Report on the micromorphological analysis of thin sections from Water Canyon, New Mexico

S.M. Mentzer and P. Goldberg

In 2015, Dr. Robert Dello-Russo and Christian Solfisburg collected four micromorphological samples from Water Canyon Locus 1 using electrical boxes. As indicated in Figure 1, the four samples overlap to provide full coverage of the transition between a lower, greenish-grey gleyed (?) unit and a darker, upper unit that exhibits visual characteristics that are consistent with a black mat. The samples were dried, indurated with resin, and processed into standard petrographic thin sections by Spectrum Petrographics. The finished thin sections were shipped to the University of Tuebingen for analysis.

Figure 1: Profile photograph with locations of the four micromorphology samples.

The thin sections were scanned on a flatbed scanner to obtain incident light images (Figure 2). The samples were then analyzed under plane- (PPL) and cross-polarized (XPL) light, as well as oblique incident light using a stereomicroscope and standard petrographic microscope. All analyses were conducted at the University of Tübingen by S. Mentzer and P. Goldberg. The samples were described using criteria defined by Stoops (2003).

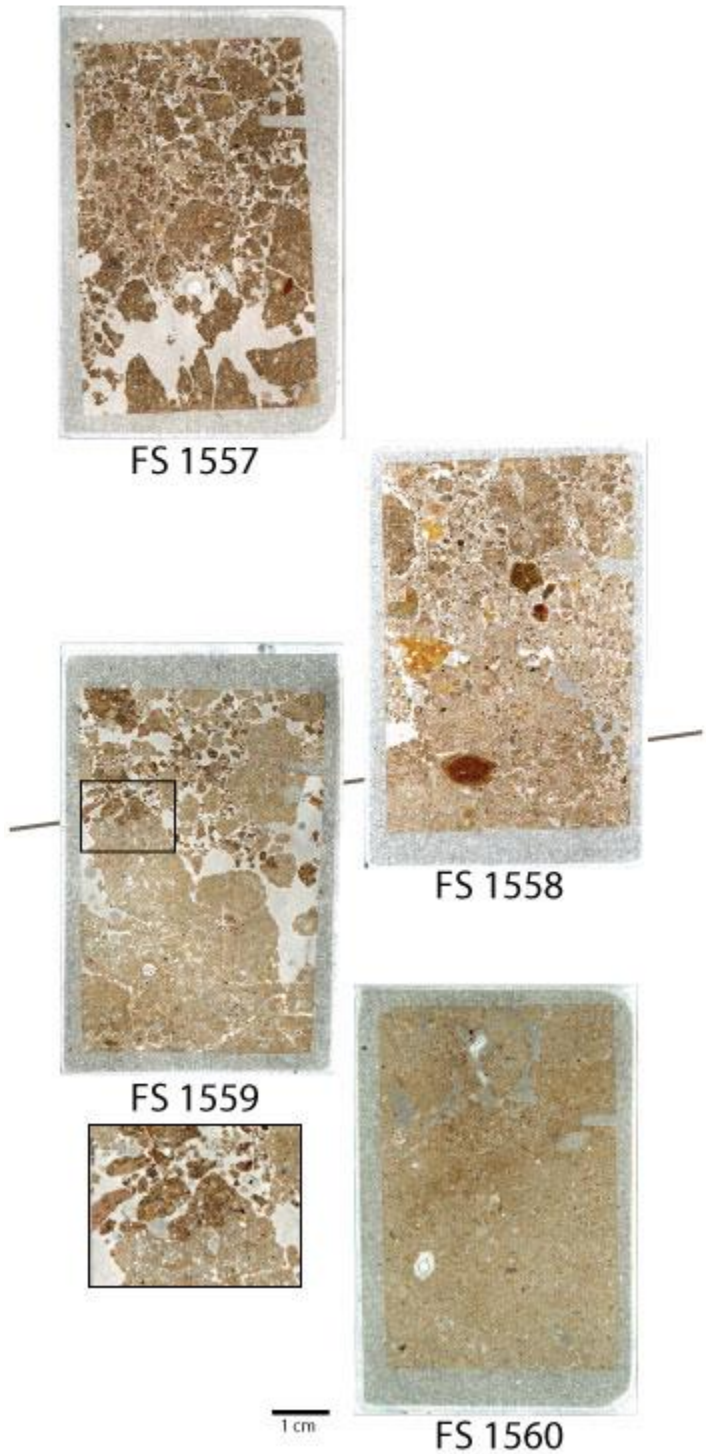

Figure 2: The four thin sections arranged in stratigraphic order, showing approximate overlap between samples. The contact between the two sedimentary units is present in the two middle thin sections, although the high porosity and granular structure indicates that there has been some disturbance of the samples, likely during removal from the profile or shipping to Spectrum Petrographics. A grey line indicates the approximate position of the contact. In sample FS1559, the contact between the units (black box and inset) is sharp and undulating. Incident light scans.

The lowest sample (FS 1560) exhibits very little soil structure. The sediment appears massive at meso-scale, but under the microscope is comprised of sand-sized aggregates of clay, silt and sand that have been compacted together, yielding a welded aggregate structure (Figure 3). This type of structure is indicative of compaction under wet conditions following insect bioturbation (Kooistra and Pulleman 2010, Kwaad and Mücher 1994, Wright 1983). Porosity is low, and the dominant void type is channels, which range in diameter from <1 mm up to 4 mm. Packing voids and vughs in the spaces between welded aggregates are also present. In general, the degree of microaggregation is higher at the base of the slide relative to the top, and conversely, the compaction of the sediment and abundance of channel voids increases upwards (see Figure 3).

Of the four thin sections, this sample contains the finest sediment. The texture varies slightly from the base of the thin sections to the top, with a weak coarsening upwards trend. Rare bands of finer sediment are present at the top of the sample. The channel voids, which are likely related to root or insect activity, are locally infilled with sediment that contains organic material, as well as calcium carbonate. The calcium carbonate crystals are fibrous or needle-shaped, which is consistent with fungal or insect activity (Verrecchia 1994). Obvious redoximorphic features are absent at microscale, although the color of the unit in the field is indicative of gleying as a result of post-depositional saturation.

