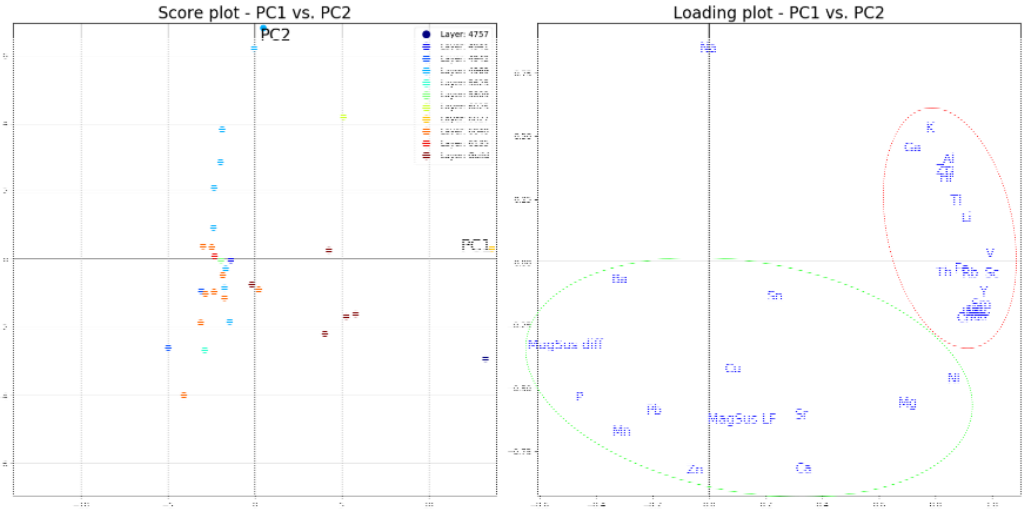
Soil geochemistry in medieval Odense

Analysis of samples from the Guild House and the Old Road area (OBM 9776 II)

Af Søren M. Kristiansen, Thomas Ljungberg, Federica Sulas



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Introduction

This report presents the results of geochemical analyses of soil samples from archaeological deposits uncovered by excavations at the medieval Guild House and the Old Road area in central Odense (OBM 9776 II). The content is closely related to the micromorphology from the OBM 9776 II site report by Sulas et al. (2021), where site formation, post-depositional processes, identification of markers of activities, and use of space and traffic are discussed in more details.

The aim of this report is to reveal what the geochemistry of sediments from OBM 9776 II site can tell about the archaeological contexts. The results provide background information for both the soil micromorphology analysis and the archaeological interpretations. This report presents only the results of soil chemistry and magnetic susceptibility, and based on these data, reflects on the environmental and cultural context of early medieval Odense. When the inorganic chemical evidence in this report is compared with the data from soil micromorphology (Sulas et al., 20121, dating, artefacts, and ecofacts, a new understanding for the precise uses of the individual houses and roads emerges.

More information on the excavation contexts and sample locations are summarised in Sulas et al. (2021). Soil micromorphology in medieval Odense - Analysis of samples from the Guild House and the Old Road area (OBM 9776 II). Soil samples were kindly provided by Mikael Manøe Bjerregaard (Odense City Museums, henceforth: OBM).

Contexts of the samples: Sampling sites

Figure 1 shows the location of the sampling sites on a contemporary map and with an inserted Braunius' map from 1593 with the approximate sampling position shown.

Figure 1 The location of excavation trenches (OBM 9776) shown by red dots in modern-day Thomas B. Thriges Gade and I. Vilhelm Werners Plads (Map sources modified from HistoriskAtlas.dk) and with Braunius' map inserted.

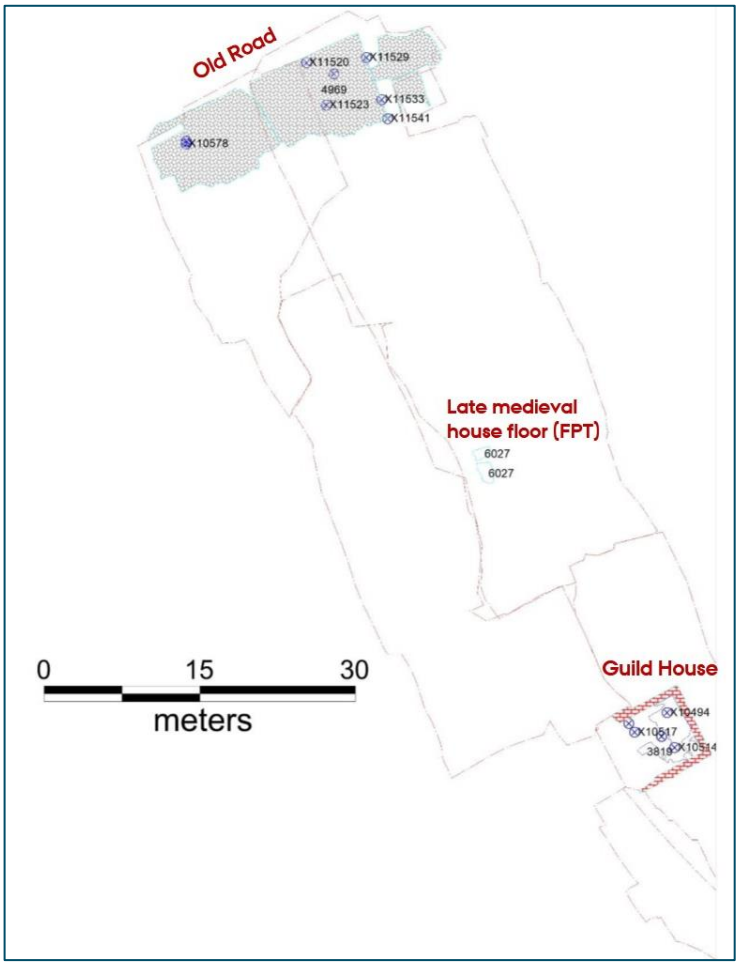

Figure 2 is a close-up of the excavation context where the exact soil sample positions are shown. This is based on the excavation reports from OBM 9776 II. Rationales for including these samples in this study are elaborated in Sulas et al. (2021). Map provided by M. M. Bjerregaard, OBM.

Materials and methods

Soil and analyses

Bulk samples for soil geochemistry were collected by the OBM team from the same contexts as the samples for micromorphology (Table 1).

A total of 32 geochemical soil samples were taken from key deposits and described by the excavation team (Table 1). Of these, 23 were from the same contexts from where the 17 Kubiena size boxes and the 6 monoliths were taken for the soil micromorphology (Sulas et al., 2021). Loose samples of sediments were taken from these deposits in small plastic bags. The full list of sample IDs, contexts and archaeological questions are provided in Table 1.

