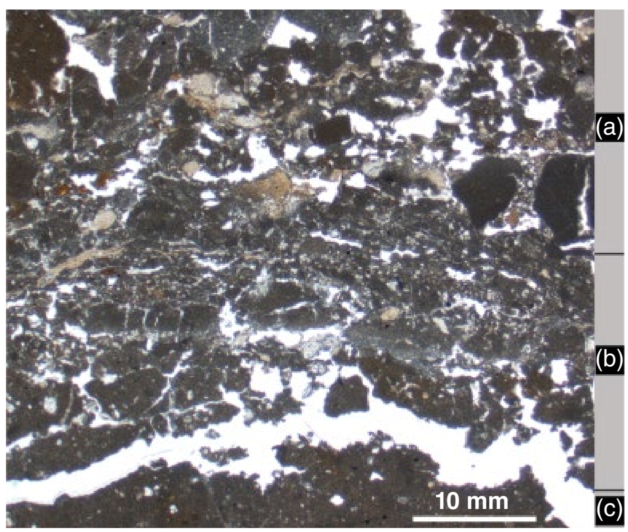

Figure 30.1 (a) Levelling layer. (b) Compacted trample (partly massive microstructure, planar and polyconcave voids, microlaminations, coarser components horizontally oriented, compressed soil peds). (c) Detached bedrock material (weak horizontal orientation of coarser components). Bronze Age royal rock-cut tomb, Tell Mishirfeh, Qatna (Syria). Thin-section scan.

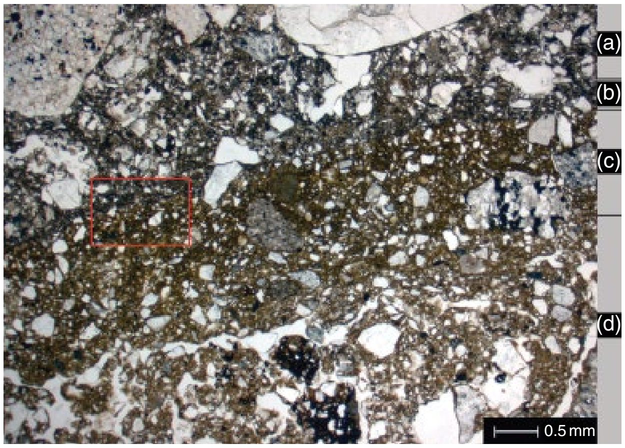

Figure 30.2 (a) Activity area; trample with microcharcoal, ashes and burnt loam (locally bedded, most coarser components horizontally oriented). (b) Compacted, trampled silt loam (massive microstructure, fine bedding, horizontally oriented coarser components). (c) Nonconstructed loam floor, upper part (massive microstructure). (d) Nonconstructed loam floor, lower part (partly massive microstructure; most coarser components horizontally oriented). Iron Age working pit of a pottery kiln, roofed area, Gasfabrik site, Basel (Switzerland). PPL.

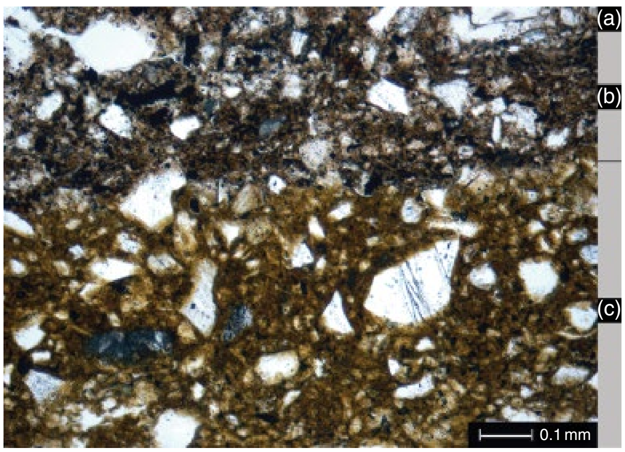

Figure 30.3 Detail of Figure 30.2 (see rectangle). PPL.

compaction features, were made in the access areas of Mycenaean tombs in Greece (Karkanas 2012, p. 2729).

A surface compacted by human activity on sandy loam was found preserved in a roofed zone of activity in a depression in front of an Iron Age ceramic kiln in Basel (Figure 30.2). The topmost trampled zone was only some 3 mm thick and very compact (<2% porosity). Unlike the unmodified lower areas, the clay and silt fraction was evenly distributed and impregnated by iron oxides. The lower boundary of this topmost compacted area was diffuse whilst the surface was sharply levelled and covered by a 0.2 mm thick and very compact layer of ash (Figure 30.3). Microcharcoals that lied on top of this surface were horizontally aligned.

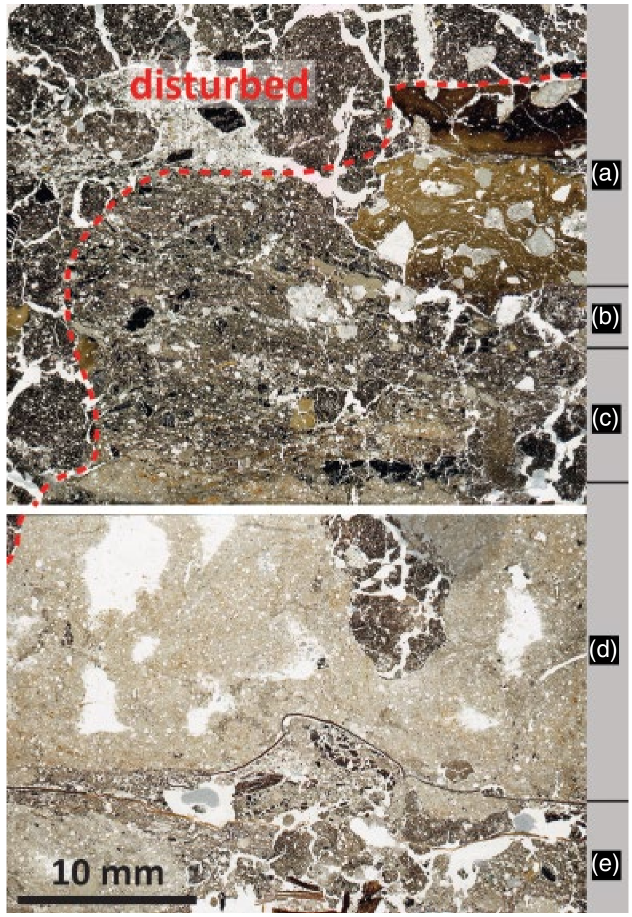

Figure 30.4 (a) and (b) Occupation layers, with ceramics. (c) Trampled occupation layer (massive microstructure, fine bedding, horizontally oriented coarser components). (d) Loam floor, sandy loam textured (massive microstructure), with basal bark layer. (e) Occupation deposit. Neolithic house, Lobsigesee, Bern (Switzerland). Thin-section scan.