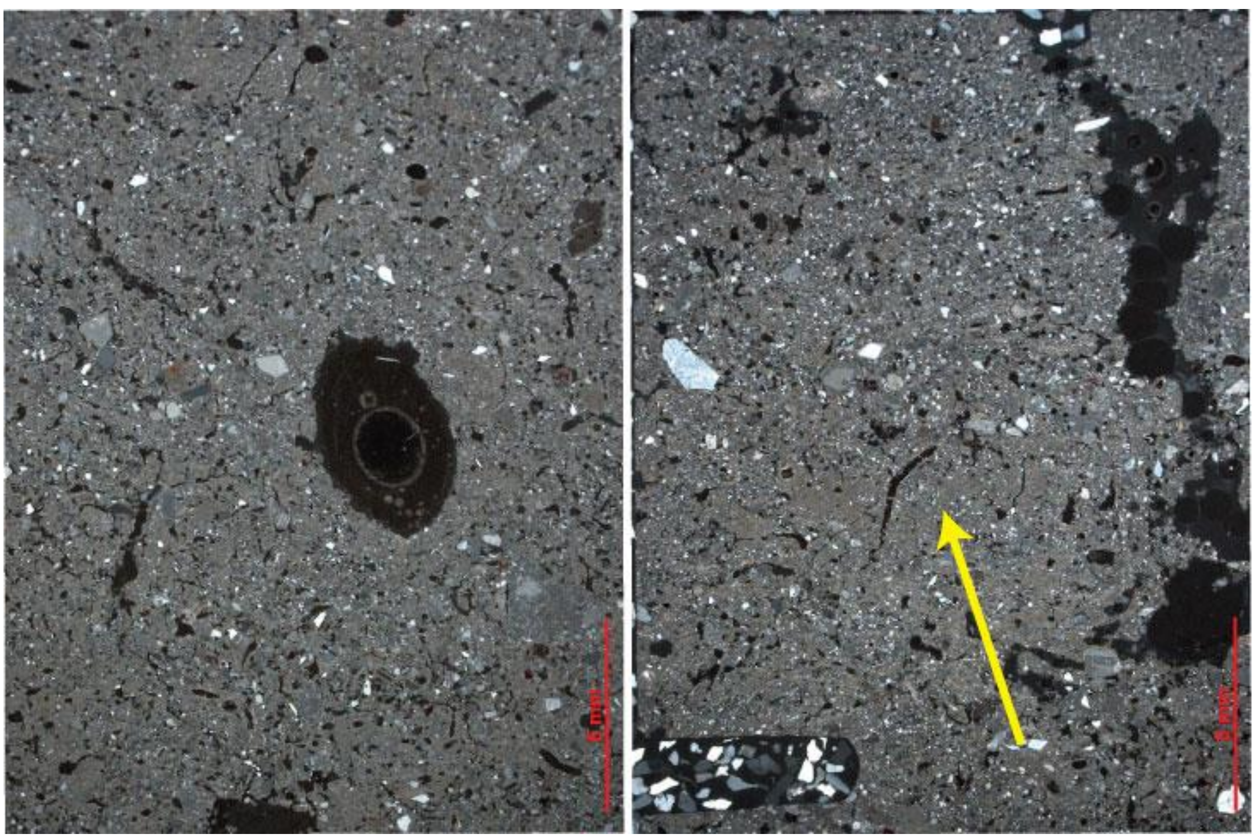

Figure 3. The sediment in the lower unit is composed of welded aggregates. The base of sample FS1560 (left) exhibits slightly higher porosity in the form of packing voids and vughs. The individual aggregates of sediment are more visible here relative to at the top of the sample (right), where channels are more abundant and occasional bands of clay (arrow) may be remnants of an original laminated fabric. XPL.

Sample FS1559 contains the lower unit, as well as the very base of the contact with the overlying black mat. The lower unit is comprised of light-colored, fine sediment and is consistent with the sediment in sample FS1560 in terms of mineralogical composition and texture. Welded microaggregates and channel voids are present; however, laminations of silt and clay are also locally present. The laminations suggest that the original depositional fabric of this unit was related to water, and was later obliterated by post-depositional insect activity and compaction. Relative to the underlying sample, the texture is finer, and the soil structure is slightly more developed, with fissures and crack voids delineating a weak angular blocky structure (Figure 4). As these voids cut across welded aggregates and channels, it is likely that structural development post-dates insect activity. Orientation of clays along the crack and fissure voids suggests some wetting and drying of the deposit.

