

# ***Kruike, East Flanders, Belgium; Soil Micromorphology***

**By:**

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## ***Extended summary***

A four-thin section study was carried out on sediments at Kruike, East Flanders, Belgium. At the sample 18 and 21 location, the lowermost sediment (21) is probably silty alluvium of likely loessic origin. Its chief characteristic is secondary micritic calcium carbonate (CaCO<sub>3</sub>) impregnation, presumably due to leaching and decalcification of overlying sediments. Upwards, a decalcified fine sandy silt loam is present (18). This again originated as an alluvium where fine river sands and loess were probably mixed. Here, pedogenesis produced an argillic Bt horizon (clay void coatings differentiated from minor alluvial clay inwash) of an *in situ*-formed Luvisol. Fluctuating water tables associated with this alluvial site, also led to some secondary iron and possible iron-manganese impregnation. Samples 1 and 3, show some contrasting traits. Sample 3 is composed of decalcified loamy fine sands and silts, and has a probable had minor anthropogenic input in the form of charcoal and burnt mineral grains; iron stained charcoal is more likely to be derived from a (local?) fire installation than be of wild fire origin. Upwards, sample 1 records a history of alluviation, characterised by bedded and laminated grey loamy silts. Some biological working and associated secondary micritic calcite impregnation probably reflects base level fluctuations. Possible sea level-related base level changes later led to iron mottling with the presence of rare yellow brown clay infills conceivably recording coastal marine inundation and deposition of marine alluvium, as found elsewhere along the North Sea coast. The report is supported by 2 tables, 30 figures and CD-rom/upload archive.

## **Introduction**

Four monolith samples from Kruike, East Flanders, Belgium were forwarded by Yvonne van Amerongen (*Archol.nl*) to *Terrascope*, Troyes, France, for thin section processing. The thin sections were then analysed using soil micromorphology employing these four thin sections and standard techniques (see below).

## **Methods**

### ***Soil micromorphology***

The undisturbed monolith subsamples (Tables 1 and 2) were impregnated with a clear polyester resin-acetone mixture; samples were then topped up with resin, ahead of curing and slabbing for thin section manufacture by *Terrascope*, Troyes, France A (Goldberg and

Macphail, 2006; Murphy, 1986) (e.g., Fig. 1). The thin section was further polished with 1,000 grit papers and analysed using a petrological microscope under plane polarised light (PPL), crossed polarised light (XPL), and oblique incident light (OIL), at magnifications ranging from x1 to x200/400. Thin sections were described, ascribed soil microfabric types (MFTs) and microfacies types (MFTs) (see Tables 1 and 2), and counted according to established methods (Bullock et al., 1985; Courty, 2001; Courty et al., 1989; Goldberg et al., 2022; Karkanis and Goldberg, 2019; Macphail and Cruise, 2001; Macphail and Goldberg, 2018; Stoops, 2003; Stoops et al., 2018).

## **Results**

### ***Soil micromorphology and preliminary interpretations***

Results are presented in Tables 1-2, illustrated in Figs 1-30 and supported by material on the accompanying CD-Rom. 14 characteristics were identified and counted from 4 layers in the 4 thin sections analysed.

#### ***M18-M21 sample series***

*M21*: This sample records a massive, probable well sorted alluvial silt, ultimately of possible loessic origin (Fig 1) (Goldberg et al., 2022, 182-191). Minor bioworking in the form of burrowing has taken place, and probably overlying alluviation led to trace amounts of dusty clay inwash (Figs 2-3) (cf. Brammer, 1971). Ground water effects include marked secondary micritic CaCO<sub>3</sub> impregnation often associated with burrows and relict (root?) channels (Figs 4-5) (Durand et al., 2018). Equally, weak iron staining has occurred.

*M18*: Above, the deposits are composed of silty fine sands and fine sandy silt loams, made up of moderately well sorted coarse silts and very fine sands (Figs 6-9). It is not a pure loess, as in M21, but mixed with very fine river sands, and thus more like a 'brickearth' (cf. Catt, 1978). Weathering (groundwater drainage and effects) of this sediment may have decalcified it, leading to the formation of secondary calcium carbonate features below (M21). Although some clay movement may be relict of flood alluviation, it is more likely that clay translocation is of pedological origin, allowing this layer to be termed a Bt (argillic) subsoil horizon (Figs 7-11) (Duchaufour, 1982, 290-292; FAO, 2015; Kühn et al., 2018). The soil can be classed as a gleyic luvisol, because of probably seasonal waterlogging effects. In fact, base level fluctuations are responsible for iron and possible iron-manganese mottling in a soil which was burrowed and rooted (Figs 6, 12-13) (Vepraskas et al., 2018).