30.2.2 Trampling on Constructed Floors

Prepared loam floors of allochthonous material are constructed features with an initial activity surface on top of the trampled floor (Courty *et al.* 1989, p. 124). Besides loam floors, this group also includes mortar floors, lime and gypsum plaster, peat or turf floors, 'brickearth' floors, and so forth, which will not be dealt with in detail here (see Adam 2011; Goldberg & Macphail 2006; Milek 2012; Matthews 2012; Huisman & Milek 2017, this book). The use of a loam floor typically results in a certain degree of alteration of the floor surface due to human activity. Consequently, the initial activity surface is covered gradually by reworked floor material on one hand and accumulated archaeological components, including organic and minerogenic soil material, on the other (Matthews 1995, 2003; Macphail *et al.* 2004; Milek 2012; Shillito & Ryan 2013; Banerjea *et al.* 2015a, b).

The constructed floors discovered at Bern-Lobsigesee (Figure 30.4) and in the Mithraeum of Biesheim

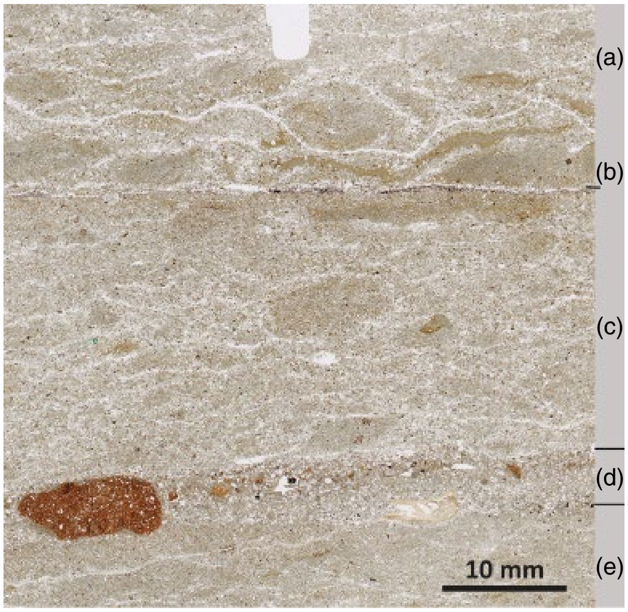

Figure 30.5 (a) Loam floor, silty sand textured (platy microstructure, locally massive, horizontally oriented lenses of elongated peds). (b) Soot layer (temple activities). (c) Loam floor, silty sand textured (same characteristics as (a)). (d) Mortar layer (renovation). (e) Loam floor, silty sand textured (same characteristics as (a)). Roman Mithraeum of Biesheim (France). Thin-section scan.

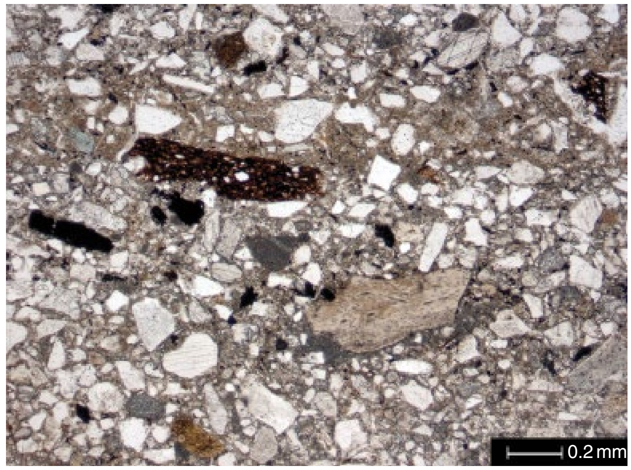

Figure 30.6 Detail of Figure 30.5, soot layer (b). In the central part trampled artefacts and microcharcoal resulting from temple activities appear on top of the dense loam floor. PPL.

(Figure 30.5), in Switzerland and France respectively, consisted of several centimetres of horizontal deposits of fine sediment with sharp upper and lower boundaries. The constructed floors exhibited characteristic traits such as a massive microstructure and low porosity. Loam fragments, which in the case of the floor uncovered at Bern-Lobsigesee originated from a Luvisol, showed a granostriated b-fabric.

The constructed floors encountered at Biesheim consisted of fine grained, carbonate rich floodplain deposits (Fortuné 2011). The floors were characterized by elongated lenses of silty sand. They also showed a massive microstructure and subhorizontal cracks separating the clods. The topmost parts of the floors were strongly compacted and overlain by trampled-in remains from activities associated with the renovation or use of the temple. The latter was attested to by the presence of very thin layers of carbon black (illumination), microcharcoals, rare burnt bones and sand (Figure 30.6). A compact layer of ash below a loam floor at Zug-Unteraltstadt (Switzerland) might have been added prior to the construction of the floor (e.g., preparation and drainage of the surface – Milek 2012; Ismail-Meyer 2012). (Figure 30.7).

30.2.3 Trampled Occupation Deposits

An accumulation of various mineral and organic components takes place, particularly in sheltered areas, during a phase of occupation (Matthews *et al.* 1997). Courty and Fedoroff (2002) have termed this a continuous succession of activity surfaces. The experimental observations made by Banerjea *et al.* (2015a), who characterized the accumulated sediment, termed 'compacted trample', in more detail (see Table 30.1), are interesting in this context. Analogous microscopic observations were made on the several centimetre-thick occupation layers unearthed in Zurich, Zug and Bern, Switzerland (Figures 30.4, 30.7 and 30.8 respectively). Such compact accretion layers generally consist mainly of (micro-)charcoal, organic fine material, ash and minerogenous components such as sand and gravel whereby the nature of the archaeological and minerogenic components depends, of course, on the respective activities. They contain areas with horizontal lenses of loam clods and show a pronounced microlamination, planar and / or polyconcave voids, a strong fragmentation of the components and a general tendency towards a horizontal orientation of the components. Moreover, sorting and a bimodal texture can also occur in places, as can a platy or sometimes blocky structure.

30.3 Poaching

At the macroscopic scale, convolutions or involutions are often associated with poaching (Figure 30.9). Such structures translate in thin section in undulating or wavy thin layers with distinct sorting of the coarse and fine fractions (Gebhardt & Langohr 1999) or with the formation of finely laminated crusts (Courty *et al.* 1989). Dusty clay coatings and crusts are normally ubiquitous and indicate surface slaking (Courty *et al.* 1989). Gebhardt & Langohr (1999) mention the presence, in areas where animals were herded (small cattle), of FeP crusts and coatings under the wavy structure and of strong reduction indicated by vivianite and pyrite.

