TURUN MUSEOKESKUS
RAPORTTEJA 23

PITKIN POIKIN AURAJOKEA

ARKEOLOGISIA TUTKIMUKSIA

PITKIN POIKIN AURAJOKEA

ARKEOLOGISIA TUTKIMUKSIA

Omistettu Kaisa Lehtosen muistolle

TURUN MUSEOKESKUS
2019

KIRJOITTAJAT

Sonja Hukantaival, FT, Åbo Akademi, tutkimusintresseinä kansanusko ja historiallisen ajan arkeologia.

Jussi Kinnunen, FM, arkeologi ja geologi, arkeologian tohtorikoulutettava, Turun yliopisto, päätutkimusalueina keskiajan-, kaupunki-, rakennus- ja luonnontieteellinen arkeologia.

Heini Kirjavainen, FM, arkeologi ja tekstiilitutkija, Arkeologia, Turun yliopisto.

Sanna Kupila, FM, rakennustutkija, Turun museokeskus.

Kaisa Lehtonen, FM, edesmennyt maakunnallisesta arkeologiasta vastannut tutkija, Varsinais-Suomen maakuntamuseo, perehtynyt mm. Aurajokilaakson asutushistoriaan.

Anne-Mari Liira, FM, osteoarkeologi, erikoistunut ihmisluihin. Arkeologia, Turun yliopisto.

Jani Oravisjärvi, FM, intendentti, Kansallismuseo ja arkeologian tohtorikoulutettava, Turun yliopisto.

Sofia Paasikivi, FM, arkeologian tohtorikoulutettava, Turun yliopisto, erikoistunut sairauksien ja tautien historiaan ja arkeologiaan.

Aki Pihlman, FL, Turun museokeskuksen arkeologi, eläkkeellä.

Jouko Pukkila, FM, arkeologi Arkebuusi osuuskunnassa, tutkimusintresseinä Lounais-Suomen pronssi- ja rautakausi.

Janne Rantanen, FM, arkeologi.

Tanja Ratilainen, FL, kaupunkiarkeologiasta vastaava tutkija, Turun museokeskus / Varsinais-Suomen maakuntamuseo ja arkeologian tohtorikoulutettava, Turun yliopisto.

Jaana Riikonen, FK, arkeologi, Arkeologia, Turun yliopisto, perehtynyt myöhäisrautakauden hautalöytöihin, erityisesti tekstiileihin.

Juha Ruohonen, FM, Arkeologia, Turun yliopisto, erikoistunut etenkin nuoremman rautakauden ja historiallisen ajan muinaisjäännöksiin sekä arkeologisiin kenttätyömenetelmiin. Hän on johtanut tutkimuksia Ravattulan Ristimäellä vuodesta 2010 lähtien.

Elina Saloranta, FM, Turun museokeskus, työskennellyt kenttäarkeologina Turun museokeskuksen kaupunkikaivauksilla vuosina 1997–2015.

Panu Savolainen, FT, arkkitehti, tutkinut erityisesti 1700-luvun kaupunkihistoriaa.

Liisa Seppänen, Kaupunkiarkeologian dosentti, Turun yliopisto ja arkeologian dosentti Helsingin yliopisto, tutkinut pääasiassa kaupunkiarkeologiaa ja kaupunkirakentamista Suomeen ja Turkuun erikoistuen.

Jasse Tiilikkala, FM, Arkeologia, Turun yliopisto.

Tiina Vasko, FM, Arkeologia, Turun yliopisto, tutkinut rautakauden ja keskiajan hautoja sekä näiden ajanjaksojen esineistöä.

Toimittajat
Riikka Mustonen & Tanja Ratilainen

Translation
englanniksi.fi

Graafinen suunnittelu
Ulla Kujansuu

Turun museokeskus Raportteja 23

ISBN 978-951-595-207-3 (pdf)
ISBN 978-951-595-208-0 (painettu)
ISSN 1797-965X

TURKU

Kansi
Kuva Harri Jokinen.

Sivu 1
Arkeologi Kaisa Lehtonen Ravattulan Ristimäellä. Kuva Juha Ruohonen.

TOIMITTAJIEN SANAT

Ajatus kirjahankkeesta virisi vuonna 2014, kun Kaisan kanssa totesimme, että paljon uutta ja mielenkiintoista tutkimusta oli meneillään, ja museon edellisestä arkeologisesta julkaisusta alkoi olla jo tovi. Kirjan punaiseksi langaksi muotoutui Aurajokilaakso, joka yhdisti sopivasti sekä maakunnallista arkeologiaa että kaupunkiarkeologista näkökulmaa. Teimme museon julkaisutoimikunnalle ehdotuksen ja laitoimme tiedusteluja mahdollisille kirjoittajille. Kirjan työnimeksi tuli *Pitkin poikin Aurajokea* A.-M. Tallgrenin klassikon (*Varsinais-Suomea pitkin ja poikin: kirjoitelmia ja kuvauksia*, 1918) inspiroimana. Julkaisua suunniteltiin vuodelle 2017.

Kohtalo päätti kuitenkin toisin, ja tästä kirjasta tuli Kaisan muistolle omistettu.

Toimitustyötä päästiin jatkamaan syksyllä 2017 Riikan aloittaessa maakunnallisen arkeologin tehtävissä. Sen aikana meille konkretisoitui, miten moneen tässä julkaistavaan tutkimukseen Kaisa oli ollut arkeologina vaikuttamassa. Kiitos Sanna Kupilan, julkaisuun saatiin myös kooste Kaisan ja Sannan yhteisprojektista Turun historiallisen ajan kylätonttien inventoinnin parissa.

Raportteja -sarjan ilme ja julkaisuformaatti päätettiin tässä yhteydessä uudistaa. Kiitos raikkaasta ja näyttävästä taitosta kuuluu Ulla Kujansuulle. Nyt myös sähköisenä ilmestyvä julkaisu tavoittaa aikaisempaa laajemman lukijakunnan.

Lopuksi esitämme kirjoittajille kiitokset kärsivällisyydestä ja kaikille hankkeessa mukana olleille kiitokset hyvin sujuneesta yhteistyöstä sekä toivotamme mielenkiintoisia lukuhetkiä arkeologian parissa, Kaisaa muistaen.

Turussa 4.2.2019

Tanja Ratilainen ja Riikka Mustonen

Kuva Elina Saloranta.

IDENTIFYING THE ORIGIN OF BRICKS AND ROOF TILES WITH pXRF

A CASE STUDY FROM MEDIEVAL TURKU, FINLAND

BY RATILAINEN, TANJA AND KINNUNEN, JUSSI

INTRODUCTION

In Finland, the origin of bricks and roof tiles has been mostly studied with Particle-Induced X-ray Emission (PIXE), which is a precise and non-invasive method for analysing chemical elements in objects.[1] Recently, a Scanning Electron Microscope (SEM) with an X-ray microanalysis system has also been successfully applied on redware ceramic materials, including a glazed floor tile from Tallinn.[2] The advantage of that method compared to PIXE and portable X-ray Fluorescence spectrometer (pXRF) is that it is possible to analyse elements of glazing, temper and clay separately, and besides the surface, the inner part of the object is also analysed. On the other hand, it is an invasive method.[3] The advantage of pXRF is that the analyser can be brought to the samples and thus does not require laboratory conditions like PIXE and SEM.[4] Some pXRF analyses on medieval bricks and roof tiles have been published, but so far, they have been few.[5] This is the first experiment on brick and tile material in Finland.

The aim of this research is to study the origin of the bricks and roof tiles found in Koroinen and the town of Turku. Reference material for this study consists of both locally made and imported pottery and bricks. The purpose is to find out if the bricks, moulded or wall bricks, were produced from local clays at the start of both sites or if they were imported. Furthermore, the aim is to investigate how the acquisition of bricks developed during the 14th and 15th centuries. Is there any difference between the bricks at Koroinen and those at the town? In addition, what do the analysed roof tiles reveal on their acquisition?[6]

It is a commonly held idea that when brick use arrived in the eastern part of medieval Sweden (current-day Finland) in the 13th century, it was the brick-building skills that arrived with the foreign builders and not the bricks themselves.[7] Among the first sites where brick was used was likely Koroinen, the predecessor of the town of Turku, where the bishop's seat was located in the 13th century. In the early 14th century, the first brick structures appeared in Turku, and during the 15th century, brick was applied more frequently there.[8] Brick is also considered to be a rare and expensive building material in the medieval period.[9] However, building archaeological, town archaeological and church archaeological research conducted during the last couple decades has started to change this view in Finland.[10]

In previous scholarship, the general idea has been that throughout the medieval period, kilns for producing (wall) bricks were usually founded for certain building projects, near the construction site. Clay for making bricks was dug nearby, and the bricks were not transported for long distances.[11] Naturally, archaeological evidence on medieval brick-making has been also found.[12] On the other hand, shipwrecks loaded with bricks show that long water routes were used to transport bricks.[13] The first bricks are known to have been imported; for example, the earliest bricks in London derived from Flanders.[14] However, in Finland, it was only in the 17th century when small, yellow wall bricks started to be imported from the Netherlands area.[15]

Where clay for making bricks was acquired and where the kilns were in Turku is not known exactly. In written sources, ditches for digging clay near the cathedral are mentioned in 1423.[16] C. J. Gardberg suggests that the clay was acquired from the nearby Lake Mätäjärvi.[17] The possible location of a kiln has been found on the north side of the cathedral.[18] The King of Sweden founded a brick kiln near the castle, on the eastern bank of the river in 1557.[19] Clay was probably being dug somewhere near there. It has also been assumed that potters acquired the clay from the river banks of Aura.[20] Geologically, the source of the clay seems to have been the same for pottery and bricks. Key factors for suitable clay were that it was plastic and non-saline and that it didn't contain organic material.[21]

In brick architecture, the ornamentation of the walls was sometimes created with black-headed bricks. They were overburnt and therefore glazed in the heat of the oven, but bricks were lead-glazed for that purpose, too.[22] In Sweden, lead-glazed bricks appeared in the 14th century.[23] Glazed bricks have also been found in Finnish medieval contexts, but so far it is uncertain whether they are glazed by lead or by overheating in the kiln.[24] Some lead-glazed floor tiles can be seen in Turku.[25]

Tiled roofs seem to have been rare in medieval Finland.[26] It is assumed that they were mainly imported, but in some cases, they were also produced locally.[27] In Turku area, the earliest roof tiles are from Kuusisto Bishop's Castle, where they are dated to the 14th century.[28] In Turku, the earliest roof tiles are possibly from the late 14th and early 15th centuries, but certainly from the first half of the 15th century. Based on possible deformed pieces, Liisa Seppänen suggests that local production had already begun by the end of the 14th or early 15th century. The first possible glazed roof tiles are from the late 15th or 16th century.[29]

After the Reformation, roof tiles were imported from Tallinn and Lubeck as well as from Holland.[30] According to written sources, the first steps in local roof tile-making were taken in 1584–1586 by German-born brickmaker Mikael Kramer.[31] The roof tile factory in Kupittaa was established in the 1760s in Turku.[32]

RESEARCH MATERIAL

In total, 76 sherds of pottery, bricks or roof tiles were selected for analysis.[33] Local and imported pottery and bricks constituted the reference material. A total of 21 local reference samples consist of 17 pieces of unwheeled and unglazed pottery[34] and 4 wheeled, unfinished redware samples.[35] Imported reference pottery consists of 15 glazed redware pieces.[36] Two of the imported reference bricks were Dutch 17th-century wall bricks deriving from the town contexts of Turku.[37] Two bricks were certainly local products from the 1320s.[38] In sum, 23 of the analysed materials were of local origin and 17 were imported.

The 36 pieces of pottery and 4 wall bricks were applied as reference material since it was not possible to take any clay samples from the possible production sites.[39] On the other hand, comparing natural clay samples with ceramic products has been considered partly misleading, because in both bricks and pottery, temper was added. It is also possible that different types of clays were mixed.[40] In addition, it must be emphasised that the production site of four local redware fragments is known, and also two raw bricks are local products.[41]

The reference pottery for this study, chosen by Aki Pihlman, comes from several archaeological excavations in the town of Turku and the site of Koroinen. The material from the former is well dated based on stratigraphy and dendrochronology. Due to the level of documentation as well as the poor conservation of organic matter, the latter group has been dated mostly through comparative ceramic analyses.[42] The contexts of the reference material, pottery and bricks and their dating are shown in Table 1.