### ***M1-M3 sample series***

**M3:** Here, there are biologically homogenised grey loamy fine sands and silts, made up of moderately well sorted silts and very fine sands (Figs 14-18). The layer has a moderate anthropogenic signature in the form of occasional fine and coarse wood charcoal (max 5mm), especially at 10mm and 60mm depths; some charcoal is iron stained and a trace of very fine burnt mineral inclusions was also found (Figs 14-20). Iron staining of charcoal can occur in fire installations associated with settlement activity – rather than being simply a wild fire result (Viklund et al., 2013). Post-depositional rooting and base level fluctuations led to occasional weak iron staining with strong iron (and FeMn?) nodular formations (Vepraskas et al., 2018).

**M1:** Massive, bedded and laminated grey loamy silts, record a history of alluviation (Figs 21-24). Some biological working and associated secondary micritic calcite impregnation probably reflects base level fluctuations (Figs 25-26) (Durand et al., 2018). Possible sea level-related base level changes later led to iron mottling with the presence of rare yellow brown clay infills conceivably recording coastal marine inundation and deposition of marine alluvium, as found elsewhere along the North Sea coast (Figs 21, 25-30) (Goldberg et al., 2022, 203-213; Macphail et al., 2010).

### **Conclusions**

A four-thin section study was carried out on sediments at Kruibeke, East Flanders, Belgium. At the sample 18 and 21 location, the lowermost sediment (21) is probably silty alluvium of likely loessic origin. Its chief characteristic is secondary micritic calcium carbonate ( $\text{CaCO}_3$ ) impregnation, presumably due to leaching and decalcification of overlying sediments. Upwards, a decalcified fine sandy silt loam is present (18). This again originated as an alluvium where fine river sands and loess were probably mixed. Here, pedogenesis produced an argillic Bt horizon (clay void coatings differentiated from minor alluvial clay inwash) of an *in situ*-formed Luvisol. Fluctuating water tables associated with this alluvial site, also led to some secondary iron and possible iron-manganese impregnation. Samples 1 and 3, show some contrasting traits. Sample 3 is composed of decalcified loamy fine sands and silts, and has a probable had minor anthropogenic input in the form of charcoal and burnt mineral grains; iron stained charcoal is more likely to be derived from a (local?) fire installation than be of wild fire origin. Upwards, sample 1 records a history of alluviation, characterised by bedded and laminated grey loamy silts. Some biological working and associated secondary

micritic calcite impregnation probably reflects base level fluctuations. Possible sea level-related base level changes later led to iron mottling with the presence of rare yellow brown clay infills conceivably recording coastal marine inundation and deposition of marine alluvium, as found elsewhere along the North Sea coast.

## Acknowledgements

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**Table 1: Kruibeke, Belgium; Soil Micromorphology samples and counts**

<b>Thin section</b>	<b>Relative depth</b>	<b>MFT</b>	<b>SMT</b>	<b>%Voids</b>	<b>Roots</b>	<b>Charcoal</b>	<b>Burnt mineral</b>	<b>Shell?</b>	<b>Dusty clay</b>	<b>Clay coats</b>	<b>Y-B clay infills</b>	<b>Silt infills</b>	<b>2ndary CaCO3</b>
M1	0-90 mm	A2	2b	25%							a		aaaaa
M3	0-90 mm	C1	2a	30%		aa	a*		a*				
M18	0-90 mm	B1	1a	20%	a*					aaaaa/aaa		aa	
M21	0-90 mm	A1	Z	20%				a-1	a*				aaaa
<i>Table 1, cont.</i>													
<b>Thin section</b>	<b>2ndary Fe</b>	<b>FeMn?</b>	<b>Thin burrows</b>	<b>Broad burrows</b>									
M1	aaaaa	aa	aa	aaaa									
M3	aa	aa?	aaaa	aaaa									
M18	aaaa	aaa	aa	aaaa									
M21	aaa		aaa	aaa									