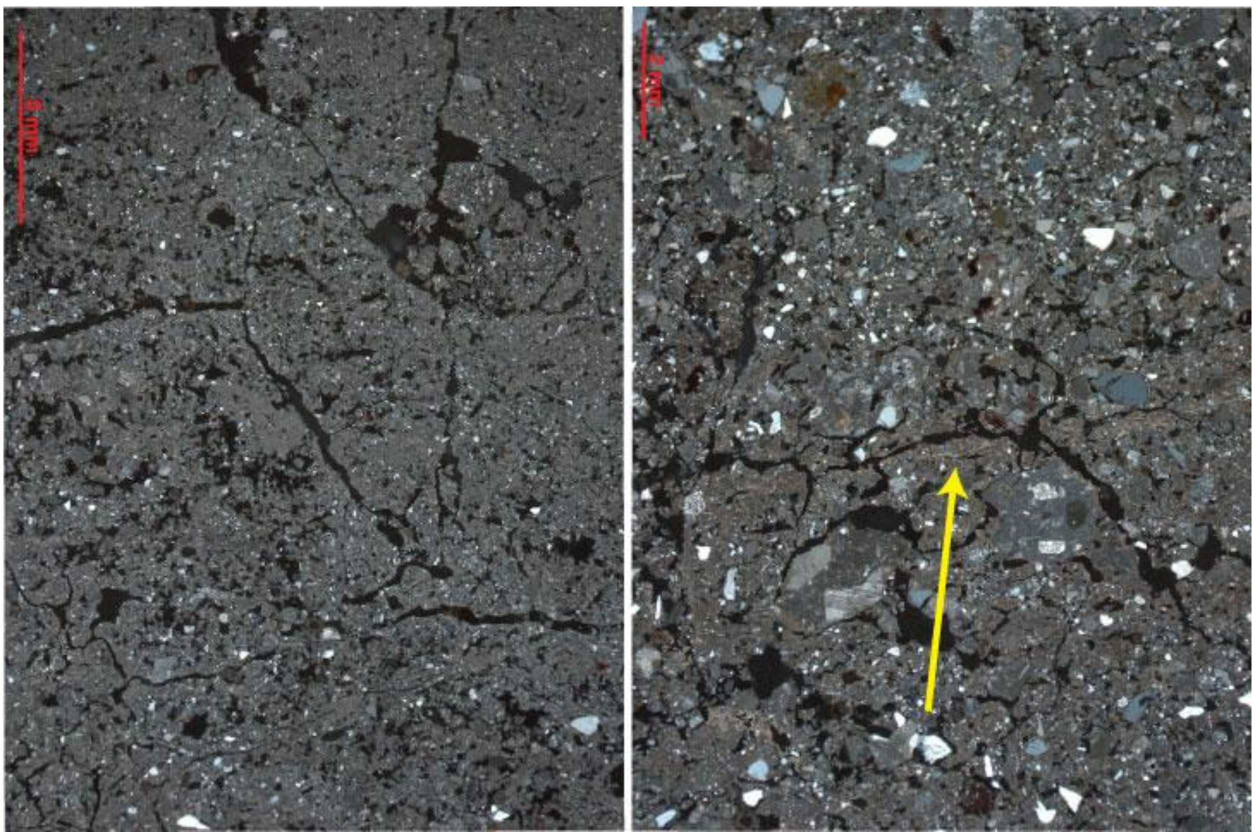

Figure 4. In sample FS1559, the top of the lower unit visible exhibits structural development and also contains remnants of laminations. Fissures separate angular blocky peds (left). At the contact with the upper unit (right), the sediment is markedly coarser, and a band of clay (arrow) is present in sample FS1558. XPL.

Due to disturbance of the sample during removal or processing, only ~1 cm of the original contact between the lower light-colored sediment, and the upper black mat is present in sample FS1559. This contact is sharp and undulating (see Figure 2, inset). Aggregates of the darker sediment at the top of the thin section likely derive from the black mat, although their original orientation is unknown due to disturbance of the sample. Relative to the underlying unit, the sediment in the black mat is coarser and contains more abundant sand-sized fragments of volcanic rock as well as microscopic fragments of organic material. The structure and fabric of this unit are difficult to discern in this sample, but some post-depositional features are visible including calcite infilling and coating the edges of channel voids.

Sample FS1558 also contains the contact between the two sedimentary units. The sample is not as disturbed as sample FS1559. Here the contact is not sharp and undulating, but instead seems to be comprised of domains of lighter and darker sediment directly above a band of oriented clay (see Figure 4). As in FS1559, the abundance of gravel-sized fragments of volcanic rock fragments – several exhibiting gleyed edges (Figure 5) – and silt-sized of organic materials increase markedly at or above the contact.