The soil samples were pre-processed with <2 mm sieving and milling at the Department of Geoscience, Aarhus University, and the chemical analyses were carried out by the Canadian company Bureau Veritas.

The chemical composition of the soil samples was determined by means of Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS). The samples were first dissolved in an HNO_3, $HClO_4$, HF, and HCl extraction, after which the molecules in the solution are dissociated and ionised through combustion in an argon plasma flame. The chemical composition is then determined by means of an ultra-trace mass spectrometer. The elements found in ICP-MS analyses in sufficiently high concentrations to be measurable above detection limits, and with sufficient precision in repeated analyses , were (in alphabetical order): Al, Ba, , Ca, Ce, Co, Cr, Cs, Cu, , Fe, Ga, Hf, K, La, Li, Mg, Mn, Na, Nd, Ni, P, Pb, Pr, Rb, , Sc, Sm, Sn, Sr, Th, Ti, Tl, U, V, Y, Zn and Zr. Noteworthy, Co is not included in further analyses as it may be contamination from the wolfram carbide mortar used for the milling.

Magnetic susceptibility was measured by a Bartington MS2b dual frequency sensor for laboratory use. The difference in magnetic susceptibility was measured with high and low frequency. In general, the difference between these two frequencies is an indicator of biologically produced iron, while the low frequency traditionally is interpreted as the iron formed due to heating, i.e. anthropogenic in Danish contexts.

The chemical data was analysed using both standard descriptive statistics and PCA (Principal Component Analysis). The latter is a relatively new method that affords a finer understanding of large multivariate datasets than descriptive statistics alone. PCA and its utilization in archaeology is discussed in Nielsen & Kristiansen (2014), Sulas et al. (2021), and references herein

All calculations and figures were made using Python 3.6 (the Numpy, Pandas, scikit-learn and Matplotlib modules).

The soil geochemical analyses have been performed without correcting for the effect of quartz dilution, which can both force artificial positive correlations and obscure negative correlations, as there is no measurement of the Si content.

As good, natural reference soil samples were not available either obtainable for the OBM 9776 II area, the results from this study were compared with relevant data from Reimann et al. (2014), providing contemporary grassland soil data. However, these are from modern-day agricultural grasslands (V. Ernstsen, GEUS, pers. comm; Reimann et al., 2014) and hence to some extent modified by lime, marl, and organic and inorganic fertilizers through centuries of farming activities.

Table 1. List of micromorphological samples and geochemical samples related to their excavation context.

Context	*Samples**	*Excavation layers*	*Key archaeological questions*
GUILD HOUSE			
Eastern area			Function and activities
section FCB	OBM 1 (X10494-9776)	3848 fill with brick rubble 5426 walkway 5381 sand floor, poss. bedding 5326 dirt layer over floor 5340 3819 limestone floor 3738 decomposed layer, brick rubble 3207 decomposed layer, brick rubble	
Walkway			Traffic
section FCH	OBM 2 (X10508-9776) OBM 18 (X1057-9776 FCH)*?	3848 fill with brick rubble 5426 walkway with humus 5381 sand floor, poss. bedding 5340 sandy floor 5326 dirt layer over floor 5340 3832 clay floor 3207 decomposed layer, brick rubble	
section FCK	OBM 3 (X10514-9776) OBM 19 (X10513-9776 FCK)*?	5588 humus 5380 brick floor 5412 soot 5340 sandy floor 5326 dirt layer over floor 5340 3819 limestone floor 3207 decomposed layer, brick rubble	Function and activities
Western area			Function and activities
section FCL	OBM 4 (X10517-9776)	5585 gravel levelling 3848 fill with brick rubble 5425 humus 3829 clay floor 3207 decomposed layer, brick rubble	
Entrance hall			Traffic
Section FCM	OBM 5 (X10520-9776) OBM 20 (X10519-9776 FCM)*?	3848 fill with brick rubble 5425 humus 3829 clay floor 3830/3207 decomposed layer, brick rubble	

Table 1 continued.

Context	*Samples**	*Excavation layers*	*Key archaeological questions*
OLD ROAD			
Easter part			Accumulation rate
section FCJ	OBM 6 (X10578-9776)	4942 top of cultural layer	/
	OBM 7 (X10581-9776 LAG 4942)	4942 fill of pavement	Dunghill?
	OBM 8 (X10584-9776 LAG 4941)	4941 fill of pavement	Dunghill?
Western part			Accumulation rate and activities
section FQE	OBM 10 (X11520-9776 FRONT)	4969 pavement and 6040 fill over it	
	OBM 11 (X11523-9776 FRONT)	Ditto	
section FLB/FQE/FQD	OBM 16 (X11561-9776 FRONT LAG 4969/6040)	Ditto	
	OBM 17 (X11571-9776 FRONT LAG 4969/6040)	Ditto	
section FLB	OBM 13 (X11529-9776 FRONT LAG 6040/6135)	/	Accumulation rate
	OBM 14 (X11533-9776 FRONT LAG 6040)	/	
	OBM 15 (X11541-9776 FRONT LAG 6040/5625)	6040 fill of pavement	
		5625	
	OBM 22 (X11593-9776 LAG 5625/6040)*?		
	OBM 23 (X11594-9776 LAG 5625/6040)*?		
section FQD	OBM 12 (X11526-9776 FRONT LAG 6040/5809	6040 fill of pavement	Accumulation rate
		5809 ditch along market stalls	
LATE MEDIEVAL HOUSE FLOOR (FPT)			
section FLB	OBM 9 (X11447-9776 FRONT)	6025 white sand	Function of the floor
	OBM 21 (X11446-9776 LAG 6027)*?	6026 paved stone floor	
		6027 clay floor	

Results

Absolute concentrations

Two different approaches were employed to investigate the levels and variations of elements found in the samples. Please see Appendix 1 for the full dataset.

The elements which are known as anthropogenic markers are included in Table 2. Only elements of interest are discussed as the understanding of bulk soil geochemistry in urban contexts still are in its infancy.

Lead concentration above the contemporary National Soil Quality Criteria in Denmark (Miljøstyrelsen, 2018) is found in 12 samples, while Cu content is above these criteria in one sample only (X11516, context 4969). Ca content in general shows that the samples are non-calcareous, and some (X11578 and X11576) are very low in Ca. High Ca in such acidic soil material is likely due to a higher content of silt-sized feldspar minerals. P content in all the samples is relatively high compared to average Danish surface soil values (Reimann et al. 2014), which reflects a high, general input of P-containing material in the medieval city. However, it should be noted that the 4-acid extraction agent used in this study is stronger than the Aqua Regia used by Reimann et al. (2014), which may also impact the results.