\* - very few 0-5%, f - few 5-15%, ff - frequent 15-30%, fff - common 30-50%, ffff - dominant 50-70%, fffff - very dominant >70%;

a - rare <2% (a\*1%; a-1, single occurrence), aa - occasional 2-5%, aaa - many 5-10%, aaaa - abundant 10-20%, aaaaa - very abundant >20%

**Table 2: Krubeke, Belgium; Soil Micromorphology samples (Descriptions and preliminary interpretations)**

Microfacies type (MFT)/Soil microfabric type (SMT)	Sample No.	Depth (relative depth)  Soil Micromorphology (SM)	Contexts and preliminary findings and interpretations
MFT A2/SMT 2b	M1	<p>0-90 mm</p> <p>SM: massive, bedded and laminated grey loamy silts (SMT 2b) with secondary calcium carbonate and weak iron staining; <i>Microstructure</i>: massive, bedded and laminated, with channel, 25% voids, fine channels and examples of subhorizontally oriented fissures; <i>Coarse Mineral</i>: C:F=95:05, well sorted silts, with very few stringers of very fine sand; <i>Coarse Organic and Anthropogenic</i>:: <i>Fine Fabric</i>: SMT 2b: dusty grey (PPL), extremely low interference colours (close porphyric, stipple speckled b-fabric, XPL), grey with rare very pale yellow (OIL), essentially minerogenic; <i>Pedofeatures</i>: <i>Textural</i>: rare yellow brown moderately well oriented clay infills; <i>Crystalline</i>: very abundant micritic calcium carbonate impregnations; <i>Amorphous</i>: very abundant moderately weak iron staining, and occasional probable iron manganese nodule formation probably linked to root traces; <i>Fabric</i>: occasional thin and abundant broad burrows; <i>Excrements</i>:</p>	<p>Massive, bedded and laminated grey loamy silts with secondary calcium carbonate and weak iron staining, composed of well sorted silts, with very few stringers of very fine sand. Rare yellow brown moderately well oriented clay infills, very abundant micritic calcium carbonate impregnations, very abundant moderately weak iron staining, and occasional probable iron manganese nodule formation probably linked to root traces, and occasional thin and abundant broad burrows, were noted. <i>Massive, bedded and laminated grey loamy silts, record a history of alluviation. Some biological working and associated secondary micritic calcite impregnation probably reflects base level fluctuations. Possible sea level-related base level changes later led to iron mottling with the presence of rare yellow brown clay infills conceivably recording coastal marine</i></p>

			<i>inundation and deposition of marine alluvium.</i>
MFT C1/SMT 2a	M3	0-90 mm SM: grey loamy fine sands and silts (SMT 2a); <i>Microstructure</i> : massive with channel, 30% voids, fine channels; <i>Coarse Mineral</i> : C:F=95:05, moderately well sorted silts and very fine sands; <i>Coarse Organic and Anthropogenic</i> : occasional fine and coarse wood charcoal (max 5mm), especially at 10mm and 60mm depths; some charcoal is iron stained; <i>Fine Fabric</i> : SMT 2a: dusty grey (PPL), extremely low interference colours (close porphyric, stipple speckled b-fabric, XPL), grey and very pale yellow (OIL), essentially minerogenic with trace amounts of very fine charcoal and very fine rubefied (burnt?) mineral inclusions; <i>Pedofeatures</i> : <i>Textural</i> : trace of dusty void infills; <i>Amorphous</i> : occasional weak iron staining with strong iron (and FeMn?) nodular formations associated with relict channels; <i>Fabric</i> : abundant thin and broad burrows; <i>Excrements</i> :	Homogeneous grey loamy fine sands and silts, made up of moderately well sorted silts and very fine sands. There are occasional fine and coarse wood charcoal (max 5mm), especially at 10mm and 60mm depths; some charcoal is iron stained and a trace of very fine burnt mineral inclusions were noted. A trace of dusty void infills, occasional weak iron staining with strong iron (and FeMn?) nodular formations associated with relict channels, and abundant thin and broad burrows, are present. <i>Biologically homogenised grey loamy fine sands and silts, made up of moderately well sorted silts and very fine sands. The layer has a moderate anthropogenic signature in the form of occasional fine and coarse wood charcoal (max 5mm), especially at 10mm and 60mm depths; some charcoal is iron stained and a trace of very fine burnt mineral inclusions. Post-depositional rooting and base level fluctuations led to occasional weak iron staining with strong iron (and FeMn?) nodular formations.</i>
MFT B1/SMT 1a	M18	0-90 mm SM: pale orange brown to dark orange brown, diffusely iron mottled loamy silty fine sands and	Pale orange brown to dark orange brown, diffusely iron mottled loamy silty fine sands and fine sandy silt