It is to be noted here that local 13th- and 14th-century pottery used as reference material is interpreted to be such. However, the evidence is very strong; the same kind of pottery has been discovered around Turku before the imported medieval redware emerged. This black, unwheeled, unglazed and undecorated pottery fired at a low temperature was very likely produced by local farmers. It was also very likely a continuation for the Iron Age tradition, remaining in use in the Aura Valley, including the town until the mid-14th century.[43]

The older redware glazed from the outside was produced in Western Europe as well as along the Southern coast of the Baltic Sea and Southern Scandinavia. It was imported to the Turku area in the 13th and 14th centuries. The redware glazed from the inside was imported starting from the 14th century onwards.[44] According to the latest research, the production of local lead-glazed redware started only in the second half of the 15th century.[45]

In addition, geological analyses of the chemical composition of natural clays in Southwest Finland as well as in two studies from Turku were applied as references.[46] Furthermore, results on the chemical composition of glacial clays in Jätkasaari basin, Helsinki were applied when necessary.[47] Limits for defining polluted clays were applied in this study, too.[48]

The rest of the samples here of which origin was under study were 3 roof tiles and 35 bricks, 17 of which were moulded.[49] See Table 1. A total of 20 bricks derive from Koroinen, the Episcopal site preceding the medieval town of Turku.[50] 38 were found in the town during the Early Turku excavations conducted near the cathedral.[51] The materials were chosen based on their context and dating.

The bricks from Koroinen were found in connection with the masonry structures by the river where the bishop's residence with a hypocaust heating system and a keep was located. It is to be noted here that the material was excavated at the turn of the 20th century, and therefore, the contexts are not documented according to modern standards. The bricks derive mostly from the brick waste layer spread above these structures, but in a few cases, the samples likely come from an in-situ structure (38, 40, 41, 47, 49). The brick waste itself is mostly from the brick house, which constituted a part of the residence. All the building remains and structures in masonry likely date from the period before 1430 AD. The heat storage hypocaust and the keep had probably already been built by the end of the 13th or early 14th century. If so, they are one of the first masonry structures on the Finnish continent. Furthermore, the oven and the brick house are among the oldest brick structures.[52] In the project "At the Dawn of the Middle Ages", bricks were dated with Optically Stimulated Luminescence (OSL).[53] The results seem to be in concordance with the above, yet they will be discussed more thoroughly in a separate article.[54]

In the Early Turku Project, excavations were carried out in three locations near the cathedral in 2005–2006.[55] The contexts of the bricks chosen for this study are mostly dated with stratigraphy and dendrochronology. The analysed bricks date from the early 14th or first half of the 14th century, but there are bricks likely dating to the first half of the 15th century as well.[56] The early 14th-century bricks are among the oldest ones found in the town.[57]

TABLE 1.
The contexts, notes and datings of the analysed pottery, bricks and roof tiles. Table by Tanja Ratilainen.

Id	Excavation / Context	Cataloguing number	Material type, local / imported	Notes on pottery by A.P. or on bricks by T.R.	Dating
1	Koroinen 1974	TMM18011:156	IAT, locally produced	No glazing	Iron Age–1350
2	Koroinen 1974	TMM18011:194	IAT, locally produced	No glazing	Iron Age–1350
3	Koroinen 1977	TMM20566:193	IAT, locally produced	No glazing	Iron Age–1350
4	Koroinen 1977	TMM20566:194	IAT, locally produced	No glazing	Iron Age–1350
5	Koroinen 1977	TMM20566:91	IAT, locally produced	No glazing	Iron Age–1350
6	Koroinen 1977	TMM20566:192	IAT, locally produced	No glazing	Iron Age–1350
7	Koroinen 1974	TMM18011:129	IAT, locally produced	No glazing	Iron Age–1350
8	Koroinen 1974	TMM18011:157	IAT, locally produced	No glazing	Iron Age–1350
9	Koroinen Appelgren 1898+1899	KM69053:55, KM86020:A74	IAT, locally produced	No glazing	Iron Age–1350
10	Koroinen Rinne	KM52100:2527	IAT, locally produced	No glazing	Iron Age–1350
11	Koroinen Rinne	KM52100:1783	IAT, locally produced	No glazing	Iron Age–1350
12	Suurtori/Raatihuone, phase 1	TMM20315, 919	IAT, locally produced	No glazing	End of 13th century
13	Suurtori/Raatihuone, phase 1	TMM20315, 938	IAT, locally produced	No glazing	End of 13th century
14	Suurtori/Raatihuone, phase 2	TMM20315, 558	IAT, locally produced	No glazing	Early 14th century
15	Suurtori/Raatihuone, phase 2	TMM20315, 547	IAT, locally produced	No glazing	Early 14th century
16	Cathedral School	TMM23146, KE557:008	IAT, locally produced	No glazing	14th century
17	Cathedral School	TMM23146, KE612:001	IAT, locally produced	No glazing	13th–14th centuries, context mixed up
18	Linnankatu 35b	TMM22890, KE153:010	LRW, pot, unfinished, unglazed	On the inner surface a small spot of glazing; on the handle clear remains of splashes of glazing and burnt remains of glazing.	18th century
19	Linnankatu 35b	TMM22890, KE153:052	LRW, vessel, unfinished, unglazed	No glazing	18th century
20	Tuomiokirkonkatu	TMM18335:369	LRW, pot, unfinished, unglazed	No glazing	End of 16th – first half of 17th century
21	Tuomiokirkonkatu	TMM18335:259	LRW, unfinished, unglazed	No glazing inside; outside with some glazing around the handle	End of 16th – first half of 17th century
22	Koroinen Rinne	KM52100:2363	IRW imported		1200–1350
23	Koroinen Rinne	KM52100:2593	IRW, imported		1200–1350
24	Koroinen Rinne	KM52100:2379	IRW, imported		1200–1350
25	Koroinen Rinne	KM52100:2558+2616	IRW, imported		13th–14th centuries
26	Koroinen Rinne	KM52100:2332	IRW, imported		13th–14th centuries
27	Nunnankatu 4	TMM22298:KE009:003	IRW, imported		First half of 14th century
28	Suurtori/Raatihuone, phase 1	TMM20315:845	IRW, imported		End of 13th century
29	Suurtori/Raatihuone, phase 3	TMM20315:380	IRW, imported		1325–1350
30	Itäinen rantakatu	TMM14681: 1018	IRW, imported		1250–1350
31	Itäinen rantakatu, between Brahenpuisto park and Cathedral Bridge	TMM14740: 92	IRW, imported		14th century
32	Cathedral School	TMM23146:KE116:003	IRW, imported		Sedond half of 13th century
33	Cathedral School	TMM23146: KE087:008	IRW, imported		First half of 14th century
34	Cathedral School	TMM23146:KE094:001	IRW, imported		First half of 14th century
35	Cathedral School	TMM23146:KE076:002	IRW, imported		First half of 14th century
~~36~~	Early Phases of Turku Project	TMM22367:KE1034:006	YRW, younger redware, imported or local		**Second half of 15th century**
37	Kaupunginkirjasto	TMM22237:KE197:003	YRW, younger redware, imported		Second half of 14th century
38	Koroinen, from the brickwaste of the keep	KM52100:1417a	Brick	Very fragile	Before 1430s / probably 14th century*
39	Koroinen, inside the keep	KM52100:1343	Moulded brick	Very fragile	Before 1430s / probably 14th century*
40	Koroinen, inside the keep	KM52100:1417b	Brick	Very fragile	Before 1430s / probably 14th century*
41	Koroinen, inside the keep	KM52100:1417c	Brick	Very fragile	Before 1430s / probably 14th century*
42	Koroinen, residence	KM52100:1430d	Brick	Compact	Before 1430s / probably 14th century*
43	Koroinen, keep	KM52100:1419	Moulded brick applied in vaulting	Compact	Before 1430s / probably 14th century*
44	Koroinen, keep	KM52100:1421	Moulded brick	Compact	Before 1430s / probably 14th century*
45	Koroinen, keep	KM52100:1420a	Moulded brick	Compact	Before 1430s / probably 14th century*
46	Koroinen, keep	KM52100:1418	Moulded brick, window jamb	Compact	Before 1430s / probably 14th century*
47	Koroinen, in front of the oven	KM52100:1450c	Brick	Compact, but porous; some charcoal particles in the mixture	Before 1430s / probably end of 13th–14th century*
48	Koroinen, in front of the oven	KM52100:1450a	Moulded brick	Compact, but porous; some charcoal particles in the mixture	Before 1430s / probably end of 13th–14th century*
49	Koroinen, in front of the oven	KM52100:1449d	Brick	Compact; mortar on both flat surfaces	Before 1430s / probably end of 13th–14th century*
50	Koroinen, inside the residence	KM52100:1432d	Moulded brick	Compact; no mortar remains	Before 1430s / probably 14th century*
51	Koroinen, inside the residence	KM52100:1437c	Moulded brick	Compact; not much mortar remains	Before 1430s / probably 14th century*
52	Koroinen, inside the residence	KM52100:1436	Moulded brick applied in vaulting	Compact; not much mortar remains	Before 1430s / probably 14th century*
53	Koroinen, inside the residence	KM52100:1434	Moulded brick, window jamb?	Compact	Before 1430s / probably 14th century*

Id	Excavation / Context	Cataloguing number	Material type, local / imported	Notes on pottery by A.P. or on bricks by T.R.	Dating
54	Koroinen, inside the residence	KM52100:1433c	Moulded brick	Compact; on the flat surfaces lots of mortar	Before 1430s / probably 14th century*
55	Koroinen, inside the residence	KM52100:1441b	Moulded brick applied in vaulting	Burnt as porous; lots of lime and salt remains	Before 1430s / probably 14th century*
56	Koroinen, inside the residence	KM52100:1441b	Moulded brick applied in vaulting	Compact; lots of lime and salt remains	Before 1430s / probably 14th century*
57	Koroinen, inside the residence	KM52100:1431	Brick, floor Brick?	Compact; slightly over heated in kiln; not much mortar remains	Before 1430s / probably 14th century*
58	Early Phases of Turku Project, R2182	RF 378, tiili73	Raw brick	Mortar on the flat surfaces, but unmortared spot was measureable	1320s
59	Early Phases of Turku Project, R2182	RF 379, tiili74	Raw brick	Not much mortar remains	1320s
60	Early Phases of Turku Project, M2213b	RF394	Piece of Brick	Small piece; no mortar; no glazing; normal consistency and colour	Older than 1320s
61	Early Phases of Turku Project, M2204d	RF434	Piece of Brick	Small piece; no mortar; no glazing; normal consistency and colour	1250–1320
62	Early Phases of Turku Project, M2208	RF400	Piece of Brick	One corner burnt greyish black and its head glazed a bit; Glazing? No mortar remains; normal colour.	Older than 1320s
63	Early Phases of Turku Project, 2204	RF399	Piece of Brick	Compact; mortar all over; normal colour	1250–1320
64	Early Phases of Turku Project, 2214	RF398	Piece of Brick	Small piece among many pieces; normal colour; no mortar	1250–1320
65	Early Phases of Turku Project, R1097	RF92	Piece of Brick	Compact; no mortar; no original surfaces; normal colour	1300–1350
66	Early Phases of Turku Project, R1662b	RF234	Roof tile	Compact; normal colour; no remains of mortar in original surfaces; possibly some copperish coating on the smooth concave surface	Before 1450
67	Early Phases of Turku Project, R1640	RF215	Roof tile	Notch; mortar remains on the notch; possible copperish shiny coating remains on the concave surface; yeallowish-read colour on tile	Before 1450
68	Early Phases of Turku Project, R1640,	RF247	Moulded brick applied in vaulting	Compact; normal colour; no glazing, possible remains of mortar on the sides; clear remains of mortar on the other flat side	Before 1450
69	Early Phases of Turku Project, R1640	RF455	Moulded brick applied in vaulting	Compact; remains of mortar on all surfaces; normal colour; no remains of glazing; not fragile	Before 1450
70	Early Phases of Turku Project, R1640	RF454	Moulded brick applied in vaulting, "ox head"	Compact; normal colour; no remains of glazing; some remains of mortar	Before 1450
71	Early Phases of Turku Project, 1096,	RF93	Moulded brick	No remains of mortar; normal colour; not fragile; no signs of glazing	Early 14th century
72	Early Phases of Turku Project, R1662A	RF230	Brick	Yellowish red; mortar on the upper flat surface and sides; lower flat side broken; seems like Dutch brick but is not	Before 1450
73	Early Phases of Turku Project, TI3006,	RF133	Roof tile	Just the noch; no mortar remains; clay mixture pretty rough; lots of quarts; dark red colour	15th–16th centuries
74	Early Phases of Turku Project, M3025 ja sen alla olevanpunaruskean orgaanisen kerroksen rajapinnasta	RF10	Piece of Brick	Colour dark red, partly yellowish colour on surface; no original surfaces; no mortar remains; organic substances in the clay mixture	14th century
75	Early Phases of Turku Project, M3022,	RF7	Piece of Brick	No mortar; normal colour; seems like a wall brick, but not absolutely sure.	14th century
77	KSK2015 Cathedral School, R618	Unlisted	Brick	Some mortar on the surface	17th century–1827
78	BPP10 Porthan park-Brahe park, R137	RF02	Brick	Lots of mortar all around, but a clean spot was found	17th century–1827
IAT	Iron Age type, locally produced, not wheeled, fired in low temperature	YRW	Younger redware		
LRW	Local redware	*	See Ratilainen et al. 2017		
IRW	Imported older redware				

METHODS OF ANALYSIS AND INSTRUMENTATION

In this study, all analyses of the materials were made with the Olympus Delta DP-6500 portable X-ray fluorescence spectrometer (hereafter pXRF) from the Department of Geography and Geology at the University of Turku. There is a 4W X-ray tube with tantalum anode and silicon PIN -photodiode as a detector in the device. The focus area of radiation (area of analysis) is 10 mm in diameter and the penetration of the radiation depends on the analysed material. For stone, ceramic and brick, it is on the order of a few hundreds of micrometres to a few millimetres.