At OBM9667, no elemental concentration is above the contemporary Soil Contamination Criteria (Miljøstyrelsen, 2018) for special land-uses and, thus, anthropogenic elemental enrichment is not considered a human toxic concern. Though, the pathways and longevities by which the contamination was exposed (organic/inorganic, dust/water, duration, etc.) to the medieval urban population could have been important for the mental and physical health in general. The absolute highest levels of anthropogenic elements were detected in sample X11516 from layer 4969 underneath the road.

PCA - including ”baseline” data from the GEMAS project

In an attempt to include reference soil materials, average values for Danish grassland soils were employed in one of the multivariate statistical PCA analyses.

The PCA showed that Danish median values from the GEMAS project for grassland soils in contemporary Denmark (Reimann et al., 2014) are significantly different than those obtained from the OBM samples. PC1, which explains c. 45 % of the variance in the data, shows that, compared with the median of the baselines extracted with Aqua Regia, the samples from OBM are enriched in most elements, clearly reflecting that Aqua Regia is a weaker extraction agent than the 4-acid used for the samples. It is, however, also seen that four of the samples from the guild house and, especially, the two samples from layers 6027 and 4757, show significantly higher contents of most or all of the elements in the group to the far left of the loading plot. This group consists primarily of rare earth elements and metals, of which several can be associated with anthropogenic activities.

Table 2. Geochemical anthropogenic markers. Analyses above the con-temporary National Soil Quality Criteria in Denmark (Miljøstyrelsen, 2018) are marked with bold. MDL denote minimum detection limit.

			Element	Ag	Ba	Ca	Cu	Mn	Ni	P	Pb	Sn	Sr
			Unit	PPB	PPM	%	PPM	PPM	PPM	%	PPM	PPM	PPM
	House/		MDL	20	1	0,01	0,1	1	0,1	0,001	0,02	0,1	1
Sample	street	Layer	Section										
X10495	Guild	Guild	FCB	721	393	3,57	88,6	766	8,8	0,289	**44,5**	4,3	196
X10509	Guild	Guild	FCH	505	402	2,82	58,8	705	10,4	0,277	34,2	5,6	170
X10515	Guild	Guild	FCK	1173	417	5,41	165	732	15,0	0,345	**104**	13,5	203
X10518	Guild	Guild	FCL	1313	389	5,31	249	609	11,8	0,299	**61,9**	20,5	191
X10521	Guild	Guild	FCM	963	471	3,13	258	718	12,5	0,383	**61,2**	752,2	177
X10579	Road	4942	FCJ	2685	444	3,87	81,6	865	6,3	0,431	**118**	2,9	166
X10582	Road	4942	FCJ	1424	415	3,53	47,5	858	6,2	0,351	22,0	88,3	149
X10585	Road	4941	FCJ	2185	390	3,15	121	691	6,1	0,299	**42,5**	2,6	144
X11448	Road	6027	FLB	973	381	6,13	50,4	500	15,3	0,113	28,5	2,9	195
X11449	Road	6025	FLB	78	378	1,15	8,6	258	9,0	0,078	16,3	0,7	108
X11512	Floor	4969	Road	655	476	1,34	15,6	626	5,2	0,442	13,6	0,9	162
X11513	Floor	4969	Road	628	436	1,15	13,3	474	4,6	0,409	21,9	0,6	149
X11514	Road	4969	Road	1809	486	1,73	26,4	819	5,4	0,454	13,3	0,9	164
X11515	Road	4969	Road	1161	440	2,03	81,1	920	5,9	0,414	41,0	2,9	132
X11516	Road	4969	Road	6334	488	2,96	**572**	866	6,9	0,377	**148**	4,2	162
X11521	Road	4969	FQE	2452	472	3,30	47,3	858	6,4	0,344	**84,2**	1,7	157
X11522	Road	6040	FQE	1449	388	3,76	42,3	457	6,9	0,279	31,0	1,6	148
X11524	Road	4969	FQE	2117	397	2,81	60,8	673	7,1	0,405	**100**	2,0	153
X11525	Road	6040	FQE	1710	417	3,55	56,1	722	7,2	0,354	**101**	1,5	157
X11527	Road	6040	FQD	1117	409	4,05	77,0	729	7,9	0,349	23,0	2,4	163
X11528	Road	5809	FQD	6403	390	3,19	66,6	600	7,6	0,299	39,8	5,5	145
X11530	Road	6040	FLB	1095	379	3,62	42,1	611	6,3	0,250	31,2	1,9	148
X11531	Road	6135	FLB	805	408	3,90	52,4	819	6,5	0,307	25,2	2,0	155
X11534	Road	6040	FLB	3475	444	4,53	87,5	829	7,9	0,463	**133**	2,2	178
X11535	Road	6040	FLB	1660	461	4,13	75,0	799	7,3	0,404	36,8	1,9	177
X11542	Road	6040	FLB	1188	490	3,40	55,8	559	8,3	0,426	33,7	2,5	172
X11543	Road	5625	FLB	1783	526	4,79	77,1	990	8,8	0,475	39,5	1,7	197
X11576	Road	4969	Road	25	467	0,73	3,1	339	4,5	0,190	12,5	0,7	143
X11577	Road	6040	Road	8008	418	3,41	82,7	741	6,9	0,334	**132**	1,9	162
X11578	Road	4969	Road	<20	422	0,76	2,6	504	4,4	0,191	11,8	0,7	147
X11579	Road	6040	Road	884	460	3,09	91,0	1010	8,4	0,423	24,4	4,6	185
X9959	Road	4757	Dirt	1006	408	5,17	56,0	749	21,8	0,389	33,3	3,3	182

PC2, which explains c. 20 % of the variance, clearly separates the median of the baselines extracted with lithium tetraborate from the samples from Odense. The loading plot reveals that this is partly because lithium tetraborate is a very aggressive extraction agent, capable of dissolving even the

most resilient minerals, causing this baseline to show high contents of Hf and Zr. At the other end of this axis, towards the Odense samples, a group of elements (including P, Pb, Zn and Sr) that are commonly associated with anthropogenic activity is found. Both the two most important axes in the PCA thereby shows signs of anthropogenic activity. However, since the baselines are extracted, and one of them also analysed, with different methods than our samples, it is not possible to calculate valid statistical measures of the differences, which are therefore only qualitatively described.