		<p>fine sandy silt loams (SMT 1a); <i>Microstructure</i>: massive, 20% voids, simple packing voids and fine channels; <i>Coarse Mineral</i>: C:F, SMT 1a=95:05-85:15, moderately well sorted coarse silts and very fine sands, quartz and feldspars; <i>Coarse Organic and Anthropogenic</i>: possible very fine root trace; <i>Fine Fabric</i>: SMT 1a: orange brown to dark orange brown (PPL), very low interference colours (close porphyric, stipple speckled b-fabric, XPL, pale yellow (OIL), minerogenic; <i>Pedofeatures</i>: <i>Textural</i>: areas of very abundant moderately oriented clay void coatings and infills, especially in upper part of sample, and occasional silt infills in burrows; <i>Amorphous</i>: abundant iron impregnative staining especially affecting textural pedofeatures, with many possibly associated iron-manganese nodular impregnations, some also picking out relict rooting patterns; <i>Fabric</i>: probably occasional thin and abundant broad burrows; <i>Excrements</i>:</p>	<p>loams, made up of moderately well sorted coarse silts and very fine sands. The deposit is characterised by possible very fine root trace, areas of very abundant moderately oriented clay void coatings and infills, especially in upper part of sample, and occasional silt infills in burrows, abundant iron impregnative staining especially affecting textural pedofeatures, with many possibly associated iron-manganese nodular impregnations, some also picking out relict rooting patterns, and probably occasional thin and abundant broad burrows.</p> <p><i>This is a decalcified alluvial sediment composed of silty fine sands and fine sandy silt loams, made up of moderately well sorted coarse silts and very fine sands. It is not a pure loess, as in M21, but mixed with very fine river sands, and thus more like a 'brickearth'.</i></p> <p><i>Weathering (groundwater drainage and effects) of this sediment may have decalcified it, leading to the formation of secondary calcium carbonate features below (M21). Although some clay movement may be relict of flood alluviation, it is more likely that clay translocation is of pedological origin, allowing this layer to be termed a Bt (argillic) subsoil horizon. The soil can</i></p>
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			<i>be classed as a Luvisol. Base level fluctuations are responsible for iron and possible iron-manganese mottling in a soil which was burrowed and rooted.</i>
MFT A1/SMT Z	M21	0-90 mm SM: Homogeneous grey silt (SMT Z) with secondary calcium carbonate and very weak iron staining; <i>Microstructure</i> : massive with channel, 20% voids, fine and medium channels; <i>Coarse Mineral</i> : C:F (Coarse:Fine limit at ~10 µm), well sorted medium and coarse silts; <i>Coarse Organic and Anthropogenic</i> : possible weathered fine size mollusc fragment; <i>Fine Fabric</i> : ; <i>Pedofeatures</i> : <i>Textural</i> : rare trace of dusty clay void coatings and infills; <i>Crystalline</i> : abundant micritic calcite impregnations and channel (and burrow) -associated void fills; <i>Amorphous</i> : many areas of very weak iron staining; <i>Fabric</i> : many thin and broad burrows; <i>Excrements</i> :	Homogeneous grey silt with secondary calcium carbonate and very weak iron staining, and composed of well sorted medium and coarse silts. A possible weathered fine size mollusc fragment, rare trace of dusty clay void coatings and infills, abundant micritic calcite impregnations and channel (and burrow) -associated void fills, many areas of very weak iron staining, and many thin and broad burrows, were recorded. <i>Massive, probable well sorted alluvial silt, ultimately of possible loessic origin. Minor bioworking in the form of burrowing has taken place, and probably overlying alluviation led to trace amounts of dusty clay inwash. Ground water effects include marked secondary micritic CaCO<sub>3</sub> impregnation often associated with burrows and relict (root?) channels. Equally, weak iron staining has occurred.</i>