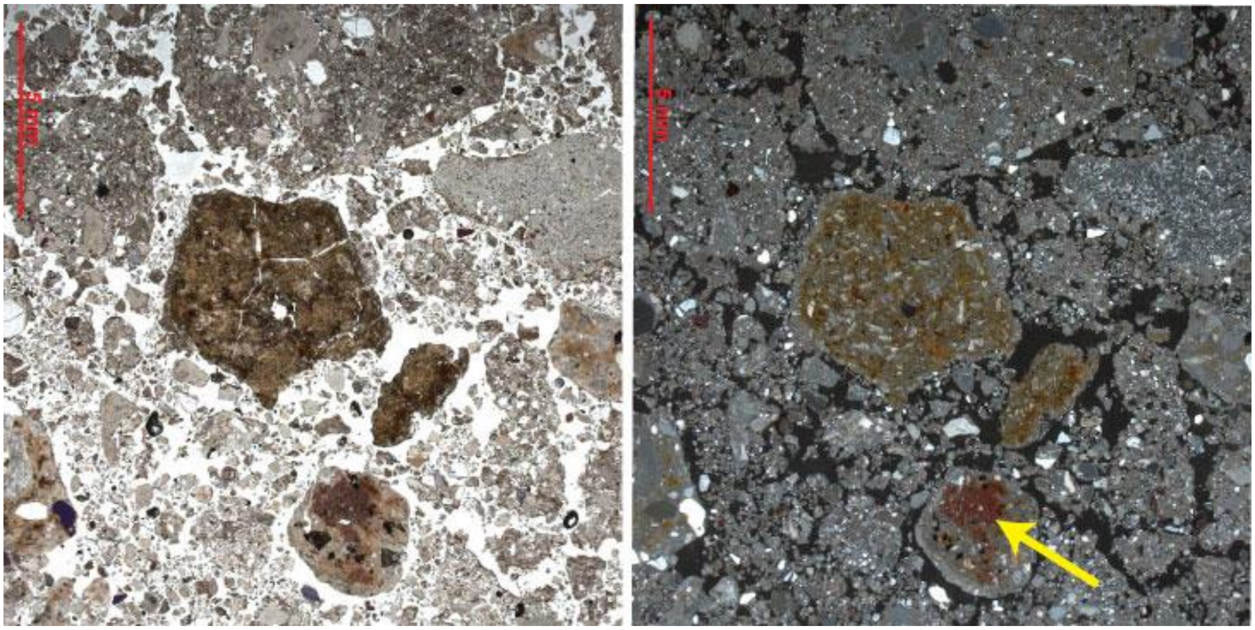

Figure 5. The sediment at the contact between the two units is disturbed. The upper sediment is coarser than the lower sediment, and contains sand- and gravel-sized fragments of volcanic rock. Here, three weathered volcanic rock fragments present at the contact between the two units exhibit post-depositional redoximorphic features. The edges of the rock fragments are lighter in color in PPL (right) and grey under XPL (left), while the centers are darker in color and contain reddish iron oxides. The iron oxides are especially prominent under XPL (yellow arrow). Bleaching of rock fragment edges, or gley, is indicative of reducing conditions within a water table. The similarity in color between the fragment edges and the surrounding sediment suggests that much of the sediment is fully gleyed.

The uppermost sample, FS1557 contains only sediment from the upper unit. Although the original structure of the deposit has been disturbed during processing, the mm- to cm-sized angular fragments of sediment with internal channels indicate that the structure may have been moderately-developed angular blocky structure, with channels and internal planar voids present (Figure 6). Within these ped fragments, aspects of the original depositional fabric are not preserved. However, some post-depositional features are visible. These include thin illuvial clay coatings, which increase in abundance towards the top of the slide. These features typically form within the subsurface horizons of soils (Kühn et al. 2010). Clays in the fine fraction are also weakly oriented around some voids and coarser components. In addition, the fragmented peds exhibit gley along their edges. Microscopic evidence for gley includes bleaching along fragment edges, with preservation of iron oxides within the ped centers (Figure 7). This distribution of iron oxides indicates that reducing conditions were present within water filling the macro-void system (fissures, cracks and channels) (Bouma et al. 1990, Tucker, Drees and Wilding 1993). As in lower samples, some channel voids are infilled with secondary carbonate (see Figure 6).