Besides these static features, the application and calibration of the device both have a considerable effect on the final results of the analyses. In the pXRF device, there are different analysis applications for the different materials. For this research, the Mining Plus application or "mode" was chosen, for in a tested condition, it was approved to be the most reliable for natural stone and manmade mineral-based artefacts.[58] During each measurement, two different radiation beams/modes are used with the Mining Plus application.[59]

Here, pXRF with the Mining Plus application is capable of detecting the following elements: V, Cr, Fe, Co, Ni, Cu, Zn, Hf, Ta, W, As, Pb, Bi, Zr, Mo, Ag, Cd, Sn, Sb, Ti, Mn, Al, Si, P, S, Cl, K and Ca. The device would also be capable of analysing Mg, but then the anode material of the X-ray tube should be rhodium. The tantalum anode also makes it difficult to analyse aluminium (Al) and silicon (Si), and their measurements can be unreliable. In addition, Cl less than 60–100 ppm cannot be detected. The limit of detection for P and S was high, too. The approximate limits of detection are presented in Table 2.[60]

The pXRF device was factory-calibrated in October 2015, and no changes were made after that. For the Mining Plus application, calibration is fundamental, which means that detected counts for any single element are proportioned to the total amount of all detected element counts and the analysis result of the single element is recorded as ppm.[61]

Olympus Delta Premium, 2-Beam, Mining plus, Ta/Au-tube, SDD-detector			
Element	LOD [ppm]		
Mg	Not available	V	7-15
Al	max. 4.0 %	Cr	5-10
Si	max. 0.75 %	Ag	6-8
P	500-700	Cd	6-8
S	100-250	Fe	5
K	30-50	Cu	5-7
Ca	20-30	Zn	3-5
Ni	10-20	Mn	3-5
Sb	12-15	Pb	2-4
Sn	11-15	As	1-3
Ti	7-15	Zr	1

TABLE 2.
Limits of detection (LOD) of Olympus Delta XRF 6500 DP (2011).

The third adjustable function is measuring time (i.e., radiation time). For the heavier elements, 10–15 seconds/beam may be enough, but a longer radiation time yields a more accurate analysis. Still, it has been noticed that the precision and reliability of pXRF data do not improve significantly at count times greater than 180 seconds. In this research, each sample was analysed/radiated for a one-minute total, 30 s/beam.[62]

Usually, more than one measurement per sample should be taken to increase the reliability of the results.[63] However, the grain size of the clay is under 0.002 mm, which makes the material almost homogenous, and one measurement is reasonable.

Four of the analysed bricks were very fragile, but all others had a firm and solid texture. One of the bricks was analysed twice from the porous and burnt as well as from the solid and firm surfaces to see if the porousness affected the analysing results.[64] Therefore, a total of 77 analysing results are presented in Appendix 1. Surfaces with mortar were avoided, and visually clean and levelled surfaces of the brick were analysed. The pottery sherds had most likely been washed with water during the post-excavation work. No pottery surfaces with lead glazing were analysed. The measurements were made in dry and clean storage facilities. It was also acknowledged that the lead results could be high in the imported redware in which the other surface was lead-glazed.

Plotting of the analysis data was made with the GeoChemical Data ToolKIT (GCDkit), which is primarily a system for handling and plotting (e.g., binary and ternary) geochemical analyses of igneous rocks. The GCDKit is written in R, a language and environment for statistical computing and graphics.[65]

Some features of the GCDkit are effective data management (searching, grouping), graphic output to publication quality, modular architecture (= easily expandable and modifiable) and transparent functionality and availability.[66] The GCDKit is open-source freeware available from the developer's web page (http://www.gcdkit.org/).

RESULTS

The results are presented in Appendix 1. Comparisons made with earlier research as well as questions born during this study affected which elements were examined in more detail in this article. Consequently, they are iron (Fe), calcium (Ca), potassium

(K), chlorine (Cl), sulphur (S), vanadium (V), lead (Pb), copper (Cu), nickel (Ni), arsenic (As), tin (Sn), zinc (Zn) and cadmium (Cd). Medians of analysed reference material are presented in Appendices 2 and 3.

IRON VS. CALCIUM

In general, the local clays are rich, containing usually 5–8%, even 11%, of iron and much less of calcium, circa 1%.[67] Based on the colour of the bricks, it was expected that the yellowish Dutch bricks contained more calcium than iron. All other bricks were fired red or reddish, and they were expected to contain more iron than calcium. This was shown to be true in the analysis. See Fig. 1.

In the reference material, imported pottery and imported bricks contained 2–4% of iron. Iron in local pottery and local bricks varied between 4% and 8%, and there was usually clearly more than 6% of iron. Furthermore, Dutch bricks were high in calcium, circa 8%, but the imported pottery was not, containing usually 1% of calcium. Their values were similar to locally produced pottery and all other bricks except for three of them. See Fig. 1 and Appendices 2 and 3.

One of the bricks (63) gave values of over 11% of calcium. However, this is likely explained by the mortar remains all over the surfaces of the brick, and it is therefore excluded from the analysis as it reflects the element composition of lime mortar.

There were also two bricks (70 and 72) that contained more than 4% of calcium and a group of bricks clearly containing less than 4% of iron (40, 47, 48, 61, 64 and 75). See Fig. 1 and Appendix 4.

IRON VS. POTASSIUM

Richard Lensen detected a clear distinction between bricks from Rheinland (Leiden) and Italy when potassium and rubidium values were studied.[68] The potassium values of Italian bricks varied between 3% and 11% and of Rheinland between 2% and 4%.

Potassium can be found in circa 3% of Finnish local clays.[69] In the reference material, however, the local pottery usually contained more than 5% of potassium and imported pottery usually 3.3%. See Fig. 2 and Appendices 2 and 3. These quantities may not be related to the clay but to their production technique; more potassium (charcoal) was perhaps mixed in them during the mixing of clay or the firing process. This could also apply to bricks serving as a fire box of the kiln and thus being in contact with charcoal.[70] The distinction between the local and imported pottery is not sharp, but it can be seen. Dutch bricks and bricks 40, 41, 47, 48, 67, 70 and 72 contained 3.3% or less of potassium. See Fig. 2.

SULPHUR VS. CHLORINE

It is usually recommended that good clay for making bricks should not contain chlorine (Cl) or sulphur (S) because their compounds cause a white substance on the surface of the bricks.[71] The natural clays may contain less than 10,000 ppm of sulphur.[72]

The detection limits for sulphur and chlorine were high. For sulphur, it was 100 ppm and for chlorine, it was 60–100 ppm.

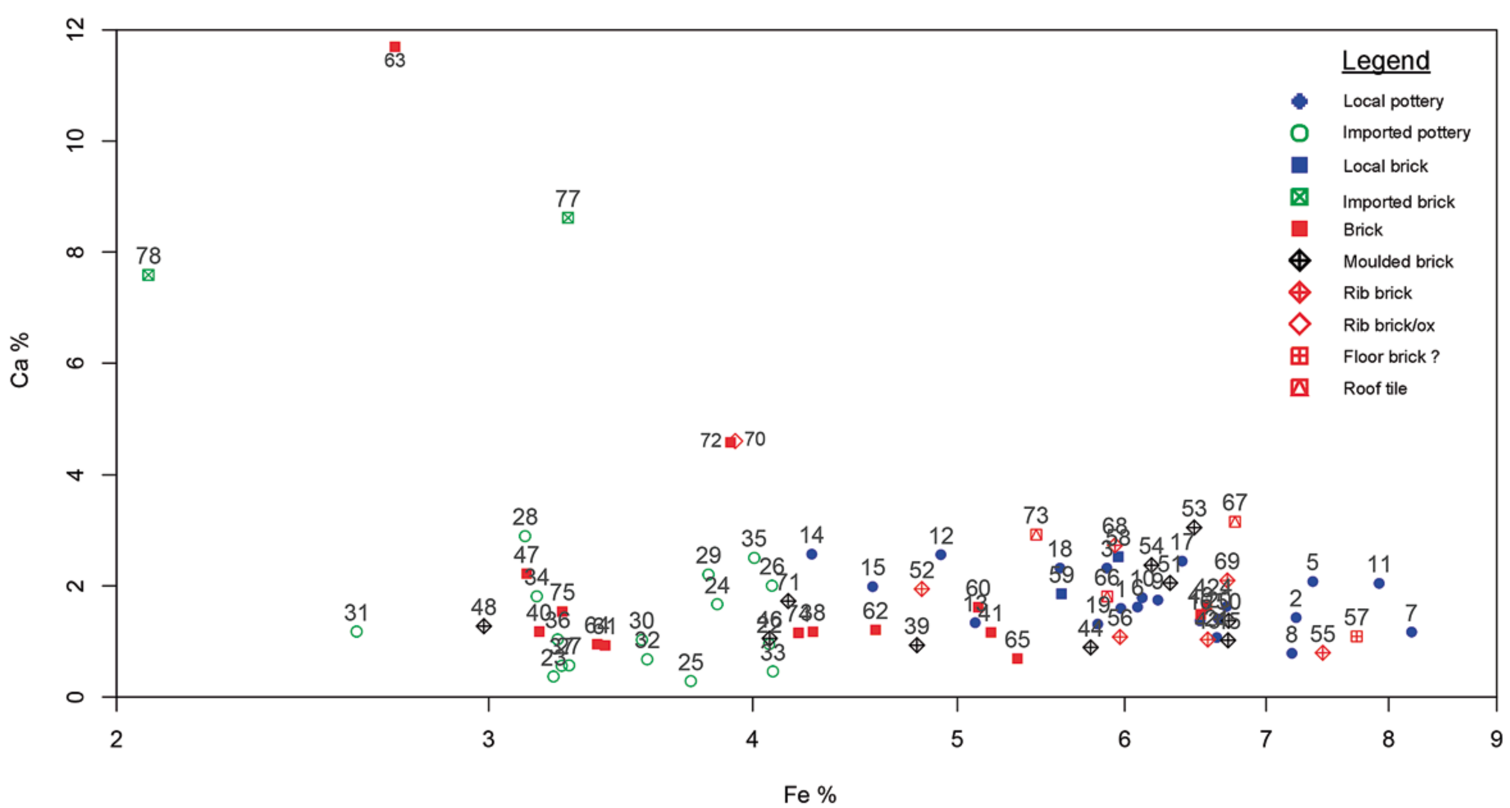

FIGURE 1.
Iron vs. calcium. All figures created with GCDKit by Tanja Ratilainen and Jussi Kinnunen.