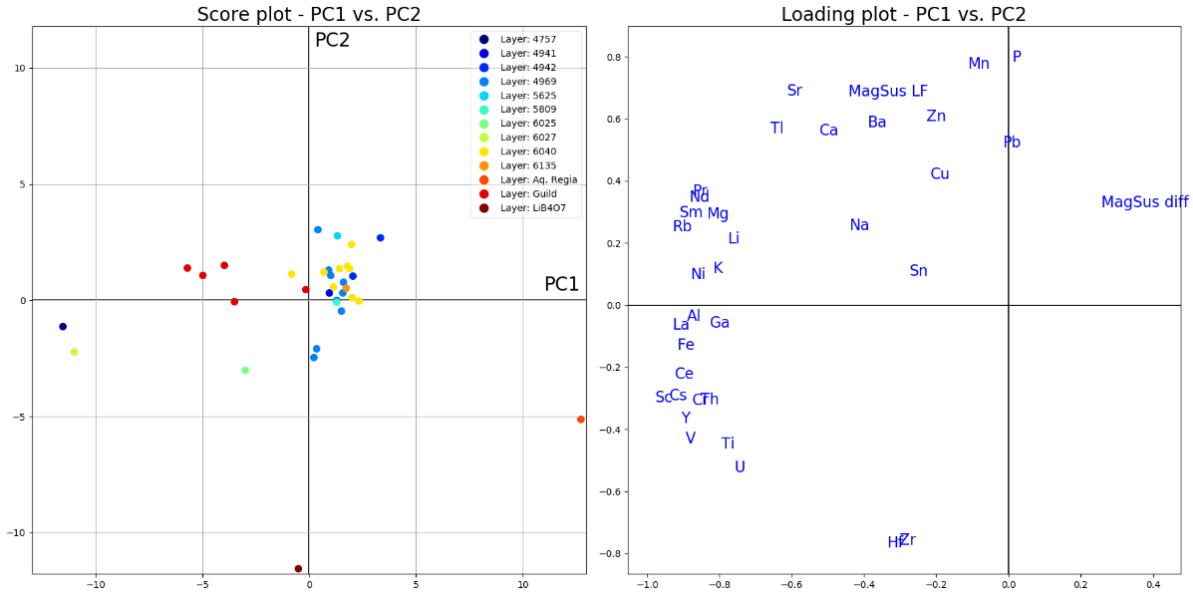

Figure 3. PCA with the baselines from the GEMAS project

The higher PCs do not reveal more information regarding the differences between the OBM samples and the baselines, they are therefore not de-scribed here.

PCA without the GEMAS data

Running the PCA without the baselines from the GEMAS project reveals some interesting patterns within the OBM 9776 II site (Fig. 4). On the right side of the loading plot a tight cluster of elements (marked with the red oval) is seen. A cluster like this is very commonly seen (if not always) in PCA's of Danish soil samples as counter-weighing the main component of soil, silicates and hence Si. PC1 is therefore usually interpreted as reflecting the clay/sand (i.e. the geological parent material) content of the samples, but in this case the cluster contains the very weathering resistant elements Hf and Ti, which are normally/often separated from the tight cluster. Furthermore, the difference in magnetic susceptibility when measured with high and low frequency respectively, which is an indicator of biologically produced iron, is found in the opposite side of the plot. This suggests that in this case PC1 (explains c. 55 % of the variation) might actually be representing the dilution of the samples with elements/substances that are not measured, quartz sand as well as organic material, rather than the clay/sand content, but it is still very likely closely related to the parent material.

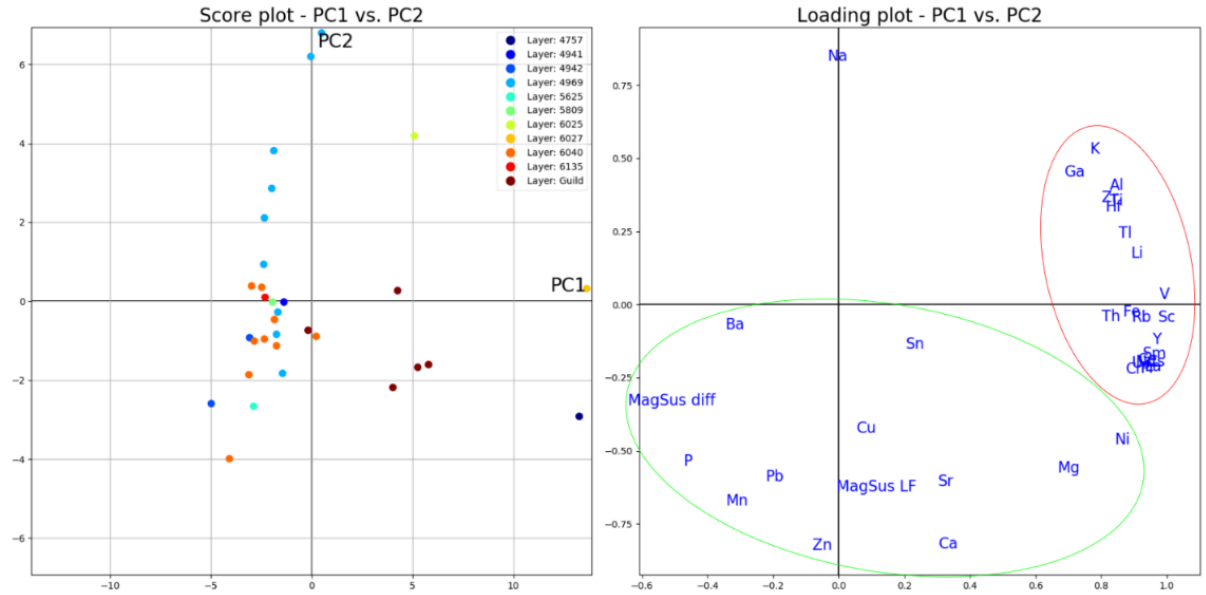

Figure 4. PCA without the baselines from the GEMAS project.

Looking at PC2 (explaining c. 17 %) we see a loose cluster in the bottom of the loading plot, which basically consists of only anthropologically influenced elements (see Sulas et al., 2019). This cluster is counter-weighed by Na, but upon closer investigation it turns out that Na is not the sole driver of this pattern. Although the samples from the old pavement has a higher concentration of Na than the rest of the samples (mean 0.873 % and 0.750 % respectively), removing this element (or any other) from the analysis does not change the vertical pattern notably. This means that the pattern is caused by the combined effect of the concentrations of several of the elements in the loose cluster.

There is no relationship between the lateral distribution of the samples and the way they plot in the PCA. The vertical "stretching" of the "4969" context could be caused by a different sampling depth below the old surface where the samples in the top of the plot are taken deeper, and hence contains less anthropogenic contamination. This is, however, only speculative, as there's no records of sampling depth. The very high elemental concentrations of metallic elements in sample X11516 is also part of the explanation and reflects that some very metal polluting human activity took place in the very near vicinity of this sample, but likely for a limited time only as the other samples from the layer 4969 are not particularly enriched.

The plot also fits very well with the samples from the contexts 6025, 6027 and 4757, which are from the medieval house, below the floor, the floor itself and dirt on the floor respectively. The floor layer and the dirt plots to the far right on the score plot due to the high clay content (i.e. low dilution with quartz/organic material), and the dirt plots below the floor layer because it has higher content of the anthropological elements as P, Cu, a.o. The layer below the floor is described as a sandy foundation layer that has held a paved stone floor, which in turn, was partly removed before the clay floor was laid out. The PCA plot suggests that it has a lower content of clay and the anthropological identifiers than the other two samples from this house.