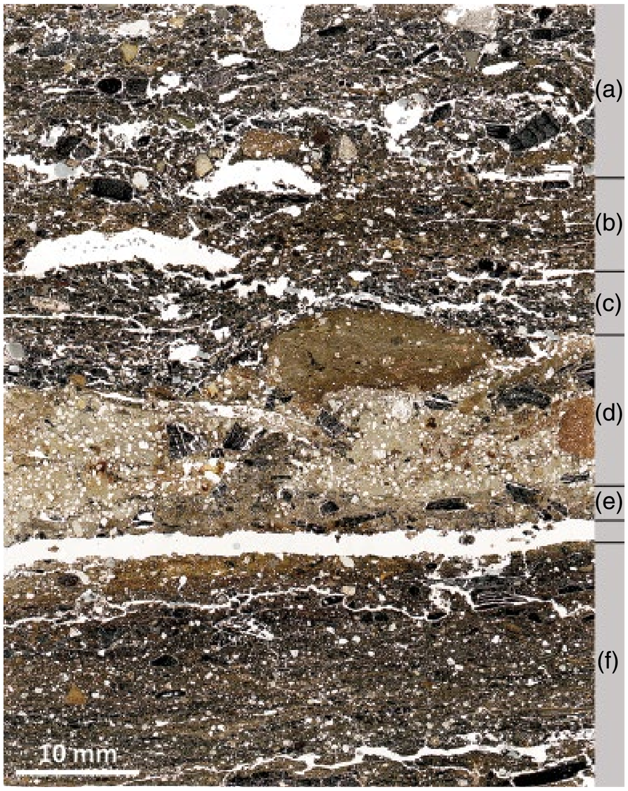

Figure 30.7 (a) Succession of activity surfaces: trample with ash, (micro)charcoal, bone and eggshell fragments (platy microstructure, planar and polyconcave voids, bedding, horizontal orientation of charcoal and elongated peds). (b) Same as (a) (massive and platy microstructure, planar and polyconcave voids, bedding, horizontal orientation of charcoal and elongated peds). (c) Succession of activity surfaces: trample with ash, (micro) charcoal, bone and burnt loam aggregates (compact grain microstructure, complex, planar and polyconcave voids, horizontally oriented coarser components). (d) Loam floor (massive microstructure, complex, planar and polyconcave voids, subhorizontally oriented coarser components). (e) Ash layer (massive microstructure, horizontally oriented coarser components). (f) Fe-P impregnated succession of activity surfaces rich in ash, (micro) charcoal and bones (massive microstructure, microlaminations, horizontally oriented coarser components). Medieval site of Zug-Unteraltstadt (Switzerland). Thin-section scan.

30.4 Traffic

Wheel ruts are mainly linear and parallel, sometimes crossing each other, and set within wide trackways (Gebhardt & Langohr 2015). Animal drawn carts can be very heavy, so ruts are usually several centimetres deep and show three main characteristics (Figure 30.10): (i) strong compression, able to lead to platy structure formation if cold conditions intervene (see Van Vliet-Lanoë 2010); (ii) common redoximorphic mottling in the compressed earth within the wheel ruts, caused by localized reduction due to impeded drainage – reduction can cause the mobilization of Fe and P and the formation of secondary features (Macphail *et al.* 2016); (iii) occasional anthropic artefacts within the trackways themselves (Paccolat *et al.* 2011).

These main micromorphological characteristics can help in differentiating wheel ruts from plough marks, as the latter are characterized by better aerated conditions, lack of redoxymorphic features and inclusions derived from manuring (see Déak *et al.* 2017, this book).

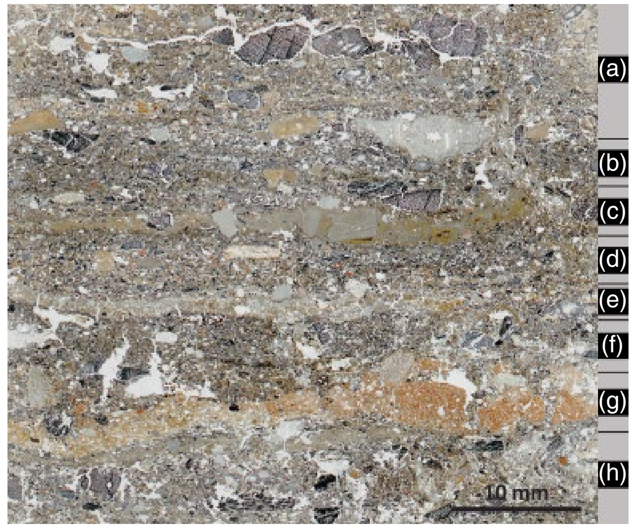

Figure 30.8 All units microlaminated and with coarser components horizontally oriented, except (c) and (g). (a) Trample of ashy loam with microcharcoal. (b) Trample of ashy loam with (micro)charcoal. (c) Trampled loam lenses (massive, partly subangular blocky microstructure). (d) Same as (b). (e) Trample of weathered daub and phytoliths (partly prismatic structure, several vesicular voids). (f) Same as (b) and (d). (g) Trampled loam lenses (massive, partly subangular blocky microstructure). (h) Trample of ashy loam with (micro-)charcoal (massive microstructure). Medieval roofed artisanal building, Münsterhof site, Zürich (Switzerland). Thin-section scan.

30.5 Experimentally Trampled Sediments and Surfaces

Experimental studies represent an approach frequently employed in geoarchaeology (e.g., Bell *et al.* 1996; Lawson *et al.* 2000; Goldberg & Macphail 2006, p. 247 – see Table 30.1). There have also been several experimental studies on the effects of trampling on artefact distributions (e.g., Stockton 1973; Courtin & Villa 1982; Nielsen 1991; Driscoll *et al.* 2016) and artefact morphology (e.g., Nicholson 1992; McBrearty *et al.* 1998; Lopinot & Ray 2007; Eren *et al.* 2010). However, such studies were carried out with geoarchaeological support only in recent years. This is different for ethnoarchaeological research