## Kruikebe Soil Micromorphology Figures 1-30

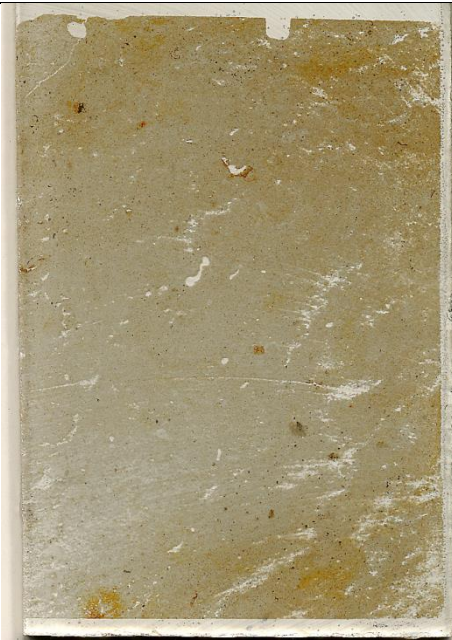


Fig. 1: Scan of M21; massive, well sorted alluvial silts, with few channels (Figs 2-3) and very weak iron staining; (root) channel associated secondary calcium carbonate features are also present (Figs 4-5). Frame height is ~90mm.

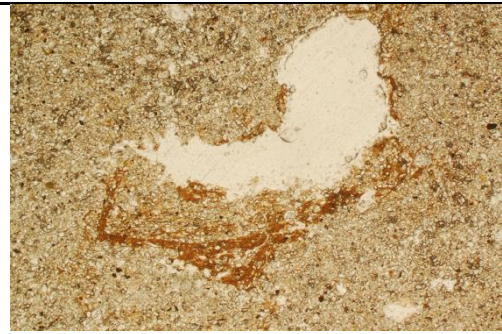


Fig. 2: Photomicrograph of M21; channel with inwashed dusty clay – possibly of alluvial flooding origin. Plane polarised light (PPL), frame width is ~4.62mm.



Fig. 3: As Fig 2, under oblique incident light (OIL), illustrating clay inwash.



Fig. 4: Photomicrograph of M21; probably fine rooted silts with associated (dark grey) micritic calcium carbonate impregnations. PPL, frame width is ~4.62mm.

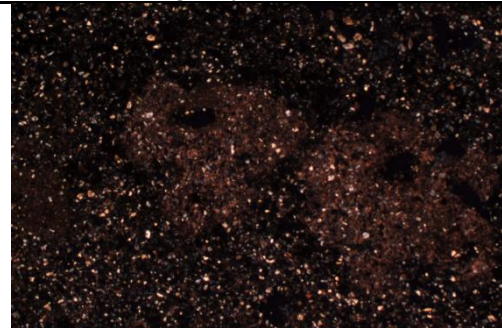


Fig. 5: As Fig 4, under crossed polarised light (XPL); note areas of higher interference colours.





Fig. 6: Scan of M18; massive decalcified silty fine sands and fine sandy silt loams, showing iron mottling, often associated with clay void coatings (Figs 7-11); some root traces are picked out by probable iron-manganese nodules. Frame height is ~90mm.

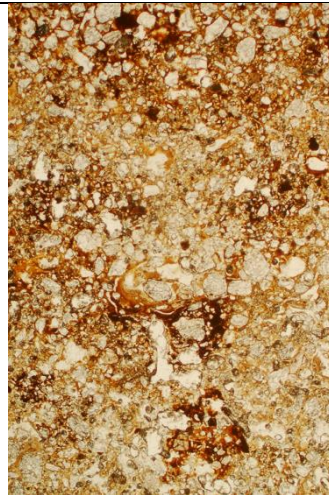


Fig. 7: Photomicrograph of M18: broad burrow in decalcified fine sandy silt loam, with both silt inwash and clay coating textural pedofeatures. PPL, frame height is ~4.62mm.

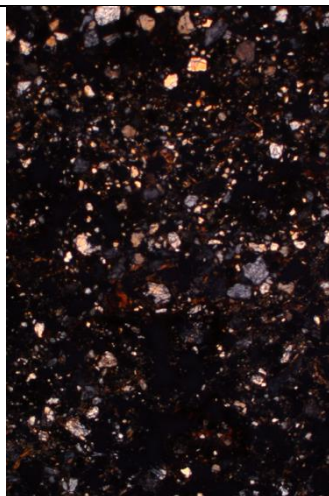


Fig. 8: As Fig 7, under XPL; silts and clay coats can be seen.