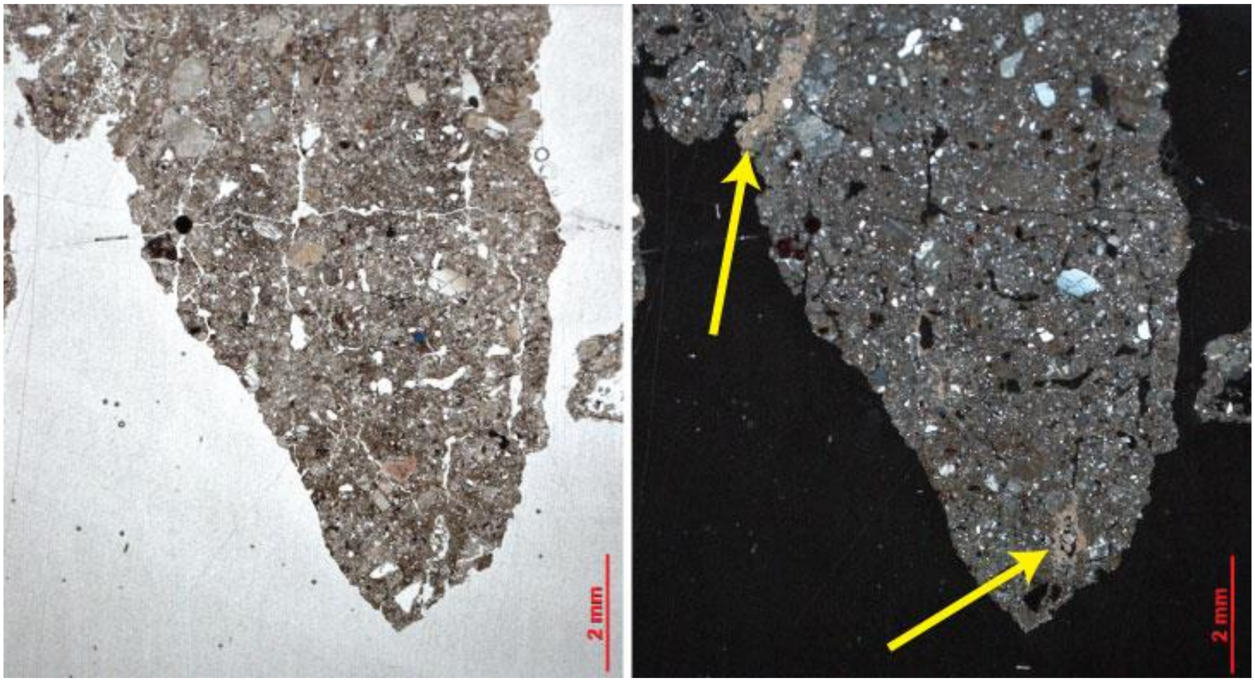

Figure 6. An angular fragment of disturbed sediment from the upper unit contains some pedofeatures and structural elements. Under PPL (right), planar fissures and channel voids are visible, which indicates that the unit likely exhibits an angular blocky structure. Under XPL (left), some of the larger channel voids (arrows) are infilled with secondary carbonate.