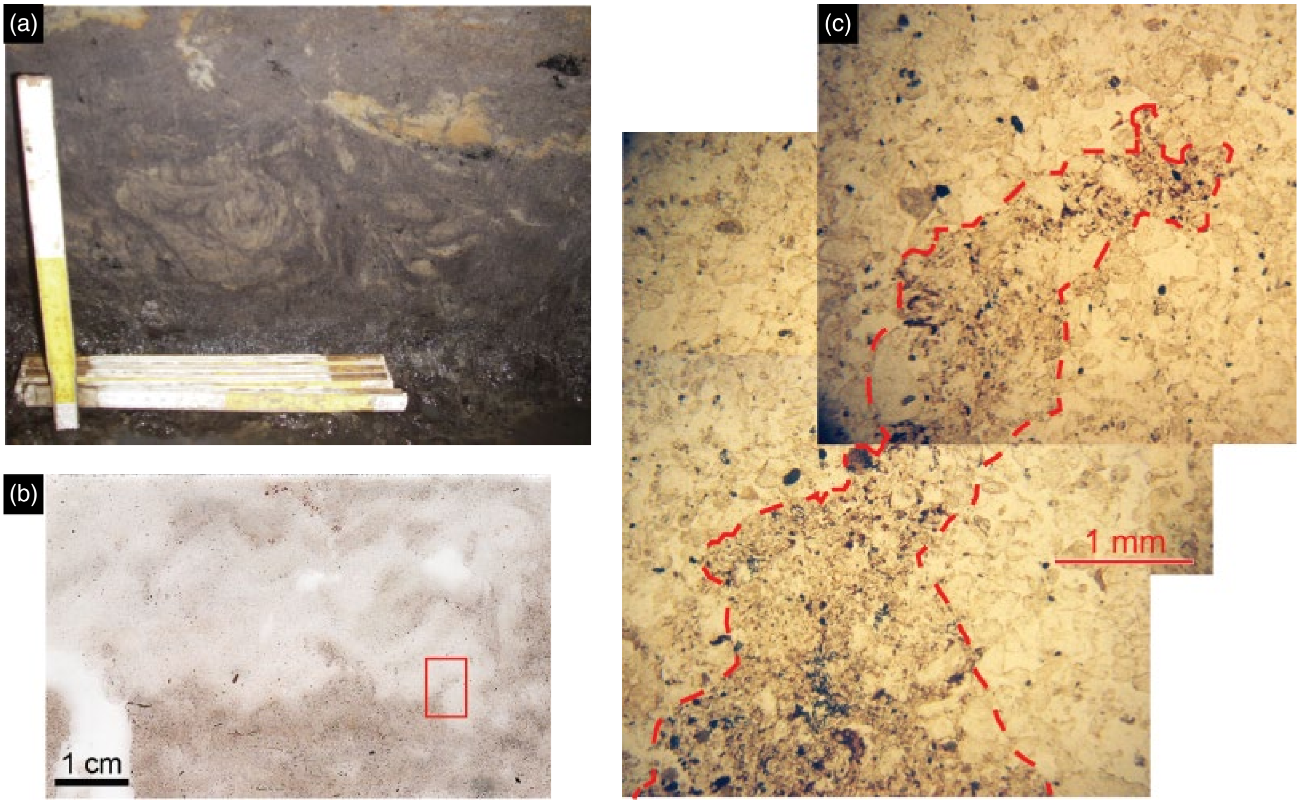

Figure 30.9 (a) Profile picture showing convolutions and involutions linked to animal poaching (Image courtesy: Y. Devos). (b) Thin-section scan, highlighting coarse sands (upper layer) protruding into fine grained organic sediments (lower layer). Note the undulating or wavy layering and the limit between the two layers. (c) Microscope view of an involution (area marked in red in Figure 30.9b). Medieval site of Petite Rue des Bouchers, Brussels (Belgium – see Devos *et al*. 2016). PPL.

on occupation surfaces, which have provided modern analogies for understanding archaeological site formation processes (e.g., Goldberg & Witbread 1993; Boivin 2000; Shahack-Gross *et al.* 2003; Milek 2012). Such ethnoarchaeological studies have enabled the development of models (Gé *et al.*, 1993) and have refined interpretive approaches to archaeological contexts (Matthews *et al.* 1997, Cammas 1998; Matthews 2010). Pedological investigations relevant to the subject of trampled sediments and surfaces have also addressed processes (e.g, crust formation) on exposed surfaces (Jongerius 1983; Boiffin & Bresson 1987; Valentin & Bresson 1992; Kwaad & Mücher 1994; Cattle *et al.* 2004) and have described the effects of compaction and consolidation on soil microstructure and porosity (Kooistra 1987; Bresson & Zambeaux 1990; Andrews 2006).

The following section presents observations on the effects of experimental trampling on different substrates, taking into consideration various circumstances (duration, environment etc.), but without the negative effects of postsedimentary processes (for a review of which see Wood & Johnson 1978). The first part describes the effects of trampling in three archaeological sites with greatly varying substrates; the second part presents experiments conducted under laboratory conditions.

30.5.1 Field Experiments

Basel Gasfabrik (Switzerland) A field test on an intensively trodden pathway within the excavation site of Basel Gasfabrik over a 6-week period resulted in an accumulation of 5 to 8 cm of reworked soil material brought in by trampling (Rentzel & Narten 2000). Two experiments simulated the following processes: trampling and compaction of an initial surface, then accumulation and redistribution of sandy loam and charcoal-rich occupation deposits both in an area protected by a tent and in an area exposed to the weather (Figure 30.11).

In the roofed area, the traces of compaction reached down from the initial surface to a depth of 10 mm, exhibiting a diffuse lower boundary. The trampled sediment showed a modified soil structure with distinctly decreased porosity, polyconcave pores, a diminution of the pore diameter and neoformation of some weakly developed

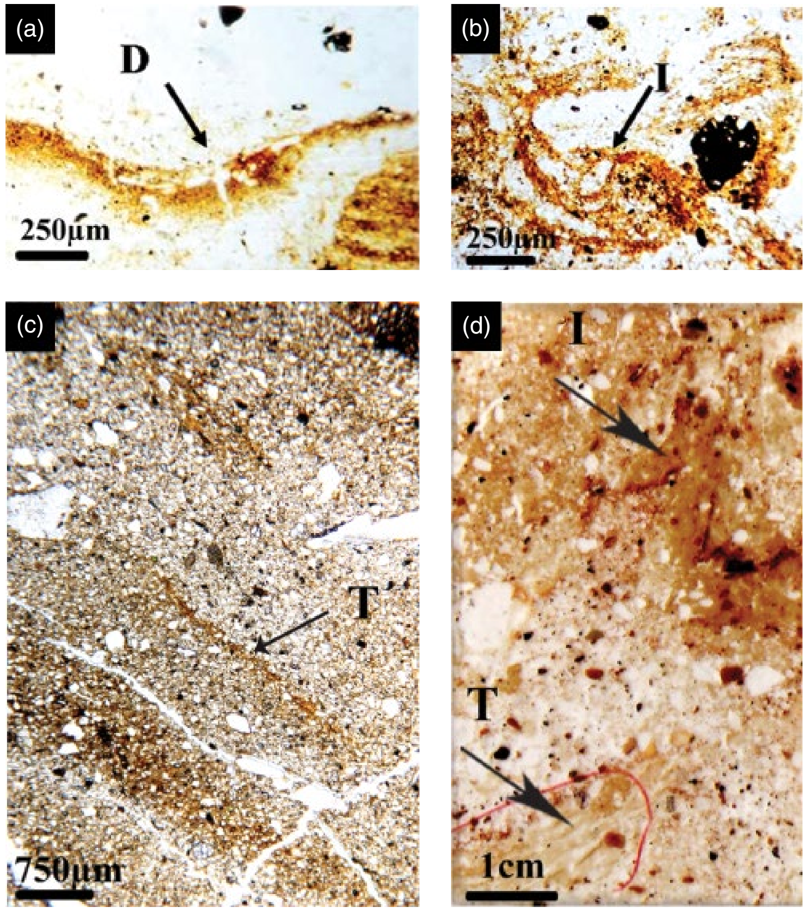

Figure 30.10 (a) Compacted dusty clay occurring in paddy context due to water stagnation within the ruts, with slightly sorted graded bedding, and small shrinkage cracks (D). Vissèche (France). PPL. (b) Involutions (I) due to compression in the muddy sediment caused by cattle pulling the carts. Vissèche (France). PPL. (c) Compaction features (T) and particle sorting. Mittelhausen (France). PPL. (d) Compaction features and particle sorting (T), with iron concretions and impregnations (I). Vissèche (France). PPL.