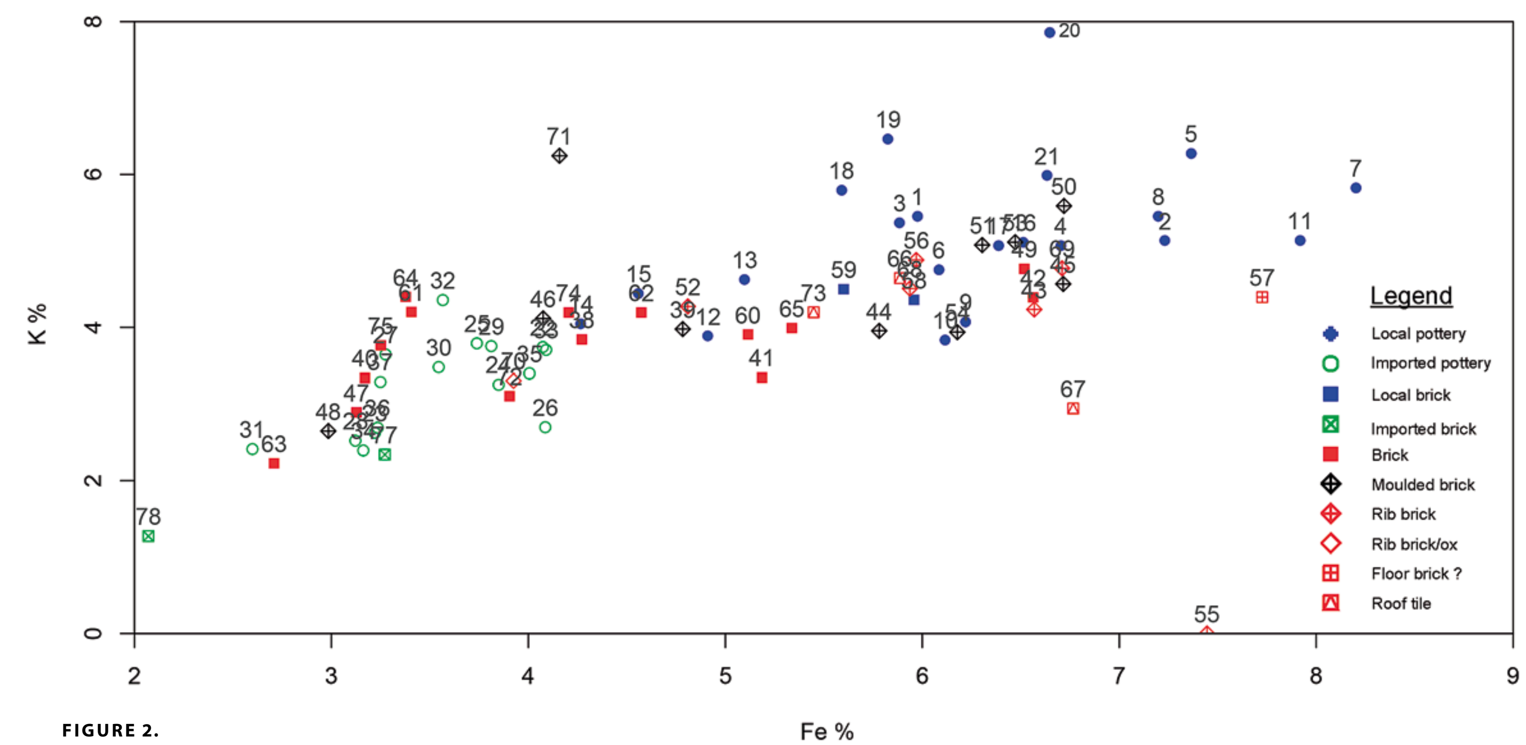

FIGURE 2.
Iron vs. potassium.

Most of the samples did not contain much chlorine, and many analyses were under the detection limit. Also, many samples clearly contained less than 20,000 ppm of sulphur. See Fig. 3 and Appendices 2 and 3.

The reference material showed that six of the imported pottery pieces contained very high values, more than 1500 ppm of chlorine and more than 75,000 ppm of sulphur in samples 23, 25, 26, 27, 31 and 34. The chlorine values of seven imported pottery fragments varied between 460 and 1,249 ppm. Their sulphur values varied between 21,000 and 72,000 ppm. Among the last group, there was one local redware (21), one piece of local unwheeled pottery (14) and two bricks (67 and 70). In the quantity of sulphur, the same roof tile and specially moulded brick stand out in addition to sample 47. See Fig. 3. The quantities of chlorine and sulphur did not correlate with the bricks in which salt was visually detected. See Table 1 and Appendix 1.

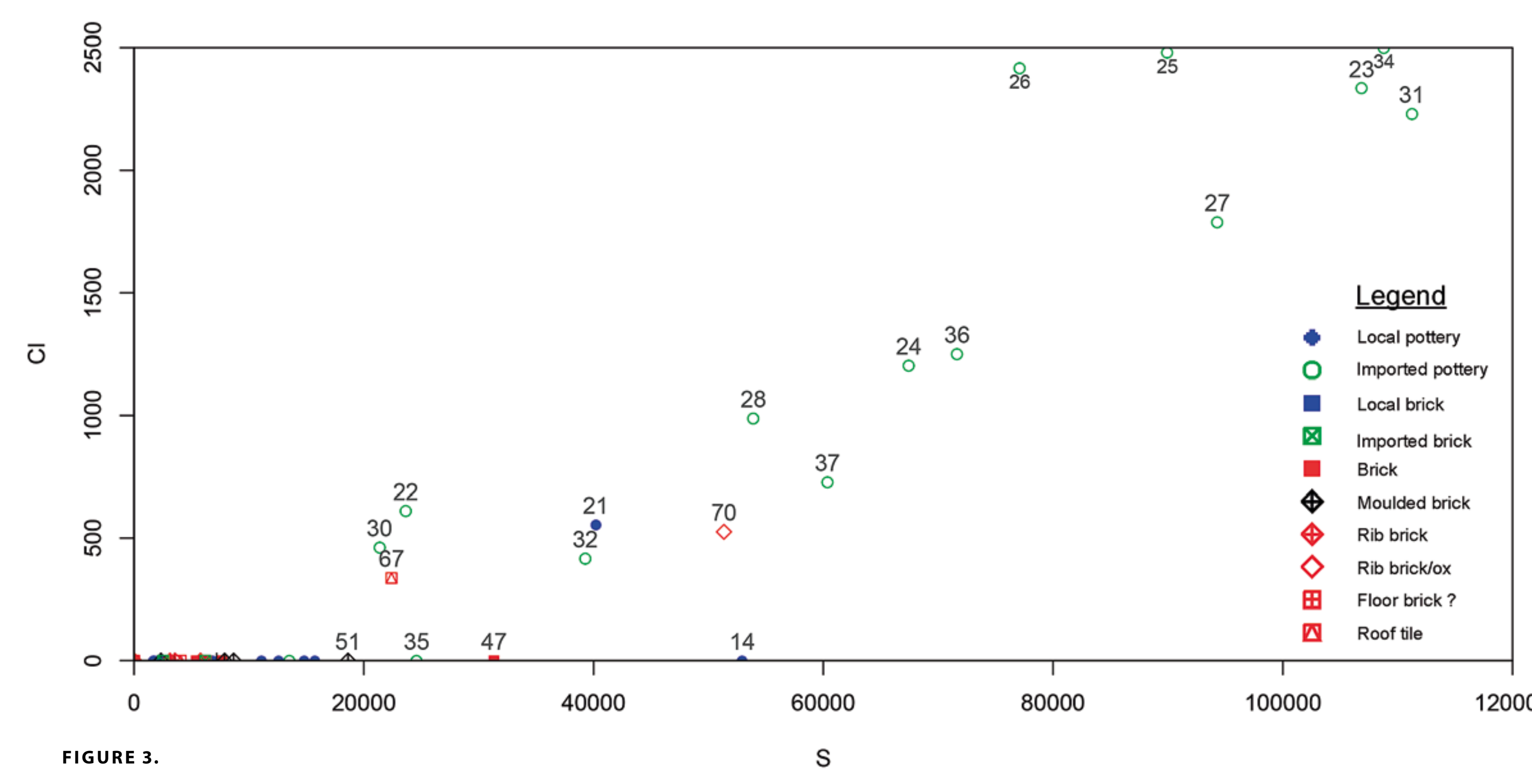

FIGURE 3.
Sulphur vs. chlorine.

VANADIUM VS. LEAD

Natural clays in Southwest Finland usually contain circa 45–90 ppm of vanadium.[73] Values over 100 ppm are considered polluted.[74] In the reference material, values of local pottery and bricks varied between circa 400 and 900 ppm. The values of imported pottery and bricks varied between 250 and 700 ppm, but most of them were in the range of 250–450 ppm. These values also included bricks 41, 45, 47, 48 and 71. See Fig. 4 and Appendices 2–4.

The natural lead values of soil are less than 60 ppm.[75] Local clays usually contain circa 20–50 ppm of lead.[76] In modern terms, values of over 100–200 ppm are considered polluted.[77]

The lead values were over 100 ppm, usually more than 1,000 ppm in all the glazed imported redware or unfinished (but intended for glazing) local redware. Furthermore, the rest of the local pottery contained less than or close to 50 ppm of lead. The Dutch bricks were low in lead. Interestingly, there were also five bricks that contained high quantities of lead (100–1,000 ppm), thus atypical for natural clay. The brick richest in lead was a roof tile (67), a wall brick (62), and three moulded bricks (68–70). See Fig. 4.

NICKEL

In SW Finland, the median content of nickel in clays is circa 56 ppm,[78] while in Turku, it is 22–24 ppm.[79] Values over 40–50 ppm are considered polluted.[80] At the Åbo Akademi University site, situated in the medieval urban area of Turku and excavated archaeologically in 1998, the nickel background content was normal.[81]

All the analysed samples contained high contents of nickel. The imported pottery nickel values varied between 145–305 ppm, but most were between 145–270 ppm. The local pottery contained circa 260–370 ppm of nickel. Among the imported reference material were bricks 38, 41, 42, 45, 47, 48, 52, 55, 61, 64, 65 and 74. Their nickel values varied between 211 and 250 ppm. See Fig. 5 and Appendix 1.

COPPER

In local clays, median content of copper is circa 29 ppm.[82] It is therefore surprising that copper values in many local unglazed and unwheeled pottery samples ranged from circa 50 to close to 200 ppm. Among these, there were also two imported pieces of pottery (32 and 29) as well as a roof tile and a brick (66, 71). However, in most of the samples, copper content was below the detection limit. See Fig. 6 and Appendix 1.

ZINC

In natural soils, zinc content is usually less than 200 ppm.[83] In SW Finland, the median values for zinc in clays vary between circa 86 and 156 ppm.[84] In modern terms, values of over 200 ppm are considered polluted.[85] The samples contained zinc mostly between 60 and 298 ppm. Again, high values of zinc were detected among local unwheeled pottery, ranging from 360 ppm to over 900 ppm. These

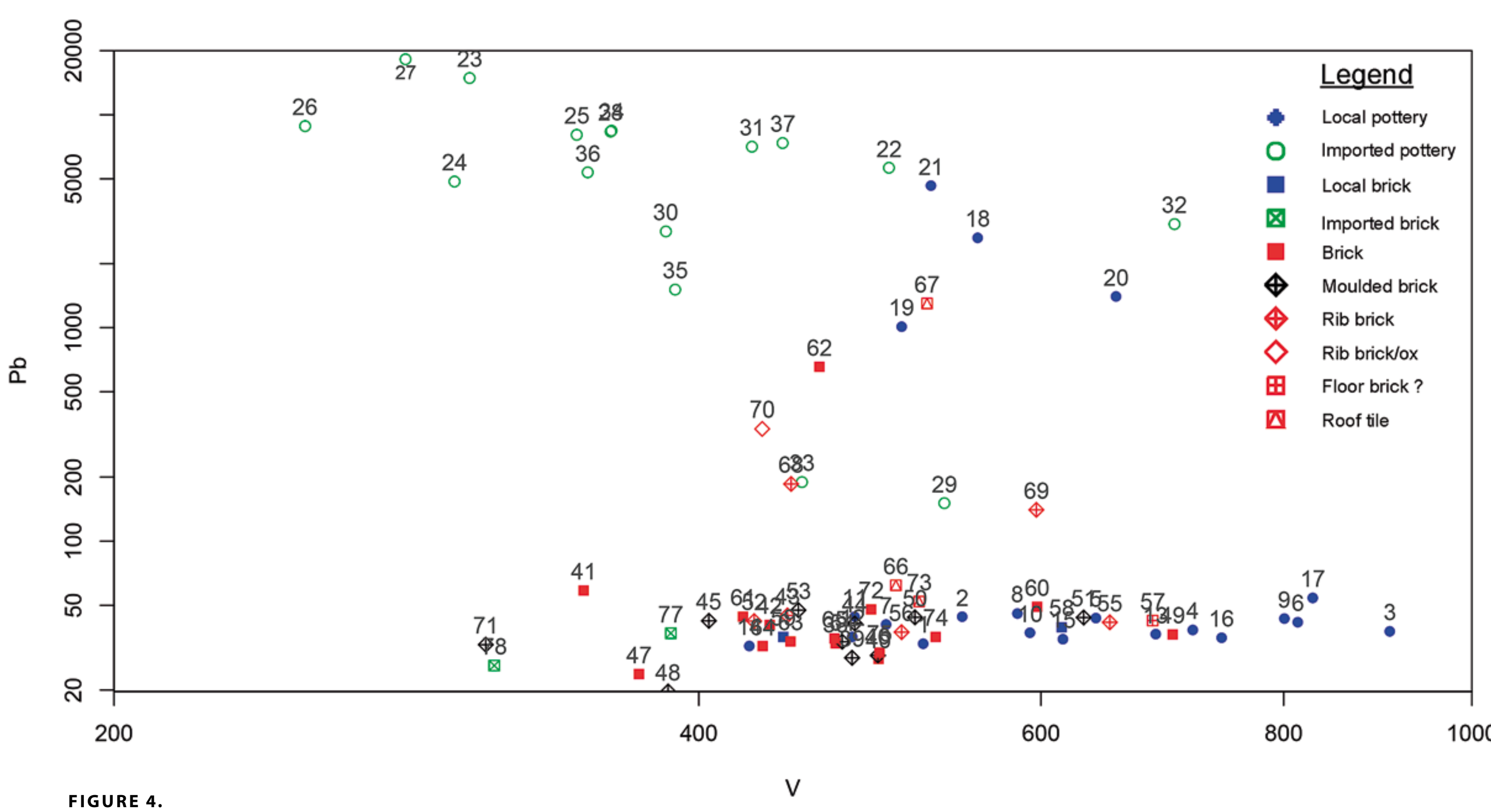

FIGURE 4.
Vanadium vs. lead.