In the guild house, the three samples X10515, X10518 and X10521 are very similar. These samples are from the functional area in the eastern room, the functional area in the Western room and the entrance, respectively. Of the five samples from the guild house, these samples shows the strongest anthropological influence. These three samples and the sample X10509 from the pathway in the eastern room seems to have a geological composition that is comparable to the foundation layer in the medieval house (6025). Though, it is different from the majority of the samples and the two top samples from the medieval house discussed above. The anthropological influence is somewhat weaker on X10509 than on the other three samples. The last sample from the guild house, X10495 from the functional area in the Eastern room, seems to be geologically closer related to the majority of the samples, i.e. more sandy/organic rich, than to the other four samples here. The anthropological influence on this sample is intermediate between the three very similar samples and X10509.

The PC's higher than 2 doesn't reveal any interpretable patterns, neither does running the PCA on a subset of the data.

Discussion and key findings

Geochemistry of samples from OBM 9776 II

Understanding the use of the early Medieval urban space at T.B. Thriges Gade in central Odense (OBM 9776 II) is a key archaeological issue in Odense City Museums' ongoing work. In recent years there has been a great development in analytical geochemistry and statistical power so it is possible to quantify a large number of elements in soil samples. This opens up for an understanding of the invisible traces in the indoor and outdoor archaeological contexts.

It must be recalled that as comparative studies from Danish medieval urban soils are lacking, reference materials were included from less suitable literature source (Reimann et al., 2014). This is in contrast to i.e. Iron Age fields where the geochemical levels and variations are better understood after decades of investigations (Dalsgaard (2009), Nielsen & Dalsgaard (2017) and Nielsen & Kristiansen (2014)).

The study of soil geochemistry has identified different elemental clusters in the deposits sampled in the Guild House, Old Road area and the late medieval house floor. These suggests that use of space and the different soil enrichment patterns can be summarised for the old road and late medieval house floor. The key results of this study are mentioned here for reference and will be discussed in details in a forthcoming paper incorporating data from more methods.

The main findings from the soil geochemistry can be summarised as follows:

1. Lead (Pb) are fund in elevated concentrations in many samples, and are above the current Danish soil quality criteria in 12 of them. This is expected in medieval towns where exposure to lead was a common pollutant.
2. That the highest absolute levels of the anthropogenic elements Cu, Pb and P are found in X11516 (layer 4969) underneath the road but not in the adjacent samples, suggests that this part of the urban environment was the most dirty and polluted in good agreement with other investigations of early medieval urban space.
3. The other variations that we observe in elemental concentration have to be discussed and interpreted in conjunction with soil micro-morphology and the other archaeological evidence.

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Appendix: Soil geochemical data

	House/street	Layer	Section	Ag	Al	As	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cs	Cu
			Unit	PPB	%	PPM	PPM	PPM	PPM	%	PPM	PPM	PPM	PPM	PPM	PPM
			Detection limit	20	0,01	0,2	1	1	0,04	0,01	0,02	0,02	0,2	1	0,1	0,1
X10495	Guild	Guild	FCB	721	2,44	3,7	393	<1	0,07	3,57	0,14	22,70	27,0	13	0,9	88,6
X10509	Guild	Guild	FCH	505	2,87	3,3	402	<1	0,08	2,82	0,20	33,97	19,6	17	1,1	58,8
X10515	Guild	Guild	FCK	1173	3,01	5,3	417	<1	0,13	5,41	0,15	28,33	21,1	16	1,3	164,6
X10518	Guild	Guild	FCL	1313	3,19	4,8	389	<1	0,21	5,31	0,20	28,90	24,7	18	1,4	249,0
X10521	Guild	Guild	FCM	963	2,96	5,0	471	<1	0,28	3,13	0,23	34,73	25,1	19	1,3	258,2
X10579	Road	4942	FCJ	2685	1,96	1,1	444	<1	0,09	3,87	0,25	16,70	19,5	9	0,7	81,6
X10582	Road	4942	FCJ	1424	2,21	1,9	415	<1	0,06	3,53	0,19	21,77	16,2	10	0,7	47,5
X10585	Road	4941	FCJ	2185	2,37	2,2	390	<1	0,10	3,15	0,22	23,66	12,3	12	0,7	120,8
X11448	Road	6027	FLB	973	3,47	3,2	381	1	0,12	6,13	0,26	40,01	21,4	23	2,0	50,4
X11449	Road	6025	FLB	78	2,86	2,2	378	<1	0,07	1,15	0,12	29,14	19,9	15	1,0	8,6
X11512	Floor	4969	Road	655	2,69	0,8	476	<1	0,05	1,34	0,11	17,14	20,2	15	0,8	15,6
X11513	Floor	4969	Road	628	2,92	1,5	436	<1	0,04	1,15	0,05	16,85	18,9	12	0,8	13,3
X11514	Road	4969	Road	1809	2,52	2,1	486	<1	<0.04	1,73	0,15	16,90	21,9	15	0,8	26,4
X11515	Road	4969	Road	1161	2,37	2,6	440	<1	0,10	2,03	0,14	20,36	17,7	11	0,8	81,1
X11516	Road	4969	Road	6334	2,53	3,4	488	<1	0,22	2,96	0,18	19,54	23,5	11	0,8	572,2
X11521	Road	4969	FQE	2452	2,46	2,2	472	<1	0,06	3,30	0,19	21,01	19,2	12	0,8	47,3
X11522	Road	6040	FQE	1449	2,27	2,2	388	<1	0,05	3,76	0,25	18,65	21,6	11	0,7	42,3
X11524	Road	4969	FQE	2117	2,45	2,3	397	<1	0,06	2,81	0,28	21,59	27,8	12	0,9	60,8
X11525	Road	6040	FQE	1710	2,34	1,8	417	<1	0,12	3,55	0,26	19,46	20,5	11	0,8	56,1
X11527	Road	6040	FQD	1117	2,40	2,3	409	<1	0,06	4,05	0,28	21,63	25,2	12	0,9	77,0
X11528	Road	5809	FQD	6403	2,35	3,3	390	<1	0,11	3,19	0,24	20,55	27,8	11	0,8	66,6
X11530	Road	6040	FLB	1095	2,27	2,7	379	<1	0,09	3,62	0,20	18,95	17,7	10	0,8	42,1
X11531	Road	6135	FLB	805	2,33	2,9	408	<1	0,07	3,90	0,24	20,54	18,9	10	0,8	52,4
X11534	Road	6040	FLB	3475	2,03	3,4	444	<1	0,08	4,53	0,29	19,55	25,7	10	0,8	87,5
X11535	Road	6040	FLB	1660	2,17	3,1	461	<1	0,07	4,13	0,26	18,79	26,4	11	0,8	75,0
X11542	Road	6040	FLB	1188	2,49	2,0	490	<1	0,07	3,40	0,35	21,38	22,9	12	0,9	55,8
X11543	Road	5625	FLB	1783	2,38	2,1	526	<1	0,09	4,79	0,40	18,44	21,2	13	0,9	77,1
X11576	Road	4969	Road	25	3,13	2,0	467	<1	<0.04	0,73	<0.02	19,24	34,5	9	0,9	3,1
X11577	Road	6040	Road	8008	2,44	3,8	418	<1	0,11	3,41	0,28	19,07	19,3	11	0,8	82,7
X11578	Road	4969	Road	<20	3,19	2,4	422	<1	<0.04	0,76	0,03	18,21	29,3	9	0,8	2,6
X11579	Road	6040	Road	884	2,62	4,1	460	<1	0,05	3,09	0,32	21,02	25,2	13	1,0	91,0
X9959	Road	4757	Dirt	1006	3,27	6,3	408	1	0,12	5,17	0,39	36,27	39,4	33	2,0	56,0