interlaced silty intercalations. The initial surface, displaying a sharp horizontal boundary, was covered by microcharcoal that originated from the archaeological occupation deposit. The overlying 80 mm thick trampled sediment was characterized by irregular horizontal bedding, horizontal cracks and horizontally oriented gravel components. Also typical are zones with massive microstructure and polyconcave pores. Most of the trampled soil peds exhibited a compressed, lenticular shape.

The second soil sample was taken from the unprotected area beyond the excavation tent (Figure 30.12). It displayed more pronounced compaction features, reaching 20 mm deep into the sediment. In the top few millimetres of the initial surface there were horizontally aligned components and plastic deformation of the clay. Interlaced silty intercalations had also formed (Figure 30.13 and 30.14). During the field experiment a 50 mm thick trample layer formed. The latter is characterized by massive microstructure, polyconcave pores and silty intercalations. In comparison to the roofed area, a more pronounced mixing was observed, locally resulting in complete homogenization and disruption of clay coatings. Horizontal cracks, horizontally bedded components and abrupt sediment changes give the impression of a stratified and successively accumulated deposit.

Brig (Switzerland) The sampling site at Brig is located on the bottom of the inner alpine valley of the Valais, where an excavation team walked daily on a several meters wide path during the summer months. Three samples were taken at a gently sloping stretch with a loose growth of trees. The underlying C horizon consisted of a loose sandy silt with some gravel, while the trampled A horizon was slightly humic (grassland use), with channel and chamber microstructure and a porosity of 20%. The scan of section EXP7 shows the following succession from top to base (Figure 30.15): (a) Trampled loose dust layer with silty-sandy texture, poorly vegetated. (b) Trampled crust, developed on recently dumped sediments (c) and (d). (e) Buried trampled crust of a former surface.

The topmost layer, (a), which represented the recent surface, had been trampled during the summer. Human trampling had led to disaggregation of the topsoil and reworking of silt and sand. The underlying compacted layer, 2 mm in thickness, (b) indicates the influence of

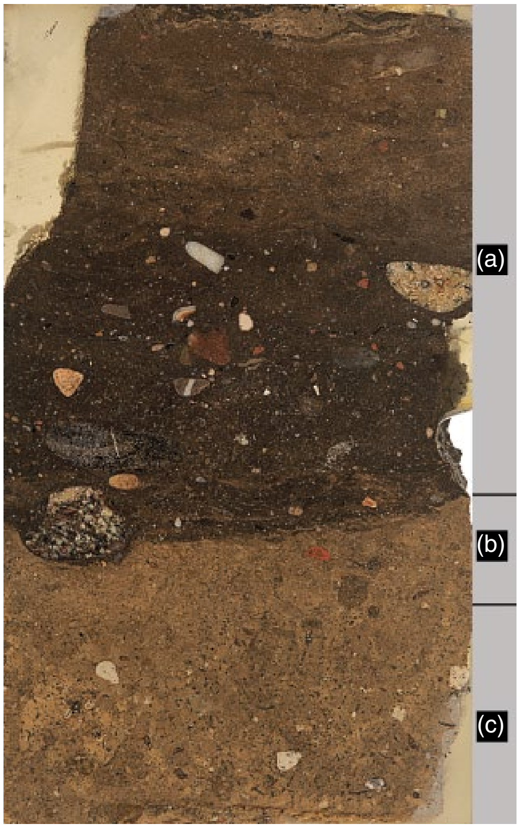

Figure 30.11 Polished block from a modern pathway in a roofed area. (a) Accumulated trample with horizontally bedded gravel and massive microstructure. Sharp lower boundary to layer (b) (initial compacted surface). (c) Natural soil. Excavation site, Basel Gasfabrik (Switzerland). Sample length: 13 cm.

Figure 30.12 Polished block from a modern pathway in an outdoor area. (a) Accumulated trample with horizontally oriented gravel, heavily compressed soil peds, massive microstructure and horizontal cracks. (b) Initial surface with trampled gravel and compaction features reaching 20 mm deep. Excavation site, Basel Gasfabrik (Switzerland). Sample length: 8.5 cm.

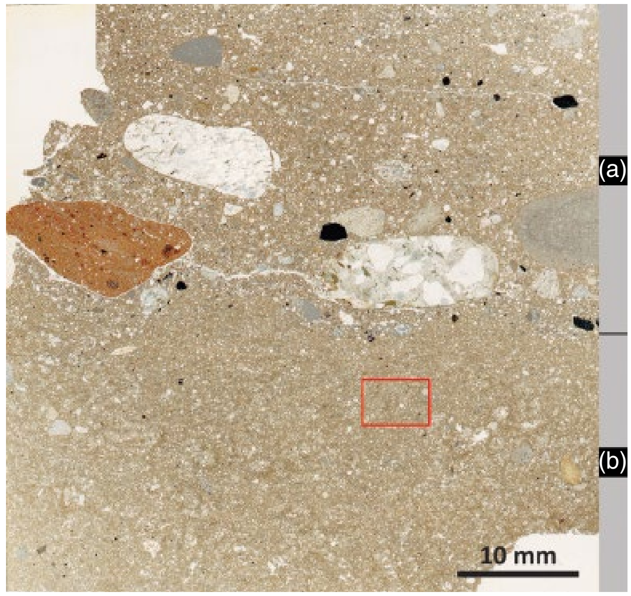

Figure 30.13 Detail of Figure 30.12 at the transition of (a) gravel-rich trample, overlying (b) compacted loamy sand. The latter shows polygon-shaped silty intercalations. Thin-section scan.