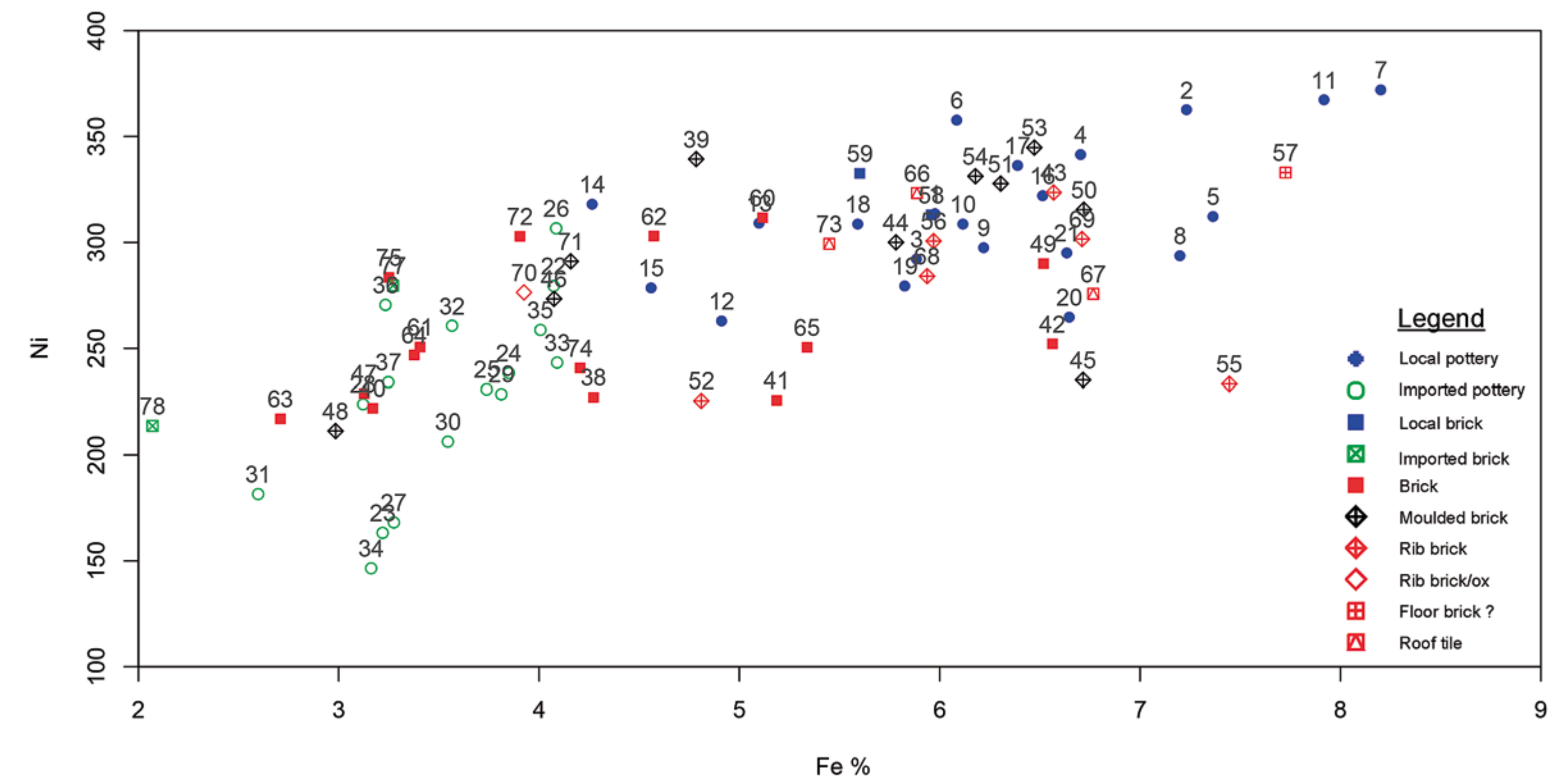

FIGURE 5.
Iron vs. nickel.

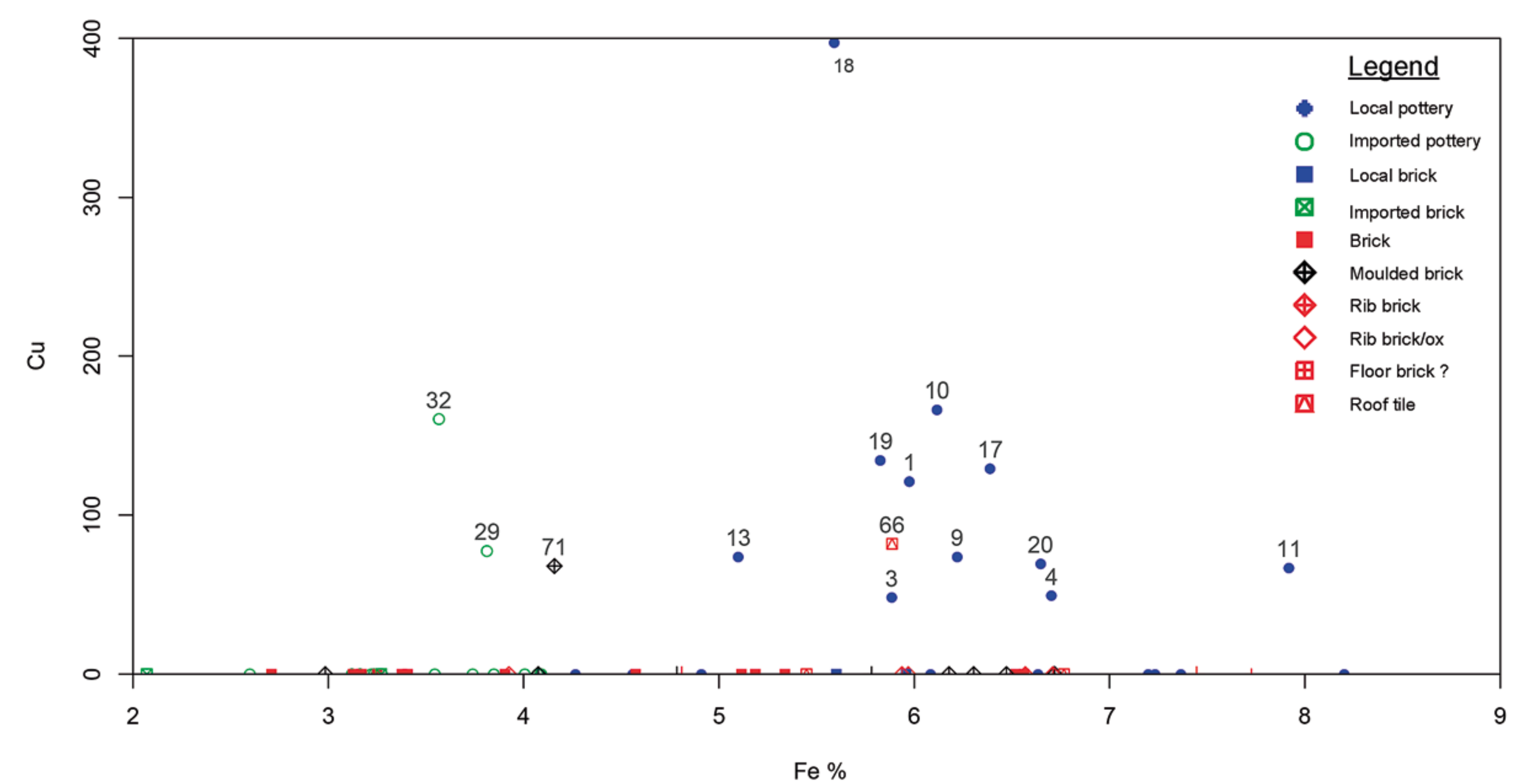

FIGURE 6.
Iron vs. copper.

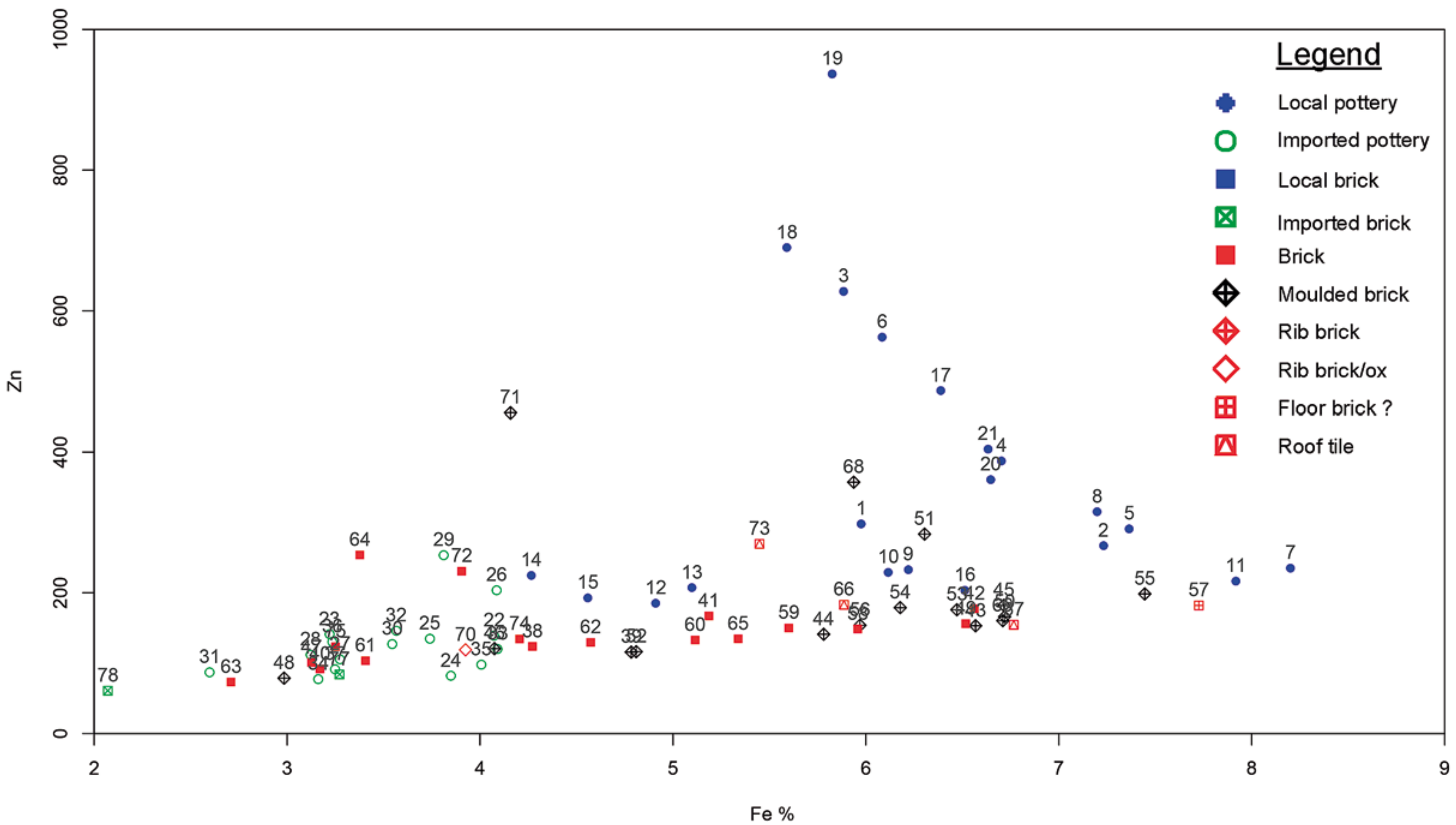

FIGURE 7.
Iron vs. zinc.