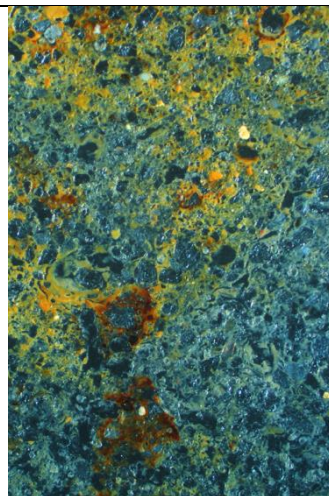


Fig. 9: As Fig 7, under OIL; secondary iron staining has affected clay coatings in particular.



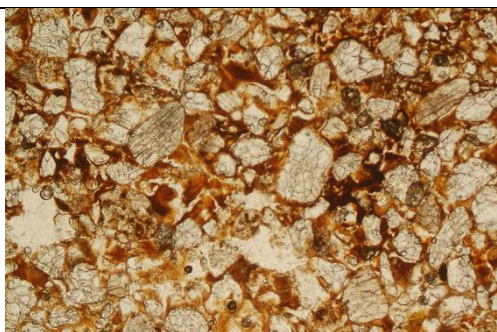


Fig. 10: Photomicrograph of M18; clayey coatings and infills are due to pedological argillic subsoil Bt horizon formation. PPL, frame width is ~2.38mm.

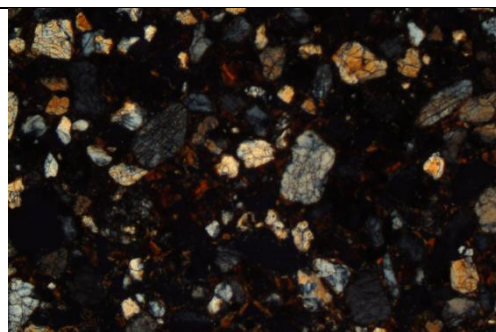


Fig. 11: As Fig 10, under XPL, showing the presence of oriented clay, albeit partially obscured by iron staining.

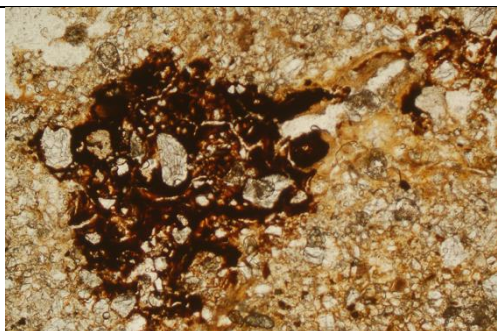


Fig. 12: Photomicrograph of M18; probable rooting feature in this gleyic luvisol, is picked out by likely iron manganese nodule formation. PPL, frame width is ~2.38mm.

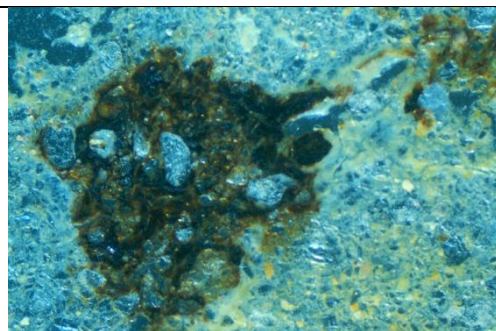


Fig. 13: As Fig 12, under OIL; FeMn is black.

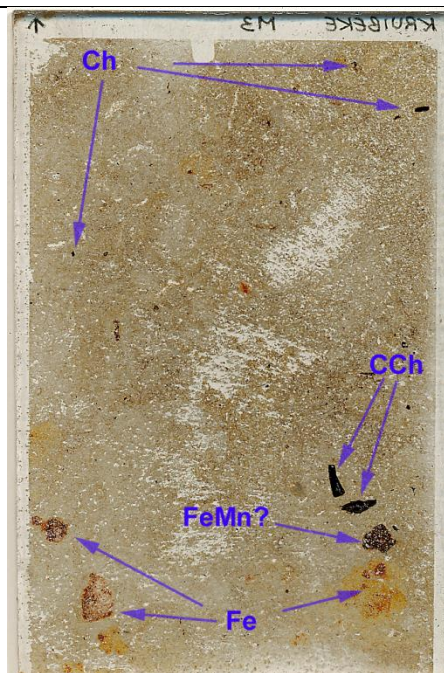


Fig. 14: Scan of M3; biologically homogenised loamy fine sands and silts (Figs 15-18), with fine charcoal (Ch) and coarse iron stained charcoal (CCh; Figs 19-20); later rooting is picked out by iron (Fe) and likely iron-manganese nodular impregnations (FeMn?). Frame height is ~90mm.