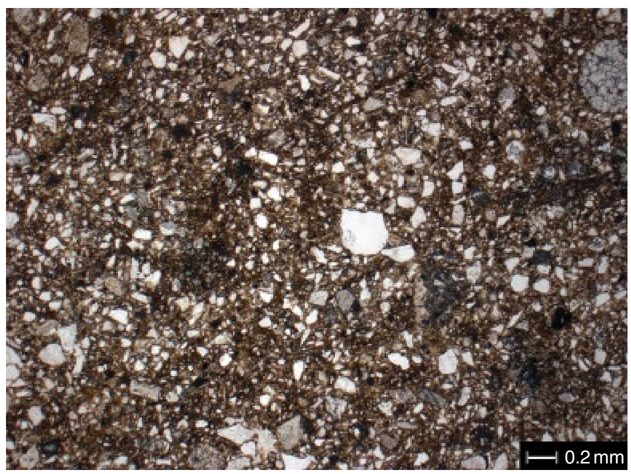

Figure 30.14 Detail of Figure 30.13 (see rectangle), highlighting the strongly compacted layer (b) with formation of polygon-shaped silty intercalation. PPL.

water puddling, which led to crust formation and lamination (Figure 30.16). Trampling is suggested by the low porosity and the platy structure overprinting the fining upward sequence that had formed in the puddle, leading partially to the deformation of the crust. Mollusc shells and leafs were highly fragmented, whereas sand grains were horizontally aligned. An older surface (e) which was preserved under a modern dump, exhibited similar characteristics.

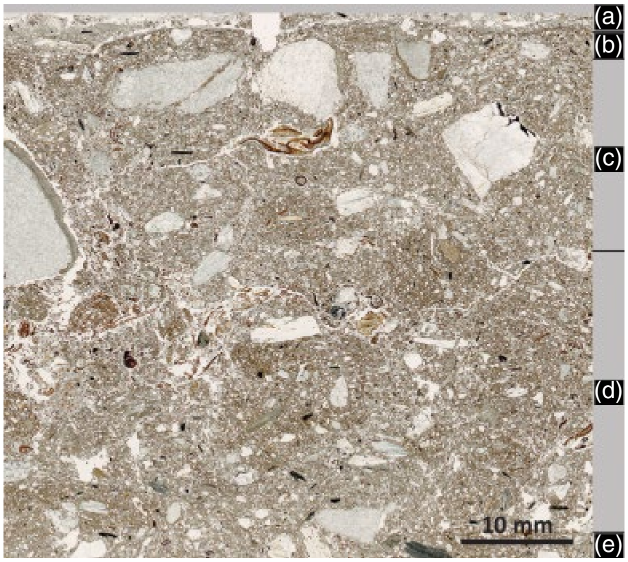

Figure 30.15 (a) Loosely packed superficial 'dust' layer. (b) Massive slaking crusts. (c) and (d) Heterogeneous layers composed of dumped material. (e) Same as (b). Excavation site, outdoor area, used as modern pathway in Brig (Switzerland). Thin section scan.

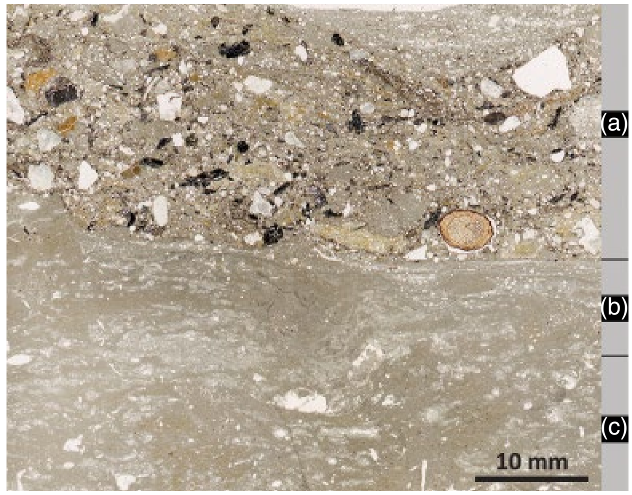

Figure 30.17 (a) Heterogeneous and puddled trample with massive microstructure. (b) Lake marl, overprinted by trampling, leading to a massive carbonate silt with convolutions and horizontal stratification. (c) Natural lake marl. Excavation site, outdoor area in Risch (Switzerland). Thin section scan.

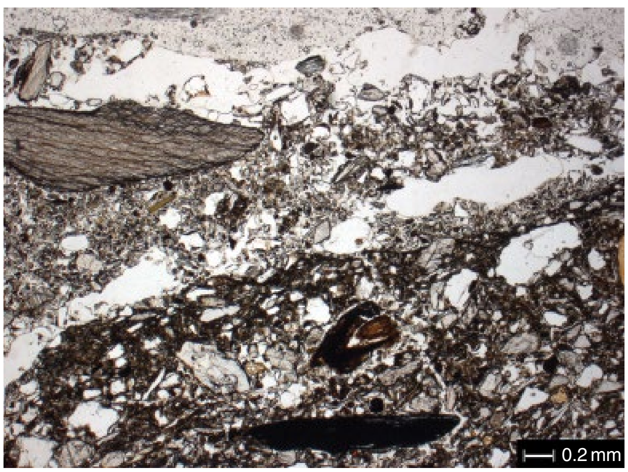

Figure 30.16 Detail of Figure 30.15, at the interface of layers (a) and (b). PPL.

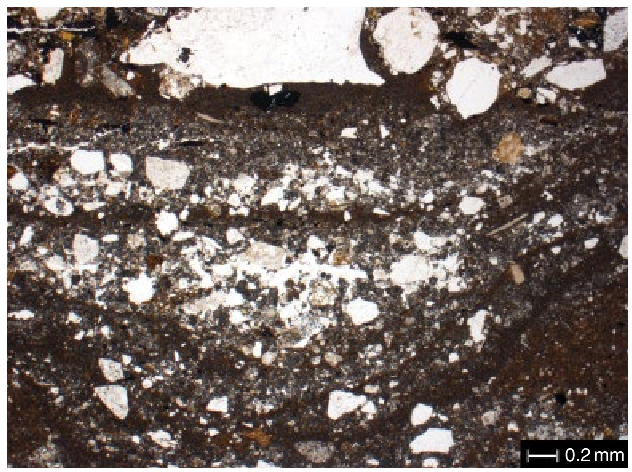

Figure 30.18 Detail of Figure 30.17 on top of trampled layer (b). Note convolutions with fining upward sequences. PPL.

Risch (Switzerland) During the excavation of the Neolithic lakeside settlement of Risch, situated on the border of Lake Zug, an exposed bare horizontal surface of lake marl (carbonate mud) was trampled by excavators over the course of four weeks (Figure 30.17). The original lake marl (c) consisted of a freshly exposed, moist sandy silt with a porosity of ca. 15–20%. It contained calcium encrusted chara stems and well preserved mollusc shells.

The initial surface was markedly changed by trampling and exhibited a slight relief with flat depressions of several cm in size, which were filled by puddles with laminated sediments (fining upward cycles – Figure 30.18). The puddling seems to be a direct consequence of the compaction that also impeded the drainage. In the trampled lake marl layer above (b) compaction features such as low porosity and planar voids were visible to a depth of 10 mm, and had a diffuse lower boundary with the underlying lake marl. Subsequent trampling during the excavation led to an accumulation of reworked and compacted material derived from archaeological layers. This ca. 20 mm thick heterogeneous layer (a) was horizontally bedded and contained compressed peds of lake marl and morainic clay, mixed with sand grains, gravel and organic

Table 30.2 Summarized micromophological results of laboratory experiments.