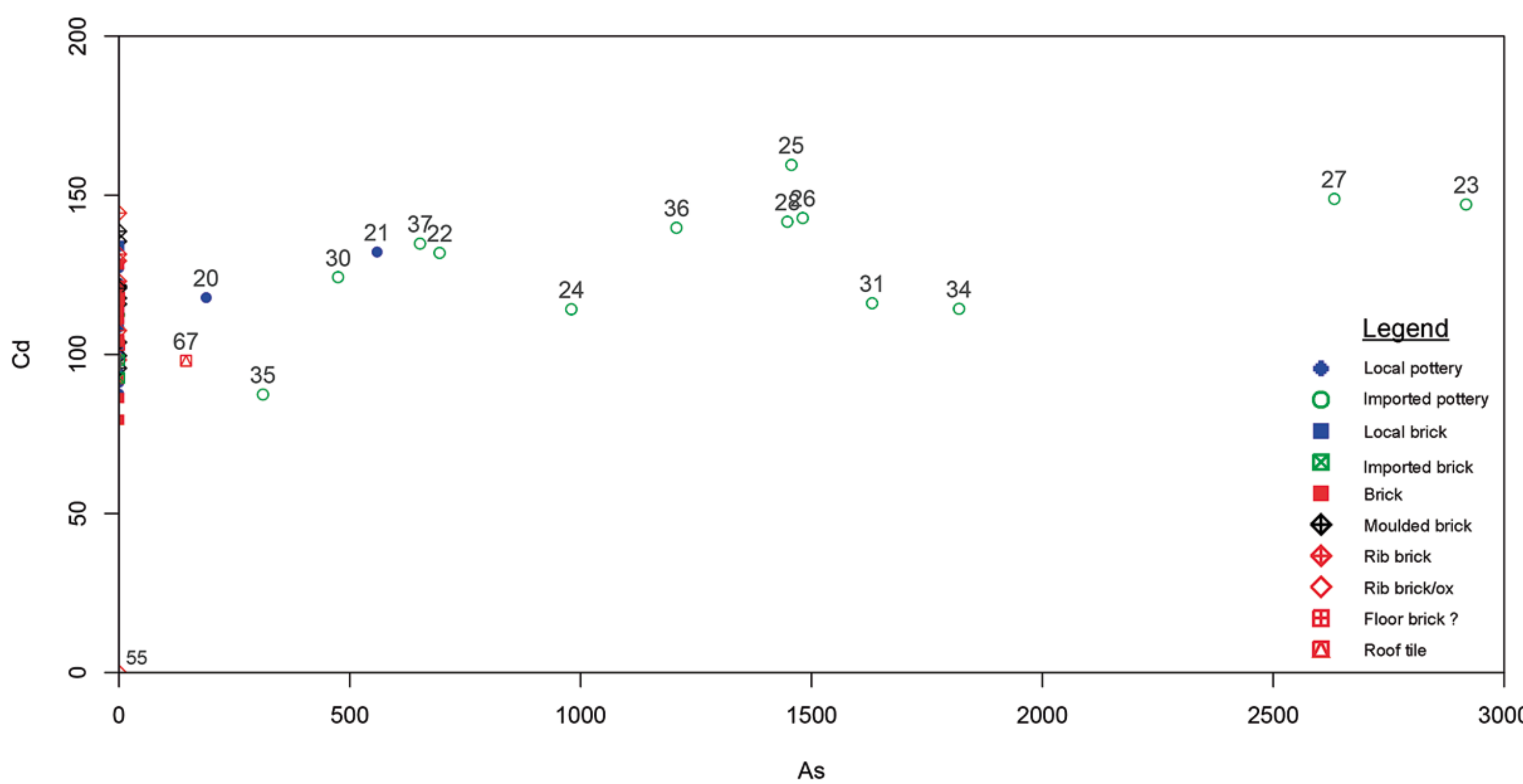

FIGURE 8.
Arsenic vs. cadmium.

included two bricks (68 and 71). See Fig. 7 and Appendix 1.

ARSENIC VS. CADMIUM

Natural clay should not contain more than 5–10 ppm of arsenic.[86] Most imported pottery contained arsenic values of 145–2,900 ppm. There were two local redwares (20 and 21) and a roof tile (67) that had high values (145–558 ppm) as well. The arsenic content for the rest of the material was below the detection limit. See Fig. 8 and Appendix 1.

Cadmium values in natural clays should be close to zero.[87] In the Turku area, the median values detected are 0.2 ppm.[88] High values of cadmium were also detected at the Åbo Akademi University site.[89] In modern terms, values of over 1 ppm are considered polluted.[90] Surprisingly, in the analysed material, all but one sample (55) contained cadmium between circa 75 and 150 ppm. See Fig. 8 and Appendix 1.

TIN

In natural soil, median tin values should not exceed 50 ppm, or it is considered polluted.[91] All the analysed material was rich in tin. Values of local pottery and bricks varied between 97 and 125 ppm. Imported pottery and bricks contained circa 87–140 ppm of tin. Interestingly, six of the bricks and roof tiles with unknown origins (44, 53, 54, 56, 60 and 68) clearly stood out from the material with tin values between 135 and 154 ppm. See Fig. 9 and Appendix 1.

DISCUSSION AND INTERPRETATION

The reference material for this study consisted of 36 pieces of pottery and 4 wall bricks whose origin was known. Comparing the results only on local raw clay samples would have been partly misleading as temper was usually added in both. It is also possible that different types of clays were mixed during production.[92] Therefore, one must keep in mind that certain recipes of brick and pottery mixtures and their element compositions are also under study here, not just elements of clay. In addition, it must be emphasised that the production site of four redware pieces and two raw bricks can be placed at Turku.

Interpretation of the results is not without challenges; the pXRF equipment measures the surface of the material from a few micrometres up to a few millimetres in depth, and the post-depositional conditions may influence the elemental composition of the surface. This applies especially to calcium and the alkali metals such as potassium. The quantity of alkali metals may be less on the surface than on the inside of the ceramic material. However, the study in question was made on eroded pottery with soft or brittle surfaces.[93] In this study, the analysed surfaces of the bricks and pottery were mostly original and uneroded or broken. Furthermore, it seems that the leaching of calcium and the reduction of potassium do not have an effect on the reference material.

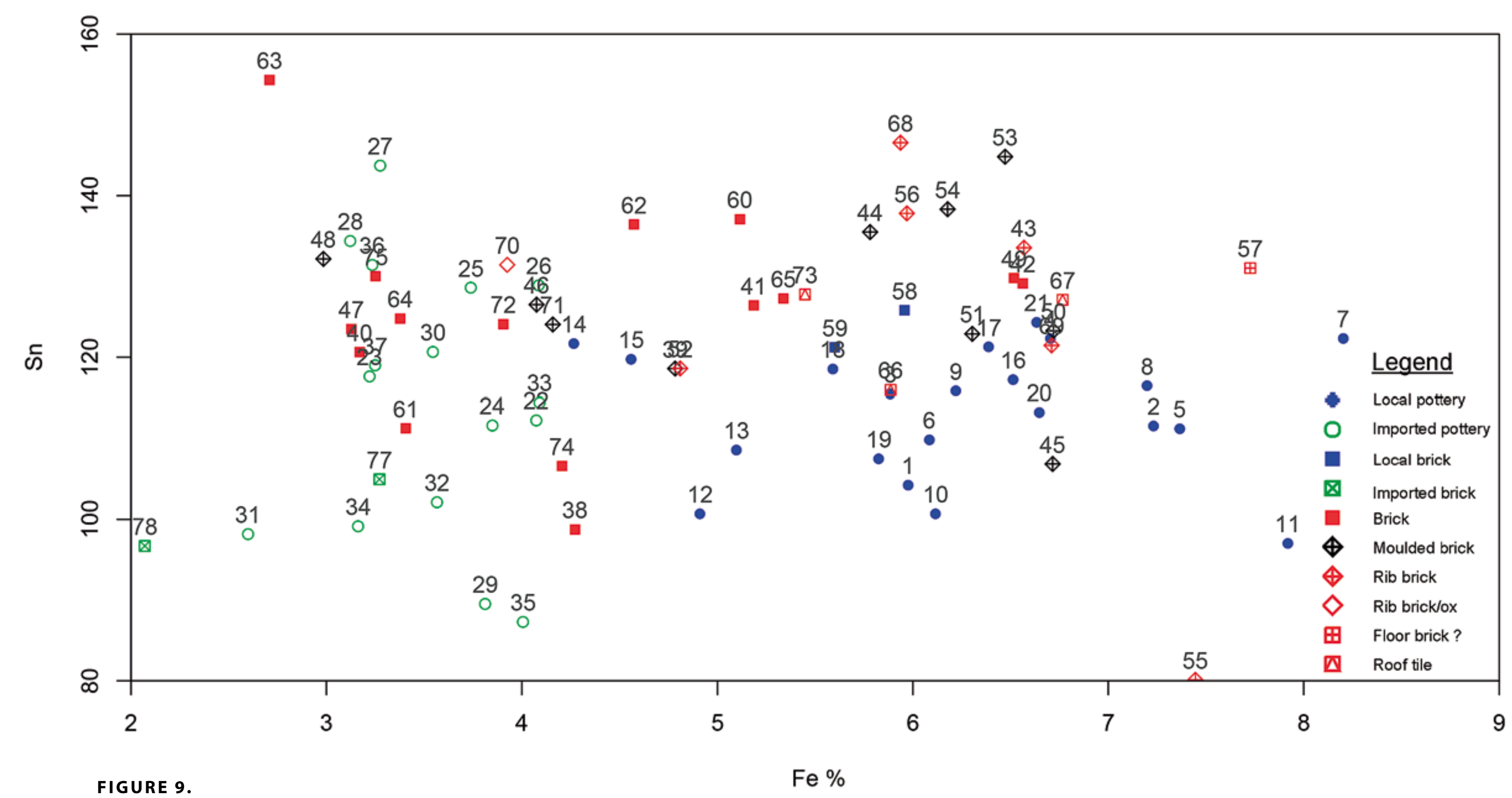

FIGURE 9.
Iron vs. tin.

Ceramic materials may have absorbed elements from the surrounding soil during their deposition.[94] In many cases, town deposits have been proven to be polluted. For example, high quantities of copper and other heavy metals were detected in the bottom sediments of the Mätäjärvi Lake.[95] Furthermore, high values of copper, lead, zinc and nickel were discovered in the layers of the Åbo Akademi University site as well as the Kirjastontontti site.[96] The abundance of these elements is mainly related to craftsmanship, e.g., potters needed lead for glazing and for creating colours (brown, black). Copper was also used to make colours (green, black). Colours in glazing bricks were achieved by different methods.[97] Another possible source of lead was the production of lead window cames.[98]

IRON, CALCIUM, POTASSIUM, CHLORINE, SULPHUR, VANADIUM AND TIN

Based on our reference material, it is likely that *the quantity of iron and calcium are the strongest indicators of the origin of clay*. A moulded brick originally applied in vaulting (70) and an ordinary wall brick (72) contained unusual quantities of calcium compared to local natural clays. The analysed surfaces were free from mortar. The yellowish colour of 72 resembles the Dutch bricks, but the size is completely different, and the context is medieval for sure.

Burning lime in a brick kiln was found to explain the high amounts of calcium in some of the bricks found at the Bo production site in Sweden.[99] This should mean, however, that the bricks in question would have been first used in a kiln, which seems unlikely. Burnt bone was also sometimes mixed into brick clay,[100] which could explain the higher amounts of calcium detected in these two bricks. In the visual inspection, no such bone remains were detected, however.[101] Therefore, bricks 70 and 72 are not likely made from local clays. However, calcium leaching may have influenced the results that not all imported bricks were detected. In addition, the bricks clearly containing less than 4% of iron (40, 47, 48, 61, 64, 75), not usual for local clays, may be imported, too.

In the reference material, the potassium values showed a division between local and imported materials. *Therefore, bricks containing unusually small quantities of potassium* (40, 41, 47, 48, 67, 70, 72) *may be imported*. However, leaching of potassium may influence the results in that local bricks could be in this group. In analysing the porosity of bricks 47 and 48, this is likely the cause for their lower potassium and nickel content. Also the porous brick 55 was low in potassium. On the other hand, charcoal was found in the visual inspection of 47 and 48, which should add to their potassium values. In addition, the bricks were probably used in the construction of the oven, which could also add potassium to them.[102] Consequently, 47 and 48 should be excluded from the potassium analysis. Of the remaining five bricks, two were roof tiles or moulded bricks applied in the vaults and were thus certainly not applied in ovens or fireplaces, nor in close contact with charcoal.

High values of chlorine and sulphur in the imported pottery could indicate that they were made of marine clays.[103] This possibly applies to bricks 47, 67 and 70 as well, suggesting they were not made of local clay. However, according to Lensen, high Cl values would indicate that bricks were fired in a kiln where peat or turf was applied as fuel.[104] This seems unlikely for the Turku area, where wood was available.