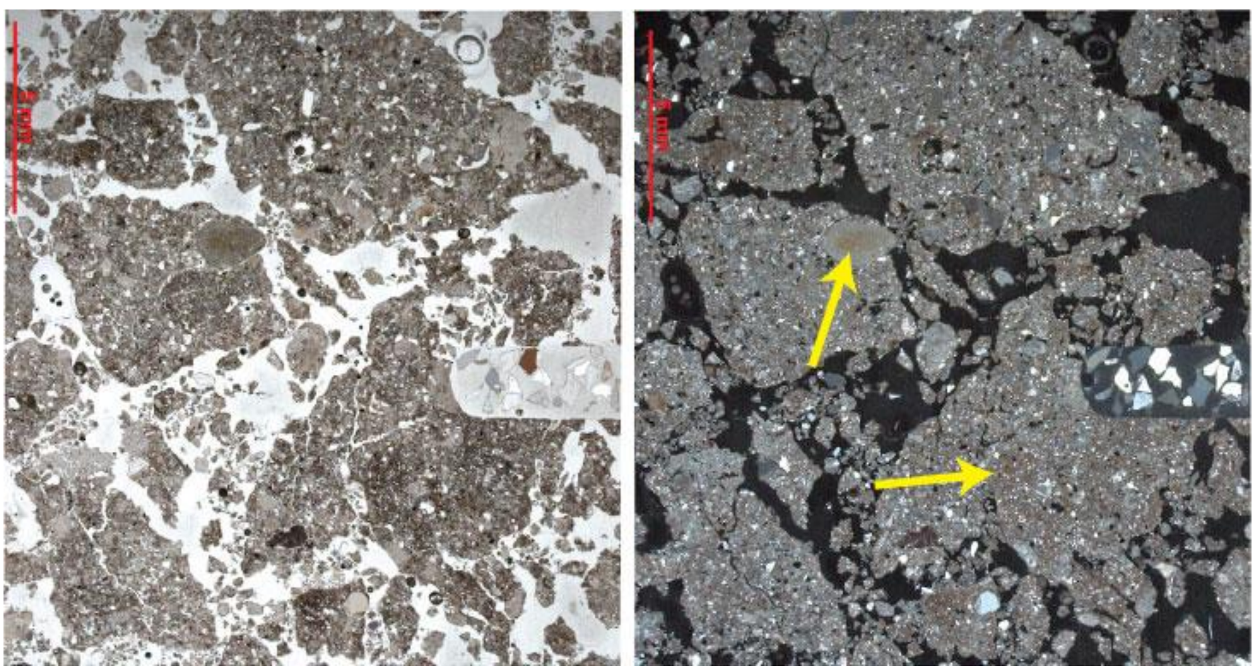

Figure 7. Fragments of sediment from the black mat contain redoximorphic features, including bleached ped edges, and iron oxides in ped centers. Under XPL (left), reddish concentrations of primary iron oxides are visible inside volcanic rock fragments (upper arrow) and ped centers (lower arrow).

To summarize, the microscopic characteristics of the sequence of samples indicate that the two units have distinctive compositions, which suggests that these are discrete depositional packages. The lower unit contains few gravel-sized fragments of volcanic rock, as well as low abundance of organic material incorporated into the fine fraction. The upper unit is coarser and contains abundant organic material (Figure 8). The mineralogy of the two units is similar, and therefore the sediment source was likely the same. The lower unit exhibits broad (cm-scale) alternations in texture, and also contains some (mm-scale) remnants of laminations, which are both consistent with deposition by water in a fluvial or alluvial setting.

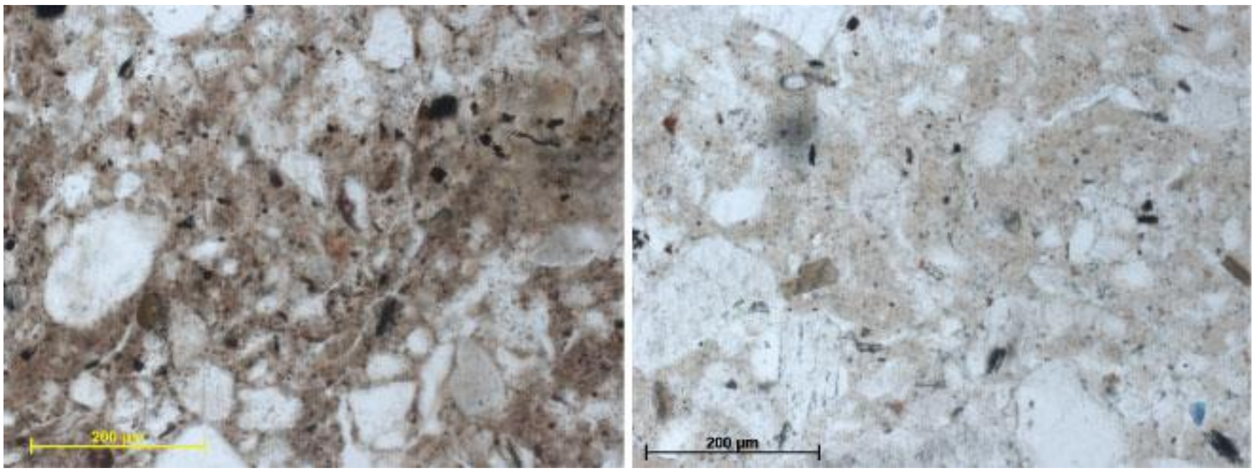

Figure 8. The fine fraction of the upper unit (left) is significantly darker and browner in color compared to the lower unit (right). Much of this difference in color is due to the presence of more abundant silt-and fine sand-sized fragments of organic material. When present, the majority of the organic material in the lower unit is concentrated in void infillings and thus likely postdates the deposition of the unit. PPL.