Sample, conditions	Depth of structural changes	Microstructure and coatings	Porosity	Bedding	b-fabric	Figure
Dry luvisol, loamy sand						
GF EXP d0 Blind sample	0	Channels and chambers, clay coatings, pore diameter up to 3 mm	15–20%	–	Cross-striated	30.19a
GF EXP d5 5 min compaction	5 mm	Channel and chambers, clay coatings, pore diameter: ca. 0.5 mm	10–15%	Weakly expressed (coarse sand)	Coss-striated	30.19b 30.20a
GF EXP d15 15 min compaction	12 mm	Top: granular, cracks and massive, rare channels and chambers. Pore diam.: ca. 0.5 mm. Absence of coatings, clay dispersed in groundmass	5–10%	Weakly expressed (coarse sand)	Granostriated	30.19c 30.20b
Moist Luvisol, loamy sand						
GF EXP m0 Blind sample	0	Channels and chambers, clay coatings (Luvisol). Pore diameter: up to 3 mm. Rare superficial cracks (dessication?)	15–20%	–	Cross-striated	30.19d
GF EXP m5 5 min compaction	10 mm	Massive, horizontal cracks, pore diameter: up to 0.3 mm. Polyconcave voids, deformation in topmost 3 mm. Absence of coatings, clay in groundmass	1–4%	Weakly expressed (coarse sand tends to horizontal orientation)	Cross-striated and granostriated	30.19e 30.20c
GF EXP m15 15 min compaction	20 mm	Massive, strong deformation, crusts parallel to surface. Microdepressions. Pore diam.: up to 0.5 mm. Clay dispersed in groundmass	1–3%	Topmost 2 mm: horizontal bedding of coarse sand	Granostriated and elongated striated clay concentrations	30.19f 30.20d

remains. Note that the most recent puddles were well expressed in the topmost part of the sample.

30.5.2 Laboratory Experiments

In a series of laboratory experiments, Kubiena boxes (530 cm^3) were used to sample a weakly developed Luvisol from Basel Gasfabrik (Switzerland), and the soil within them was subsequently compacted with a stamp corresponding to a person of 70 kg for periods of 0, 5 and 15 minutes, under both dry and moist conditions. Three samples were first oven-dried (40 °C) during one week, then compacted (60 strikes / minute). Water (100 cm^3) was added to three other samples before trampling was simulated.

The control sample consisted of an unstratified, decalcified loamy sand, with channels and chambers (porosity: 15–20%) that were up to 3 mm in diameter (see Table 30.2 and Figure 30.19). The clay fraction was dispersed in the groundmass (cross-striated b-fabric) and formed clay coatings.

Compaction for 5 min produced microstructural changes in the topmost 3–5 mm of this dry soil horizon. In this zone, macropores had largely disappeared and porosity decreased by around 5%. The largest pores still measured 0.5 mm (mean 0.1–0.2 mm) in diameter, with an increase in elongated or polyconcave voids (Figure 30.20a). There was also a tendency towards horizontal alignment of particles and slight fragmentation of the iron oxides. Compaction for 15 min resulted in a further decline in porosity and the development of a granular microstructure at the worked dry surface. Microstructural changes were most distinct in the top 3 mm, where concentrations of aligned sand particles and horizontal cracks dominated (Figure 30.20b). Traces of compaction were visible to a depth of 9–12 mm, with a diffuse lower boundary. Within this area, increased mechanical stress resulted in the fragmentation of iron precipitations and destruction of clay coatings. The clay fraction was homogenously distributed and exhibited a cross-striated b-fabric.

Five-minute compaction of the moist soil led to deformations detectable in the topmost 10 mm, with formation of polyconcave voids, destruction and integration of clay coatings into the groundmass. A massive microstructure and horizontal cracks dominated this soil (Figure 30.20c), and horizontal lenses of sand grains indicate diffuse deformation structures. Fifteen-minute compaction created strong deformation phenomena and a mostly massive microstructure, again with collapse and redistribution of clay coatings. This advanced stage is expressed by the appearance of parallel surface crusts and the formation of microdepressions with uplifted marginal areas that had a tendency to migrate towards the centre of depression (Figure 30.20d).

30.6 Conclusion

A comparison between the key features of trampling and poaching that were observed in the archaeological and experimental contexts mentioned in this chapter, and the published literature (Table 30.1) allows us to consider as reliable the following micromorphological indicators:

- Microstructural modifications, such as the reduction in overall porosity, the formation of massive or platy microstructures and of polyconcave voids. These are generally more marked and extend further down in moist sediments in comparison to dry deposits. In contrast, trampling effects are limited to the topmost few millimetres of the trampled surface under dry conditions, accompanied by an increased fragmentation of less durable components, including soil peds. Overall, the laboratory tests made it evident that the effects of trampling events of limited duration – in the absence of accumulation of introduced material – are confined to the top 2–3 cm below the original surface.
- Development of bedding (e.g., at Basel Gasfabrik in the experimentally trampled deposits). Successive accumulations of 'trample' (see Banerjea *et al.* 2015a, b), generally heterogeneous and containing compressed elongated peds, also result in bedding or layering of trampled deposits. In outdoor areas, depending on soil moisture and intensity of trampling, the accumulated trample can have a homogeneous aspect.
- Horizontal orientation of coarser components, including sand grains, charcoal, bone and mollusc shells. Mechanical influence ('crushing' or 'snapping') on bones or molluscs and formation of microcharcoal.
- Formation of crusts of silty clay or dusty clay with normal grading or microlaminations, and of convolutions as the result of poaching.

Traffic (section 30.4) brings about features related to strong compaction (microstructural changes, reduction) within the wheel marks, and to poaching and topsoil disturbance in the trackways.