The values of vanadium were also exceedingly high compared to natural clay. Based on the reference material values, vanadium varied mostly between 250 and 450 among imported pottery and bricks. Thus, bricks 41, 45, 47, 48 and 71 could be imported.

It is difficult to find an explanation for the fact that all the analysed material was rich in tin. Medieval potters or brickmakers did not need it in the production process. One possibility is that tin was absorbed in them from the surrounding deposits, possibly due to other craftsman activities. Since the samples 44, 53, 54, 56, 60, 62 and 68 clearly stand out from the material, it is possible that the values reflect their foreign origins. However, they are not applied alone in the following group analysis in interpreting which bricks and roof tiles were likely imported.

THE ORIGINS OF LEAD

The bricks and a tile with high values of lead (67–70) all derive from the same context; they were applied in the pavement of a narrow street in the second half of the 15th century and were obviously in secondary use.[105] Brick 70 was likely originally applied in the vaulting of the cathedral.[106] Two others (68–69) were moulded bricks applied in the vaulting as well. Seppänen suggests that the roof tile (67) from the pavement also derives from the cathedral.[107] There were no visible traces of glazing in them. However, the roof tile (67) possibly received some kind of surface treatment or wash to make the tile appear a bit shiny.

A piece of brick 62 was found in the fill, preceding an oven built in the 1320s. The corner of the brick is glazed, but it is also burnt blackish inside. Furthermore, in other normally fired surfaces of the brick, no traces of glazing were visible.[108] Therefore, it seems that the brick was not originally intentionally glazed, yet it has a high lead content.

To exclude the possibility of lead seeping into the bricks when they were deposited, we should have analysed the layers above and under the street and the fill under the oven, but this was not possible. However, secondary contamination seems unlikely since bricks and a roof tile analysed from above and below the contexts in question do not contain similar quantities of lead (58–61, 64, 66 and 72).[109] Therefore, it seems likely that the lead in the bricks is original.

The local unfinished redware (18–20), which was not lead-glazed, contained lots of lead, too. It appears that the potter's workshop was so rich in lead that it even shows in the unglazed material. Consequently, bricks 62, 68, 69 and 70 could have been handled in a similar kind of environment.

It is highly interesting that according to the latest research, the production of local lead-glazed redware started only in the second half of the 15th century in Turku.[110] The earliest evidence of production waste date to the end of the 16th or beginning of the 17th century.[111] Furthermore, stove tiles also began to be produced in Turku only in the 16th century.[112] However, tiled stoves began to be constructed using imported tiles already in the first half of the 15th century.[113]

The bricks and a roof tile (67–70) containing lots of lead were in secondary use in the pavement dating to the second half of the 15th century. It is therefore likely that they were produced and primarily used before that, at least in the first half of the 15th century. But how did the lead get into the bricks if all the redware was imported at that time and yet no production took place in Turku?

If lead-glazed redware was not produced in Turku at that time, it seems unlikely that locally produced bricks would have been lead-glazed. The roof tile (67) was probably coated with lead and the moulded bricks were handled in an environment where lead was abundant. Therefore, it seems possible that they were imported to Turku. On the other hand, it is also possible that pottery production began earlier, i.e., in the first half of the 15th century, and potters in Turku produced bricks and roof tiles as well. However, brick 62 older than 1320s could have been imported.

OTHER HEAVY METALS

Many heavy metals such as nickel, copper, zinc, cadmium and arsenic were found in large quantities, and it seems possible that they were absorbed into the bricks from the surrounding deposits, so they were excluded from the interpretation. They likely reflect more about the activities of the craftsmen in the area rather than the origin of the clay. This is perhaps also shown by the low nickel values of porous brick surfaces (55, 47, 48) as well as the low values of cadmium and tin (55). However, high copper values in roof tile 66 may also indicate remains of coating. The remains detected visually support this interpretation.

IMPORTED BRICKS

The bricks with exceptional element values are presented in Table 3. The more there are of the different elements, the more likely it is that the brick was not made of local clays. Based on the discussion above, the most decisive elements are iron and calcium, which are interpreted to indicate foreign origin alone. Due to the risk of leaching potassium, the potassium values alone are not applied. The single values of heavy metals such as Ni, Cu and Sn are considered anomalies that are left out of the interpretation.

At least three bricks from Koroinen (40, 47, 48) and five bricks and a tile from town (61, 64, 67, 70, 72, 75) are most likely imported. In addition, it seems likely that a fourth brick from Koroinen (41) and three more bricks from the town (45, 68, 71) were also imported. Among them are seven bricks or pieces of brick and six moulded bricks, three of which were applied in the vaults. The oldest of these (41, 48, 61, 64, 71) date to the second half of the 13th or the early 14th century. Both moulded and ordinary wall bricks are among them. One of the imported bricks (75) dates to the 14th century. The rest of the imported bricks likely date to the first half of the 15th century. Among these are a roof tile and three moulded bricks applied in the vaults. See Table 3.

It is possible that a roof tile 66 and a moulded brick 69 were made in an environment where lots of lead and copper were handled. However, as they are dated to the first half of the 15th century, it is possible that they were imported, but it is equally possible that local production began earlier. If brick 62 did not absorb lead from the deposits, which seems likely as the raw bricks found above and other bricks found below did not contain lots of lead, it seems likely that it was imported in the early 14th century.

LOCAL BRICKS

Among the local bricks were 11 wall bricks and 11 moulded bricks, four of which were applied in the vaulting. It seems that seven of them, likely dating to the end of the 13th or first half of the 14th century, are mostly normal wall bricks (49, 58, 59, 60, 62, 63 and 65). However, there are several moulded bricks that date mostly to the 14th century, but possibly to the 13th as well. Both moulded and ordinary wall bricks seem to have been produced in the early phase. See Table 3.

Roof tile 73 is likely produced locally, supporting earlier notions that roof tiles were made in the Turku area already in the 15th century.

CONCLUSIONS

In this study, 20 bricks from Koroinen and 17 bricks and 3 roof tiles from the town of Turku were analysed with the pXRF method. The reference material included imported and local pottery as well as two imported and two local bricks. The analysed element content was also compared to geological analyses of local clays. Leaching of calcium and potassium as well as porosity were taken into consideration in interpreting the results. It seems that it is best to interpret the indicator elements

Elements / Local	Id	Catalogue number	Excavation / context	Brick type	Dating
Fe, K	40	KM52100:1417b	Koroinen, inside keep	Brick	Before 1430s / probably 14th century*
V, Ni, K	41	KM52100:1417c	Koroinen, inside keep	Brick	Before 1430s / probably 14th century*
Ni, V	45	KM52100:1420a	Koroinen, keep	Moulded brick	Before 1430s / probably 14th century
Fe, K, S , V, Ni	47	KM52100:1450c	Koroinen, in front of the oven	Brick	Before 1430s / probably end of 13th-14th century*
Fe, K, V, Ni	48	KM52100:1450a	Koroinen, in front of the oven	Moulded brick	Before 1430s / probably end of 13th-14th century*
Fe, Ni	61	M2204d, RF434	Early Phases of Turku Project	Piece of brick	1250–1320
Pb, Sn	62	M2208, RF400	Early Phases of Turku Project	Piece of brick	Older than 1320
Fe, Ni	64	2214, RF398	Early Phases of Turku Project	Piece of brick	1250–1320
Cu	66	R1662b, RF234	Early Phases of Turku Project	Roof tile	Before 1450
K, Cl, S, Pb, As	67	R1640, RF215	Early Phases of Turku Project	Roof tile	Before 1450
Pb, Zn, Sn	68	R1640, RF247	Early Phases of Turku Project	Rib brick	Before 1450
Pb	69	R1640, RF455	Early Phases of Turku Project	Rib brick	Before 1450
Ca, Fe, K, S, Cl, Pb	70	R1640, RF454	Early Phases of Turku Project	Rib brick, "Ox"	Before 1450
V, Cu, Zn	71	1096, RF93	Early Phases of Turku Project	Moulded brick	Early 14th century
Ca, Fe, K	72	R1662A, RF230	Early Phases of Turku Project	Brick	Older than 1450
Fe	75	M3022, RF7	Early Phases of Turku Project	Piece of brick	14th century
Local	38	KM52100:1417a	Koroinen, from the brickwaste of the keep	Brick	Before 1430s / probably 14th century*
Local	39	KM52100:1343	Koroinen, inside keep	Moulded brick	Before 1430s / probably 14th century*
Local	42	KM52100:1430d	Koroinen	Brick	Before 1430s / probably 14th century*
Local	43	KM52100:1419	Koroinen, keep	Moulded brick applied in vaulting	Before 1430s / probably 14th century*
Local	44	KM52100:1421	Koroinen, keep	Moulded brick	Before 1430s / probably 14th century*
Local	46	KM52100:1418	Koroinen, keep	Moulded brick, window jamb	Before 1430s / probably 14th century*
Local	49	KM52100:1449d	Koroinen, in front of the oven	Brick	Before 1430s / probably end of 13th-14th century*
Local	50	KM52100:1432d	Koroinen, inside residence	Moulded brick	Before 1430s / probably 14th century*
Local	51	KM52100:1437c	Koroinen, inside residence	Moulded brick	Before 1430s / probably 14th century*
Local	52	KM52100:1436	Koroinen, inside residence	Moulded brick applied in vaulting	Before 1430s / probably 14th century*
Local	53	KM52100:1434	Koroinen, inside residence	Moulded brick, window jamb?	Before 1430s / probably 14th century*
Local	54	KM52100:1433c	Koroinen, inside residence	Moulded brick	Before 1430s / probably 14th century*
Local	55	KM52100:1441b	Koroinen, inside residence	Moulded brick applied in vaulting	Before 1430s / probably 14th century*
Local	56	KM52100:1441b	Koroinen, inside residence	Moulded brick applied in vaulting	Before 1430s / probably 14th century*
Local	57	KM52100:1431	Koroinen, inside residence	Floor brick?	Before 1430s / probably 14th century*
Local	58	R2182, RF 378, brick73	Early Phases of Turku Project	Raw brick	1320s
Local	59	R2182, RF 379, brick74	Early Phases of Turku Project	Raw brick	1320s
Local	60	M2213b, RF394	Early Phases of Turku Project	Piece of brick	Older than 1320s
Local	62	M2208, RF400	Early Phases of Turku Project	Piece of brick	Older than 1320s
Local	63	2204, RF399	Early Phases of Turku Project	Piece of brick	1250–1320
Local	65	R1097, RF92	Early Phases of Turku Project	Piece of brick	1300–1350
Local	73	TI3006, RF133	Early Phases of Turku Project	Roof tile	15th–16th century
Local	74	M3025, RF10	Early Phases of Turku Project	Piece of brick	14th century
*See Ratilainen et al. 2017					

TABLE 3.
The bricks and roof tiles with exceptional element values as well as local bricks and roof tiles. The more there are of the different elements, the more likely it is that the brick/roof tile was not made of local clays. Iron and calcium are interpreted to indicate foreign origin alone. Due to the risk of leaching potassium, the potassium values alone are not applied (porous bricks marked with red). The single values of heavy metals such as Ni, Cu and Sn are considered anomalies that are left out of the interpretation. Table by Tanja Ratilainen.

(iron, calcium, lead, sulphur, potassium, chlorine, nickel, copper, zinc, arsenic, cadmium and tin) as a whole, although quantities of iron and calcium indicate foreign origin alone. On the other hand, heavy metals could not be used alone due to possible contamination from the surrounding soils.

Among the 35 analysed bricks in addition to two Dutch bricks, there are at least 9 imported bricks, but likely 13 in total. Not just special bricks were imported, i.e., moulded bricks or roof tiles, but also normal wall bricks. Importing seems to have happened not only in the early phase, in the second half of the 13th and early 14th centuries, but also in the 15th century, when brick use began to be more common in Turku. From the local perspective, both moulded and ordinary wall bricks were also produced locally from the early phase onwards.

There were only three roof tiles in the analysis, but the results suggest that they were acquired both locally (73) and through importation (66?, 67) in the 15th century. The roof tile (67) likely covered with surface treatment containing lead is the first such tile from Turku dating to the first half of the 15th century. High copper values in roof tile 66 may also indicate remains of coating.

To conclude, the results suggest that in Finland, the acquisition of bricks in the early and later Middle Ages was more complex than previously thought. Surprisingly, it adds moulded bricks and ordinary wall bricks to the list of imported goods. Thus, not only did the foreign brickmakers arrive in Turku but also their bricks. In the earlier research, brick was considered rare and expensive building material, which could be supported by the fact that they were also imported. On the other hand, bricks may have been imported simply because there was a lack of skilled brickmakers or because they could not locally produce the amounts of bricks needed.