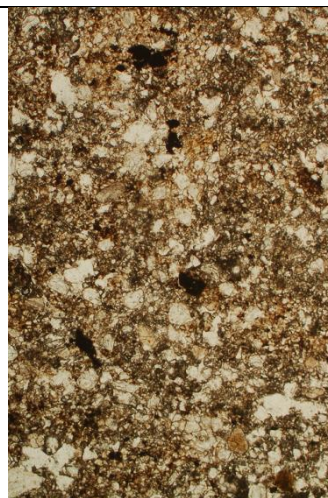


Fig. 15: Photomicrograph of M3; burrowed and mixed (biologically) homogenised loamy fine sands and silts, with small amounts of very fine charcoal present. PPL, frame height is ~4.62mm.



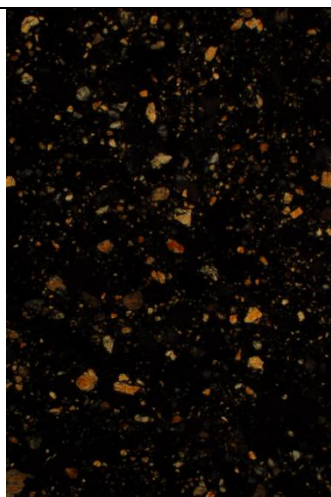


Fig. 16: As Fig 15, under XPL, illustrating silt and very fine sand content.

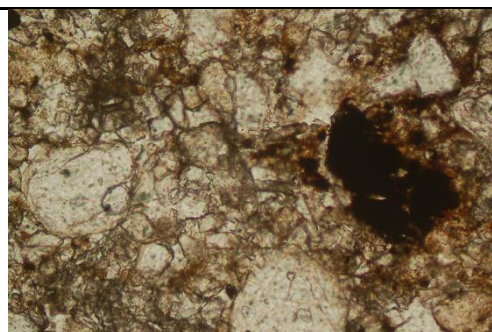


Fig. 17: Detail of Fig 15; sparse fine fabric with very fine charcoal present. PPL, frame width is ~0.90mm.

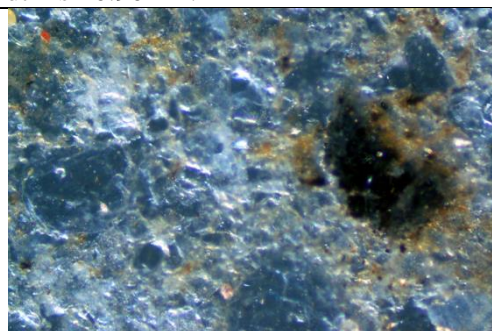


Fig. 18: As Fig 17, under OIL.

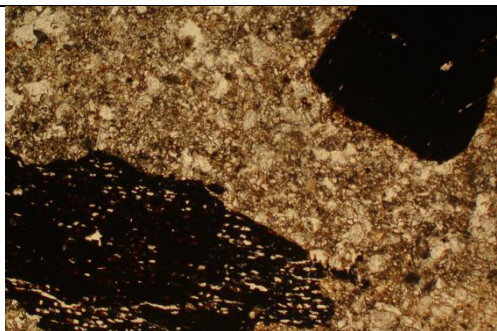


Fig. 19: Photomicrograph of M3; grey loamy silts and sands with coarse charcoal. PPL, frame width is ~4.62mm.

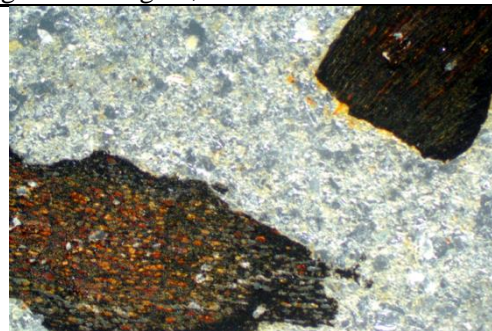


Fig. 20: As Fig 19, under OIL, showing iron stained charcoal fragments.



Fig. 21: Scan of M1; massive, bedded and laminated loamy silts (Figs 22-24), with micritic impregnations, patchy iron staining, inwashed clay (CL; Figs 24-29) and secondary iron-manganese nodular impregnations probably linked to later rooting (FeMn?). Frame height is 90mm.