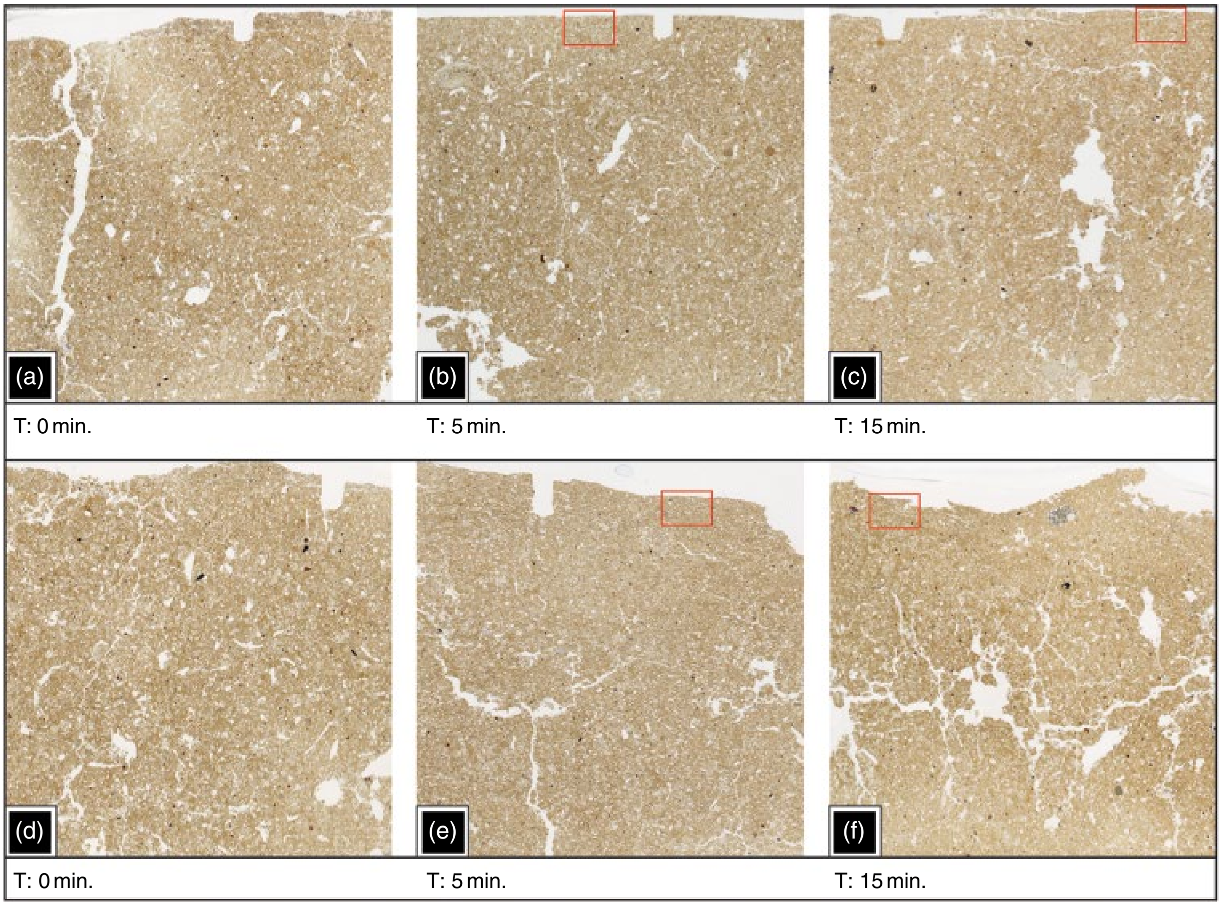

Figure 30.19 (a–f) Experimental laboratory samples with compacted topmost parts. For description, see Table 30.2. Thin section scans (image width: 4.5 mm).

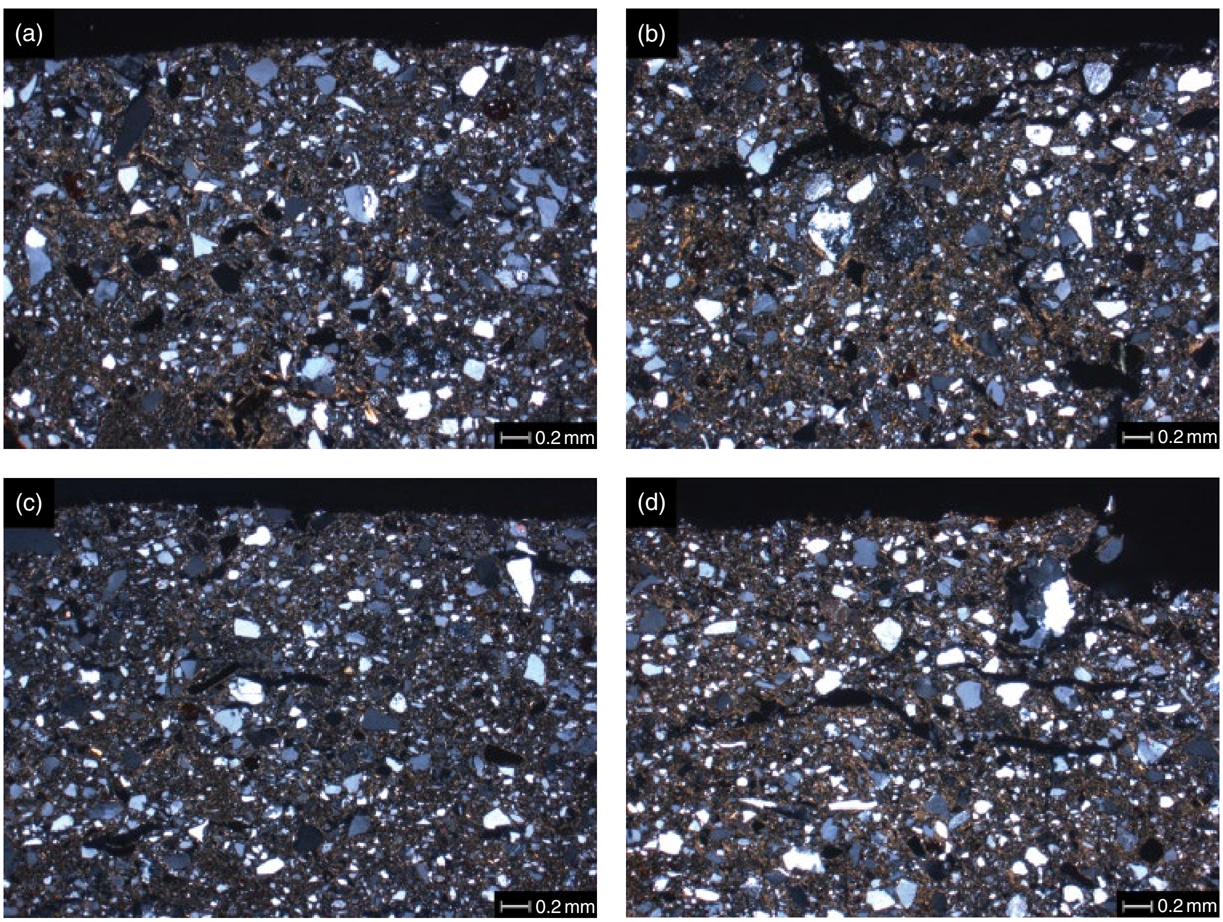

Figure 30.20 (a) Detail of Figure 30.19b (see rectangle). XPL. (b) Detail of Figure 30.19c (see rectangle). XPL. (c) Detail of Figure 30.19e (see rectangle). XPL. (d) Detail of Figure 30.19f (see rectangle). XPL. For descriptions, see Table 30.2.

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