Appendix Continued

Id	Sample	House/street	Layer	Section	Dy	Er	Eu	Fe	Ga	Gd	Hf	Ho	In	K	La	Li	Lu	Mg	Mn	Mo	Na	Nb	Nd	Ni	P	Pb	Pr	Rb	Re
					PPM	PPM	PPM	%	PPM	PPM	PPM	PPM	PPM	%	PPM	PPM	PPM	%	PPM	PPM	%	PPM	PPM	PPM	%	PPM	PPM	PPM	PPM
					0,1	0,1	0,1	0,01	0,02	0,1	0,02	0,1	0,01	0,01	0,1	0,1	0,1	0,01	1	0,05	0,001	0,04	0,1	0,1	0,001	0,02	0,1	0,1	0,002
SMK_329	X10495	Guild	Guild	FCB	1,5	0,8	0,4	0,86	5,52	1,8	1,18	0,3	0,01	1,27	11,3	5,6	0,1	0,20	766	1,15	0,747	3,28	11,3	8,8	0,289	44,53	2,7	52,2	0,007
SMK_330	X10509	Guild	Guild	FCH	1,9	0,9	0,5	1,07	5,53	2,5	1,66	0,4	<0.01	1,52	14,9	7,5	0,1	0,20	705	1,06	0,808	3,89	14,5	10,4	0,277	34,15	3,6	61,2	<0.002
SMK_331	X10515	Guild	Guild	FCK	1,8	0,9	0,4	1,21	6,40	2,4	1,44	0,4	0,01	1,40	13,9	7,8	0,2	0,23	732	1,08	0,774	3,78	11,9	15,0	0,345	103,90	3,3	63,5	<0.002
SMK_332	X10518	Guild	Guild	FCL	1,9	0,9	0,5	1,24	6,85	2,0	1,37	0,4	0,03	1,54	14,4	8,8	0,2	0,26	609	0,89	0,804	4,15	13,2	11,8	0,299	61,88	3,3	63,0	0,008
SMK_333	X10521	Guild	Guild	FCM	2,0	1,0	0,4	1,15	6,59	1,9	1,37	0,4	0,02	1,55	16,3	8,9	0,2	0,24	718	1,05	0,859	4,15	14,6	12,5	0,383	61,24	3,7	62,2	0,007
SMK_334	X10579	Road	4942	FCJ	0,8	0,5	0,3	0,65	4,19	1,2	1,09	0,2	0,01	1,09	8,4	5,2	<0.1	0,21	865	1,60	0,691	2,71	7,2	6,3	0,431	118,03	1,8	45,7	0,003
SMK_335	X10582	Road	4942	FCJ	1,1	0,6	0,3	0,77	4,81	1,4	1,16	0,3	<0.01	1,15	10,9	5,1	<0.1	0,23	858	1,14	0,724	2,73	8,9	6,2	0,351	21,99	2,3	48,4	<0.002
SMK_336	X10585	Road	4941	FCJ	1,1	0,6	0,3	0,80	5,38	1,4	1,18	0,2	0,01	1,29	11,6	5,2	<0.1	0,23	691	1,12	0,735	3,22	9,8	6,1	0,299	42,48	2,4	51,7	<0.002
SMK_354	X11448	Road	6027	FLB	2,4	1,5	0,6	1,43	7,55	3,2	2,51	0,5	<0.01	1,73	19,9	14,3	0,2	0,36	500	0,38	0,750	5,91	18,0	15,3	0,113	28,51	4,7	65,7	0,003
SMK_355	X11449	Road	6025	FLB	2,2	1,4	0,5	0,94	5,85	2,6	2,21	0,4	0,02	1,59	15,0	7,6	0,2	0,19	258	0,20	0,775	4,30	14,9	9,0	0,078	16,28	3,8	52,3	0,003
SMK_337	X11512	Floor	4969	Road	1,2	0,6	0,2	1,06	6,28	1,1	1,26	0,2	0,02	1,46	8,2	8,0	0,1	0,18	626	0,44	0,914	4,03	6,2	5,2	0,442	13,55	1,8	50,1	0,004
SMK_338	X11513	Floor	4969	Road	0,9	0,5	0,3	1,03	6,78	1,3	1,18	0,2	0,02	1,47	8,2	7,2	0,1	0,16	474	0,27	0,905	3,45	7,0	4,6	0,409	21,89	1,8	53,0	0,002
SMK_339	X11514	Road	4969	Road	1,0	0,6	0,3	0,96	6,61	1,5	1,32	0,2	<0.01	1,40	8,3	7,2	<0.1	0,15	819	0,61	0,847	4,39	6,6	5,4	0,454	13,32	1,8	51,2	0,002
SMK_340	X11515	Road	4969	Road	1,1	0,5	0,3	0,92	5,80	1,3	1,22	0,2	0,02	1,32	9,7	6,8	0,1	0,18	920	0,87	0,768	3,63	9,2	5,9	0,414	41,00	2,2	50,4	<0.002
SMK_341	X11516	Road	4969	Road	1,4	0,7	0,4	1,10	5,75	1,7	1,36	0,3	0,01	1,39	9,2	6,4	0,1	0,18	866	1,08	0,788	3,53	9,4	6,9	0,377	147,91	2,2	54,7	<0.002