Furthermore, several of the post-depositional features in the lower unit (microaggregation, channel formation, and compaction/welding of aggregates) seem to predate the deposition of the overlying black mat sediment. Other stages, such as formation of secondary carbonates in voids and development of weak soil structure could either pre-date or post-date deposition of the black mat sediment. Secondary carbonates are present throughout the sequence, and unfortunately, disturbance of the upper sediment unit during sampling has prevented observation of soil structure. The angular shapes of the sediment seem to suggest that an angular blocky structure may have extended from the black mat downward into the top of the lower unit.

In sum, the observations suggest a general timeline for the formation of this sequence:

1) Deposition of the lower unit by water, likely multiple events

2) Bioturbation and obliteration of much of the original laminated fabric in the lower unit

3) Deposition of the upper unit

4) Wetting and compaction of the lower unit

5) Complete gleying of the lower unit, with partial gleying of the base of the upper unit

6) Drying of the two units, with formation of secondary carbonates, illuvial clay coatings, and possible development of a weak angular blocky structure due to subsequent soil formation.

It is possible that steps 3, 4 and 5 were related to a single event, and thus the deposition of the upper unit is contemporaneous with a rise in the water table that impacted both units.

Finally, the sediment in the upper unit was described in the field as a black mat. Harris-Parks (2016) has recently published a micromorphological comparison of 25 samples from black mats in four localities throughout the American Southwest. Relative to the samples described in her work, the sediment from Water Canyon is coarser in texture and apparently represents an increase in depositional energy relative to the underlying unit. It also lacks clear laminations, and contains significantly less organic material and humic staining visible in thin section. Diatoms, phytoliths and gastropods were also not present within the Water Canyon micromorphology samples. Although calcium carbonate is present at Water Canyon, it appears to be associated with a later phase of drying of the sequence, possibly related to plant activity (roots) and soil formation. In addition, much of the structure of the unit visible in thin section appears to be related to a later phase of soil formation following burial. Bioturbation features such as microaggregates and infilled burrows are not visible, although the presence of distinctive sedimentary domains along the contact may suggest that burrows were once present. Clay coatings are suggestive of soil forming processes occurring at depth.

Based on the micromorphological analyses the Water Canyon samples do not neatly fit into the classification system proposed by Harris-Parks (2016: Table 2). Although the unit exhibits characteristics indicative of a high water table (gley) and moisture fluctuations (slickensides), the remaining features are not consistent with those of other black mat samples indicative of permanent or intermittent standing water. At best, the Water Canyon samples are most similar to black mat samples derived from moist, productive soils.

References

Bouma, J., Fox, C. A., & Miedema, R. (1990). Micromorphology of hydromorphic soils: applications for soil genesis and land evaluation. Developments in Soil Science, 19, 257-278.

Harris-Parks, E. (2016). The micromorphology of Younger Dryas-aged black mats from Nevada, Arizona, Texas and New Mexico. Quaternary Research, 85(1), 94-106.

Kooistra, M. J., & Pulleman, M. M. (2010). Features related to faunal activity. In Stoops, G., Marcelino, V., and Mees, F. (eds). Interpretation of micromorphological features of soils and regoliths. Elsevier.

Kühn, P., Aguilar, J., & Miedema, R. (2010). Textural pedofeatures and related horizons. In Stoops, G., Marcelino, V., and Mees, F. (eds). Interpretation of micromorphological features of soils and regoliths. Elsevier, 217-250.

Kwaad, F. J. P. M., & Mücher, H. J. (1994). Degradation of soil structure by welding—a micromorphological study. Catena, 23(3), 253-268.

Stoops, G. (2003). Guidelines for analysis and description of soil and regolith thin sections. Soil Science Society of America Inc.

Tucker, R. J., Drees, L. R., & Wilding, L. P. (1993). Signposts old and new; active and inactive redoximorphic features; and seasonal wetness in two Alfisols of the gulf coast region of Texas, USA. Developments in Soil Science, 22, 149-159.

Verrecchia, E. P. V. K. E. (1994). Needle-fiber calcite: a critical review and a proposed classification. *Journal of Sedimentary Research*, *64*(3).

Wright, V. (1983). A rendzina from the Lower Carboniferous of South Wales. Sedimentology, 30(2), 159-179.