Fig. 22: Photomicrograph of M1; relict sedimentary layers and laminae composed of loamy silts and very fine sands. PPL, frame height is ~4.62mm.

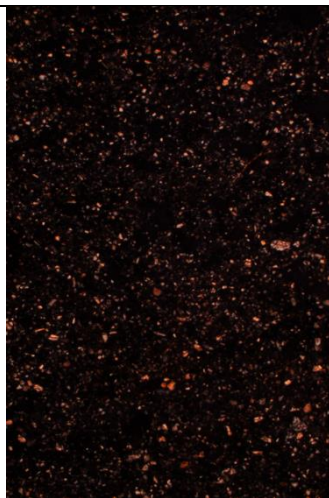


Fig. 23: As Fig 22, under XPL, showing silt and very fine sand content.



Fig. 24: As Fig 22, under OIL; note very weak iron staining.



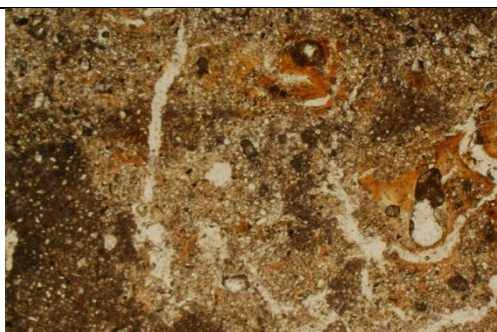


Fig. 25: Photomicrograph of M1; fine fabric with dark grey micritic calcium carbonate impregnations and channel infills of yellow brown clay. PPL, frame width is ~4.62mm.

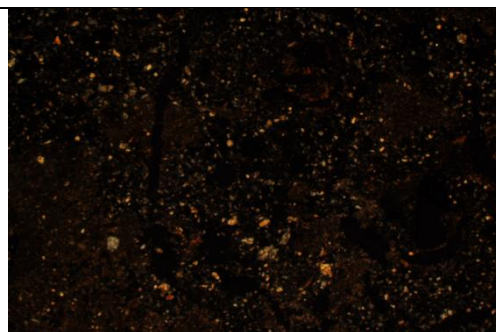


Fig. 26: As Fig 25, under XPL;  $\text{CaCO}_3$  impregnations with enhanced interference colours.

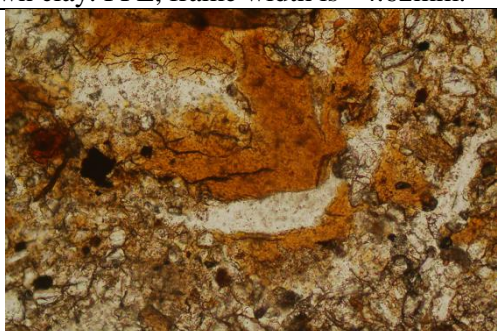


Fig. 27: Detail of Fig 25; yellow brown clay infill. PPL, frame width is ~0.90mm.

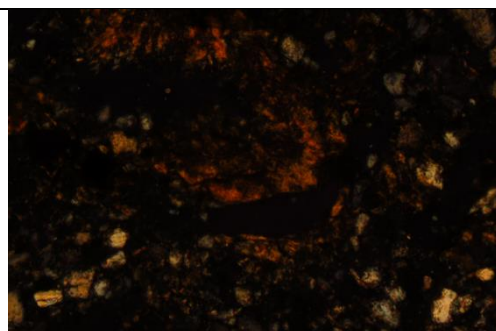


Fig. 28: As Fig 27, under XPL; note birefringent clayey infills.

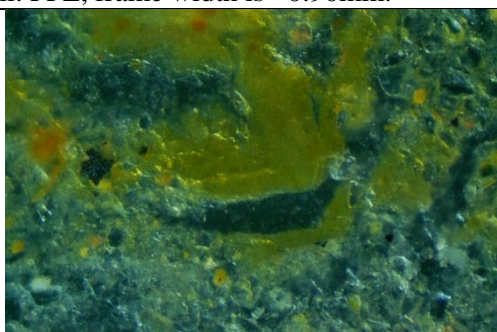


Fig. 29: As Fig 27, under OIL, showing weak iron stained clay is present.



Fig. 30: Photomicrograph of M1; another example of clay inwash. PPL, frame width is ~2.38mm.