SMK_342	X11521	Road	4969	FQE	1,3	0,8	0,3	0,89	5,43	1,4	1,39	0,2	<0.01	1,34	10,1	5,5	0,1	0,20	858	0,85	0,798	3,13	8,8	6,4	0,344	84,20	2,4	54,8	0,002
SMK_343	X11522	Road	6040	FQE	1,1	0,6	0,2	0,76	4,86	1,2	1,24	0,2	0,02	1,22	9,1	5,6	0,1	0,22	457	1,05	0,750	3,36	8,6	6,9	0,279	30,97	2,2	51,1	0,004
SMK_344	X11524	Road	4969	FQE	1,0	0,6	0,3	0,89	5,21	1,1	1,16	0,2	0,01	1,25	10,6	6,4	0,1	0,22	673	1,23	0,714	3,16	9,6	7,1	0,405	100,20	2,4	52,7	0,004
SMK_345	X11525	Road	6040	FQE	1,2	0,6	0,3	0,81	5,27	1,0	1,13	0,2	0,02	1,19	9,1	5,8	0,1	0,21	722	1,23	0,725	3,14	7,8	7,2	0,354	100,53	2,1	51,1	<0.002
SMK_346	X11527	Road	6040	FQD	1,2	0,7	0,3	0,80	5,25	1,5	1,11	0,3	0,01	1,17	10,5	5,8	0,1	0,19	729	1,54	0,767	3,34	8,7	7,9	0,349	22,98	2,3	51,1	0,005
SMK_347	X11528	Road	5809	FQD	1,2	0,7	0,4	0,90	4,82	1,3	1,08	0,2	0,02	1,17	10,6	5,6	0,1	0,19	600	1,22	0,759	3,15	8,8	7,6	0,299	39,79	2,5	49,0	0,002
SMK_348	X11530	Road	6040	FLB	1,2	0,7	0,4	0,82	4,77	1,2	1,14	0,2	<0.01	1,20	10,1	5,4	0,1	0,17	611	1,31	0,753	3,23	7,6	6,3	0,250	31,15	2,3	49,1	<0.002
SMK_349	X11531	Road	6135	FLB	1,2	0,7	0,4	0,83	5,08	1,3	1,43	0,2	<0.01	1,21	10,6	5,2	0,1	0,18	819	1,15	0,795	3,23	7,7	6,5	0,307	25,24	2,3	50,3	<0.002
SMK_350	X11534	Road	6040	FLB	1,1	0,7	0,3	0,80	4,53	1,0	0,53	0,2	<0.01	1,07	10,1	5,2	0,1	0,25	829	1,41	0,633	3,31	8,9	7,9	0,463	133,10	2,3	44,5	0,003
SMK_351	X11535	Road	6040	FLB	1,2	0,7	0,3	0,76	4,95	1,3	1,10	0,2	<0.01	1,16	10,0	5,6	<0.1	0,24	799	1,55	0,688	3,20	8,1	7,3	0,404	36,83	2,2	48,2	<0.002
SMK_352	X11542	Road	6040	FLB	1,1	0,8	0,3	0,82	4,99	1,4	1,26	0,2	<0.01	1,25	11,0	6,3	0,1	0,24	559	1,70	0,748	3,19	8,9	8,3	0,426	33,71	2,3	48,4	<0.002
SMK_353	X11543	Road	5625	FLB	1,1	0,7	0,3	0,84	5,57	1,4	1,21	0,2	<0.01	1,23	9,3	6,3	<0.1	0,23	990	1,42	0,748	3,14	7,3	8,8	0,475	39,49	2,2	47,6	0,003
SMK_356	X11576	Road	4969	Road	1,2	0,7	0,4	0,84	7,03	0,9	1,78	0,2	0,02	1,59	9,7	9,6	0,1	0,14	339	0,26	1,064	4,37	7,9	4,5	0,190	12,47	1,9	54,2	0,004
SMK_357	X11577	Road	6040	Road	1,0	0,7	0,4	0,90	5,31	1,3	1,26	0,2	0,02	1,25	10,1	5,5	0,1	0,18	741	1,57	0,795	3,37	8,1	6,9	0,334	131,91	2,1	52,6	<0.002
SMK_358	X11578	Road	4969	Road	1,2	0,8	0,4	1,06	7,65	1,2	1,37	0,2	<0.01	1,58	9,1	7,8	0,1	0,16	504	0,36	1,055	4,36	7,3	4,4	0,191	11,79	1,9	55,0	0,002
SMK_359	X11579	Road	6040	Road	1,6	0,7	0,4	1,02	5,77	1,4	1,50	0,3	<0.01	1,32	11,2	8,2	0,1	0,24	1010	1,95	0,783	4,04	9,2	8,4	0,423	24,41	2,4	56,3	<0.002
SMK_360	X9959	Road	4757	Dirt	2,5	1,3	0,7	1,63	7,69	2,8	2,04	0,5	0,03	1,53	19,7	13,1	0,2	0,39	749	2,17	0,639	5,83	17,3	21,8	0,389	33,26	4,4	72,7	0,003

Appendix continued

Sample	House/street	Layer	Section	S	Sb	Sc	Se	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y	Yb	Zn	Zr	MagSus LF	MagSus diff
			Detection limit	%	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	%	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM		
				0.04	0.02	0.1	0.3	0.1	0.1	1	0.1	0.1	0.05	0.1	0.001	0.05	0.1	0.1	1	0.1	0.1	0.1	0.2	0.2		
X10495	Guild	Guild	FCB	<0.04	1,12	2,6	0,3	2,1	4,3	196	0,3	0,2	0,09	2,7	0,102	0,29	0,1	0,9	18	>200.0	9,1	0,8	49,8	46,1	3,82E-07	0,79240
X10509	Guild	Guild	FCH	<0.04	1,37	3,2	<0.3	2,6	5,6	170	0,3	0,2	0,07	4,0	0,122	0,35	0,2	0,9	22	>200.0	10,0	1,1	46,3	60,4	6,24E-07	1,2097
X10515	Guild	Guild	FCK	<0.04	4,92	3,5	0,5	2,2	13,5	203	0,3	0,2	0,17	3,3	0,117	0,34	0,1	0,9	22	>200.0	10,0	1,0	54,2	52,7	6,66E-07	1,9867
X10518	Guild	Guild	FCL	<0.04	2,92	3,6	<0.3	2,5	20,5	191	0,4	0,2	0,18	3,4	0,128	0,34	0,2	1,0	27	>200.0	10,1	1,0	59,1	47,7	8,34E-07	3,0308
X10521	Guild	Guild	FCM	<0.04	1,50	3,4	<0.3	2,8	752,2	177	0,3	0,2	0,11	4,2	0,132	0,36	0,2	1,0	26	>200.0	10,7	1,1	72,5	53,7	6,44E-07	2,1819
X10579	Road	4942	FCJ	0,42	0,36	1,8	0,4	1,4	2,9	166	0,2	0,1	0,11	2,1	0,087	0,27	0,1	0,6	12	193,2	5,7	0,7	78,0	38,8	6,61E-07	0,77108
X10582	Road	4942	FCJ	0,24	0,24	2,0	0,7	1,5	88,3	149	0,3	0,2	0,07	2,9	0,089	0,26	0,1	0,7	12	192,9	6,5	0,8	58,6	40,0	5,1E-07	1,1113
X10585	Road	4941	FCJ	0,17	0,39	2,1	0,3	1,7	2,6	144	0,3	0,1	<0.05	4,4	0,102	0,28	0,1	0,7	14	155,9	6,5	0,7	56,4	46,8	4,55E-07	0,91024
X11448	Road	6027	FLB	<0.04	1,38	4,9	<0.3	3,5	2,9	195	0,4	0,4	0,18	4,9	0,196	0,38	0,2	1,2	38	150,0	14,0	1,4	58,3	75,6	4,45E-07	-31,6996
X11449	Road	6025	FLB	<0.04	0,49	3,5	<0.3	2,8	0,7	108	0,4	0,3	0,11	3,6	0,171	0,37	0,2	0,9	24	155,5	12,1	1,4	46,7	78,2	3,52E-07	3,83E-07
X11512	Floor	4969	Road	0,06	0,13	2,3	<0.3	1,3	0,9	162	0,2	0,1	<0.05	2,5	0,121	0,30	<0.1	0,6	18	196,5	6,0	0,7	43,5	44,9	2,79E-07	2,3036
X11513	Floor	4969	Road	<0.04	0,17	2,5	<0.3	1,4	0,6	149	0,2	0,1	<0.05	2,3	0,115	0,31	<0.1	0,6	17	153,0	5,7	0,6	29,5	46,4	3,08E-07	2,0497
X11514	Road	4969	Road	0,08	0,12	2,3	<0.3	1,4	0,9	164	0,3	<0.1	<0.05	2,3	0,130	0,28	0,1	0,6	17	>200.0	6,2	0,7	51,2	49,9	2,47E-07	4,0702
X11515	Road	4969	Road	0,09	0,42	2,4	<0.3	1,5	2,9	132	0,3	0,1	0,06	2,5	0,123	0,28	<0.1	0,5	17	162,3	6,0	0,7	54,6	50,3	3,93E-07	1,8177
X11516	Road	4969	Road	0,20	0,86	2,3	<0.3	1,6	4,2	162	0,3	0,1	0,09	2,5	0,113	0,30	0,1	0,7	15	199,0	7,0	0,8	91,7	51,7	6E-07	2,1552
X11521	Road	4969	FQE	0,12	0,24	2,3	0,6	1,6	1,7	157	0,3	0,1	0,08	2,8	0,110	0,28	0,1	0,7	15	164,2	7,0	0,7	63,5	48,7	5,29E-07	0,55382
X11522	Road	6040	FQE	0,32	0,26	2,2	0,4	1,7	1,6	148	0,3	0,1	0,08	2,8	0,098	0,26	0,1	0,7	13	174,5	6,6	0,7	59,4	47,0	4,62E-07	1,0003
X11524	Road	4969	FQE	0,21	0,38	2,3	0,4	1,9	2,0	153	0,3	0,1	0,08	2,9	0,107	0,27	<0.1	0,7	15	>200.0	5,8	0,6	75,3	43,7	3,96E-07	1,3825
X11525	Road	6040	FQE	0,24	0,27	2,1	<0.3	1,4	1,5	157	0,3	0,1	0,08	2,7	0,098	0,28	<0.1	0,7	13	153,4	6,4	0,8	71,4	43,2	5,09E-07	2,0682
X11527	Road	6040	FQD	0,36	0,44	2,5	0,3	1,7	2,4	163	0,2	0,1	0,07	2,5	0,106	0,28	0,1	0,8	13	198,7	7,8	0,8	75,2	46,0	2,76E-07	2,9245
X11528	Road	5809	FQD	0,28	0,41	2,3	<0.3	1,6	5,5	145	0,3	0,2	0,32	3,6	0,118	0,25	<0.1	0,8	15	195,8	7,1	0,8	62,7	41,9	4,36E-07	2,7542
X11530	Road	6040	FLB	0,33	0,21	2,1	<0.3	1,3	1,9	148	0,2	0,2	0,25	2,7	0,110	0,25	0,1	0,7	14	144,2	6,3	0,7	62,5	42,4	4,28E-07	3,289
X11531	Road	6135	FLB	0,27	0,29	2,1	<0.3	1,6	2,0	155	0,2	0,2	0,19	2,6	0,106	0,27	0,1	0,8	13	160,0	6,7	0,7	62,1	50,0	4,28E-07	3,0534
X11534	Road	6040	FLB	0,39	0,47	2,0	<0.3	1,4	2,2	178	0,1	0,2	0,33	3,1	0,106	0,22	0,1	0,8	13	188,6	6,1	0,8	90,0	23,9	3,87E-07	3,1211
X11535	Road	6040	FLB	0,38	0,32	2,0	<0.3	1,4	1,9	177	0,2	0,1	0,38	3,2	0,106	0,24	0,1	0,7	13	>200.0	6,3	0,8	79,3	40,9	4,03E-07	2,4386
X11542	Road	6040	FLB	0,32	0,23	2,5	<0.3	1,5	2,5	172	0,3	0,2	0,07	3,2	0,118	0,27	<0.1	0,7	16	154,1	6,1	0,7	103,8	43,6	3,91E-07	2,4603
X11543	Road	5625	FLB	0,25	0,37	2,3	<0.3	1,4	1,7	197	0,3	0,2	0,09	2,7	0,107	0,27	<0.1	0,7	15	150,4	6,5	0,8	88,6	44,5	3,38E-07	37,2335
X11576	Road	4969	Road	<0.04	0,08	2,4	<0.3	1,4	0,7	143	0,3	0,1	0,09	3,9	0,161	0,30	0,1	0,8	18	>200.0	6,3	0,7	27,3	62,0	9,4E-08	-9,4572
X11577	Road	6040	Road	0,27	0,27	2,1	<0.3	1,4	1,9	162	0,2	0,1	0,31	2,6	0,115	0,26	0,1	0,8	14	156,7	6,6	0,7	90,0	44,1	5,08E-07	-3,0047
X11578	Road	4969	Road	<0.04	0,12	2,5	<0.3	1,3	0,7	147	0,3	<0.1	0,08	3,0	0,147	0,31	0,1	0,8	19	199,8	6,7	0,8	26,4	48,7	9,58E-08	-10,003
X11579	Road	6040	Road	0,25	0,29	2,5	0,5	1,7	4,6	185	0,3	0,1	0,40	3,1	0,140	0,27	<0.1	0,9	18	194,9	7,3	0,8	84,8	51,6	3,86E-07	-3,2096
X9959	Road	4757	Dirt	0,47	0,39	5,0	<0.3	3,6	3,3	182	0,5	0,4	0,58	5,3	0,196	0,35	0,2	1,4	37	>200.0	14,5	1,5	97,3	71,9	2,85E-07	-4,4148