In our view, this study has shown the potential of pXRF in origin studies of bricks and roof tiles. The benefits of the analyser are that it can be brought to the samples, and a large amount of data can be collected in a reasonable time. In addition, with careful sampling, it can also be applied in confirming surface treatments of roof tiles and bricks. On the other hand, the analyser is still costly, and in Finland, it remains under the supervision of the Radiation and Nuclear Safety Authority (STUK). Furthermore, due to different analysing applications and calibrations, analysing the results is not directly comparable among different pXRF brands or even among different devices by the same brand.

For a deeper look into the aspects of brick and tile production and trade and to increase the statistical credibility of the study, another pXRF analysis with a greater collection of material from various sites should be made. To avoid possible contamination from the polluted soils, standing buildings could be suitable targets, and combined with brick sizes, the study could add more to the subject. Another interesting experiment would be to see if the method could be applied in confirming building phases in a building project. Before any further clay studies using pXRF are carried out, laboratory and pXRF analyses and comparisons should be made for the calibration of the measuring pXRF device using the same carefully selected samples found in Turku as well as some soil clay samples.

ACKNOWLEDGEMENTS

We would like to thank Aki Pihlman for dating and choosing the pottery samples for this study. We also thank Adjunct Professor Auli Bläuer, Professor Visa Immonen and Adjunct Professor Kari Uotila for their valuable comments on the manuscript, as well as TUCEMEMS for providing financial support for the language revision of this article.

1. Lindahl 1988, 515–535; Wahlberg 2000; Comparison of the PIXE and XRF methods see: Verma 2007; On the method in ceramic analysis see: Rizzutto et Tabacniks 2017
2. Holmqvist-Saukkonen et al. 2013; Holmqvist-Saukkonen et al. 2014
3. Holmqvist-Saukkonen et al. 2013, 441–444 and references therein.
4. Verma 2007; Holmqvist 2017; Rizzutto et Tabacniks 2017
5. Donais et George 2013; Bonizzoni et al. 2013; Lamm et Lindahl 2014; Lensen 2015; pXRF analysis mostly on Iron Age pottery, see: Jokisalo 2018, 48–51; pXRF analysis on building stones, see: Kinnunen et Seppänen in print.
6. Jussi Kinnunen wrote the chapter on Methods of analysis and instrumentation. In the conclusions, the last two paragraphs were written together.
7. Lindberg 1919, 14–16; Gardberg 1957, 6–7, 20, 32; Drake 2007, 115; Seppänen 2012a, 7. However, cfr. Winnari 1925, 60
8. Uotila 2003; Ratilainen 2010; Ratilainen et al. 2017
9. Ailio 1913, 1; Lindberg 1919, 15–16; Gardberg 1957, 4–5, 20, 31; Valonen 1958, 21; Hiekkanen 1996, 70
10. Uotila 2009; Ratilainen 2010; Seppänen 2012b, 647–650
11. Kuokkanen 1981, 42–46; Smith 1985, 39, 60; Antell 1986, 9; Andersson et Hildebrand 2002, 51–55; Hiekkanen 2003, 31–32; Svanberg 2013, 31–32
12. Knapas 1974; Uotila 2000, 121; Ratilainen 2014, 99
13. Lejoneke et Kistner 2002; Lejoneke et Kistner 2004; Seppänen 2012b, 649 and reference therein
14. Egan 2012, 37; McComish 2015, 24
15. Gardberg 1957, 96–97; Uotila 1991, 167; Andersson et Hildebrand 2002, 52
16. REA 407
17. Gardberg 1971, 219
18. Brusila 1984, 109, 111
19. Ruuth 1909, 166; Gardberg 1959, 311, 319–320; Nikula 1985, 401
20. Tulkki et al. 2002, 397
21. Winnari 1925, 82, 85; Paulsson et al. 1936, 4; Järvenpää 1949, 6–7; Lindgren et Moeschlin 1985, 19; Tjernström 2003, 12
22. Ose 2015, 69
23. Andersson et Hildebrand 2002, 58–59
24. see e.g. Venhe 1994, 37; Suna 1994, 19 According to Ratilainen's experience the glazed surfaces are usually also burnt black under the surface, in which case you cannot be certain if its lead-glazing or just due to over burning in the kiln.
25. Seppänen 2012b, 700–701
26. Gardberg 1957, 100; Lindahl 1988; Venhe 2000, 113; Seppänen 2012b, 797–799
27. Venhe 2000, 114; Uotila 2009, 311; Seppänen 2012b, 802–803
28. Suna 1994, 19; Venhe 2000, 113; Cfr. Seppänen 2012b, 797
29. Seppänen 2012a, 20 fig. 8; Seppänen 2012b, 797–802
30. Antell 1986, 9–11; Venhe 2000, 114, 118
31. Gardberg 1957, 65; Gardberg 1959, 498, 509–510; Kuokkanen 1981, 102; Venhe 2000, 114
32. Nikula 1971, 643–644; Venhe 2000, 114
33. Pottery material for this study was chosen by Aki Pihlman. Bricks were chosen by Tanja Ratilainen.
34. 1–17, See the pottery in question: Pihlman 1989, 104; 2002, 342–43; 2003a, 102; 2003b, 199; 2010a, 80–84
35. 18–21. On 20–21 see: Tulkki 2001 Appendix 1, List of analysed pottery; Tulkki 2002; Tulkki et al. 2002, 396–401; Tulkki 2003; On 18–19 See: Sipilä 2013
36. 22–35, 37. Id 36 was later excluded from the reference material, but is visible in the figures.
37. 77–78
38. 58–59
39. The principal set of samples was analysed in the winter, when no archaeological excavations near the sites in question were open.
40. Tite 2008, 225; Holmqvist-Saukkonen et al. 2014, 4; Lensen 2015, 115
41. Ids 18–19 See Pihlman et Savolainen in print; Ids 20–21, See Tulkki 2003; Ids 58–59 See Ratilainen 2014
42. Pihlman 2018
43. Pihlman 1989; 2002; 2003a; 2003b, 199; Pihlman 2010a
44. Pihlman 1989, 104; Pihlman 2003b, 196–198; Pihlman 2010a, 85; Holmqvist-Saukkonen et al. 2013, 444–446 and refefences therein
45. Pihlman 1989, 104; 1995, 227–228: 2003b, 189–199; Majantie 2010, 274
46. Salminen et al. 1997; Salmi 2000; Kolu 2000 was not available, therefore his results cited in Salmi 2000 are applied when necessary.
47. Rantataro 1996.
48. Manninen et Willamo 1993; Ympäristöministeriö 2007
49. Roof tiles are 66–67, 73. Moulded bricks are 39, 43–46, 48, 50–56, 68–71. Normal wall bricks or likely their pieces are: 38, 40–42, 47, 49, 57–65, 72, 74–78.
50. See on Koroinen e.g. Gardberg 1971; Koivunen 2003; Hiekkanen 2014; Ratilainen et al. 2017
51. On the project, See Pihlman 2007a; Pihlman 2007b; Pihlman 2010b
52. Ratilainen et al. 2017
53. Oinonen et Eskola 2018
54. Ratilainen et al. Manuscript
55. On the projkect, See Pihlman 2007a; Pihlman 2007b; PiIhlman 2010b
56. Ainasoja et al. 2007
57. Ratilainen 2010; Ratilainen 2014
58. Tenovuo 2015; Olympus 2011
59. Innov-X Systems 2005; Olympus 2011; Olympus 2016
60. Olympus 2011

61. Thomsen 2007; Hall et al. 2013
62. Newlander et al. 2015; Tenovuo 2015; Olympus 2012
63. Bonizzoni et al. 2013, 267
64. 55–56
65. Janoušek et al. 2006
66. *Ibid.*
67. Frosterus 1922, 18; Winnari 1925, 82-83; Salminen et al. 1997, 120
68. Lensen 2015, 109
69. Salminen et al. 1997, 120; Salmi 2000, 21–22 See also Rantataro et al. 1996, 28
70. See on the kilns Lindgren et Moeschlin 1985, 30; Ankarberg et Nyström 2007, 38
71. Frosterus 1922, 18; Winnari 1925, 272–273
72. Rantataro,1996, 18–19; Salminen et al. 1997, 122–124
73. Salminen et al. 1997, 120; Salmi 2000, 45
74. Ympäristöministeriö 2007, Liite 14/1
75. *Ibid.*, Liite 2/3
76. Rantataro,1996, 15–16 and references therein. Kolu 2000 cited in Salmi 2000, 34
77. Manninen et Willamo 1993, 54; Ympäristöministeriö 2007, Liite 14/1
78. Salminen et al. 1997, 120
79. Kolu 2000 cited in Salmi 2000, 42
80. Manninen et Willamo 1993, 56; Ympäristöministeriö 2007, Liite 14/1
81. Salmi 2000, 41
82. Salminen et al. 1997, 120
83. Manninen et Willamo 1993, 54; Rantataro, 1996, 21; Ympäristöministeriö 2007, Liite 14/1
84. Salminen et al. 1997, 120; Kolu 2000 cited in Salmi 2000, 31
85. Ympäristöministeriö 2007, Liite 14/1
86. *Ibid.*
87. Rantataro, 1996, 21
88. Kolu 2000 cited in Salmi 2000, 32
89. Salmi 2000, 32
90. Ympäristöministeriö 2007, Liite 14/1
91. Manninen et Willamo 1993, 56
92. Tite 2008, 225; Holmqvist-Saukkonen et al. 2014, 4; Lensen 2015, 115
93. Schwedt et al. 2004, 95–96; See also Tite 2008, 225–226 and references therein
94. Holmqvist-Saukkonen et al. 2013, 443
95. Salonen et al. 1989
96. Salmi 2000; Tuovinen 2004, 28
97. Blair et Ramsay 1991, 191
98. Egan 2012, 51
99. Lamm et Lindahl 2014, 91
100. Ratilainen et al. 2017
101. In addition, magnesia is one of the (MgO) elements present clays rich in CaO and talc as well. But this could not be used in the comparison, since the pXRF equipment cannot measure it.
102. See e.g. Middleton et Price 1996
103. Lensen 2015, 111
104. *Ibid.*, 117
105. Ainasoja et al. 2007
106. Drake 2009, 126–127.
107. Seppänen 2012b, 797
108. Pers. comm. by Aki Pihlman, 6th of April 2018
109. Only samples below the street were analysed.
110. Pihlman 1989, 104; 1995, 227–228: 2003b, 189–199; Majantie 2010, 274
111. Tulkki 2003, 219
112. Majantie 2007, 95–96; Majantie 2010, 276–278
113. Majantie 2010, 166

REFERENCES

Unpublished

Ainasoja, M., Harjula, J., Majantie, K., Pihlman, A., Ratilainen, T., Saloranta, E., Seppänen, L., Tuovinen, T. 2007. *Turku I. Tuomiokirkontori. Varhainen Turku -hanke. Kaupunkiarkeologiset tutkimukset 2005–2006.* Excavation report, Archives of Museum Centre of Turku.

Jokisalo, S. 2018. *Astiasi arvelussa. Kaarinan Ravattulan Ristimäen keramiikkalöydöt 2010–2016*, Master's thesis, Archaeology, University of Turku.

Lensen, R. 2015. *Early brick production and use in the coastal regions of the Low Countries 1200–1350*, MA-thesis, University of Leiden. https://openaccess.leidenuniv.nl/handle/1887/44892.

McComish, J.M. 2015. *A Guide to Ceramic Building Materials*, York, York Archaeological Trust. https://www.yorkarchaeology.co.uk/wp-content/uploads/2015/05/A-guide-to-ceramic-building-material-reduced.pdf

Oinonen, M. et Eskola K.O. 2018. *Turku, Koroinen 2015–2018*. Dating report. Laboratory of Chronology, University of Helsinki.

Pihlman, A. 1995. *Keskiaikaiset savi- ja puuastiat Turun kaupungissa ja Turun linnassa*. Licentiate thesis, Department of Archaeology, University of Turku.

Pihlman, A., *pers. comm.*, 6th of April 2018.

Salmi, T. 2000. Åbo Akademin tontin kulttuurikerrosten alkuainepitoisuudet ja erityisesti ihmistoiminnan vaikutus raskasmetallikuormitukseen 700 vuoden aikana, Master's thesis, Department of Geology, University of Turku.

Sipilä, J. 2013. Turku VII-5-9. *Linnankatu 35b. Kaupunkiarkeologinen pelastuskaivaus 2012.* Excavation report, Archives of the Museum Centre of Turku.

Tenovuo, N. 2015. *Kannettavan XRF-laitteen* käyttö kallioperänäytteiden analysoinnissa, BA-thesis, Department of Geology, University of Turku.

Tulkki, C. 2001. *Todisteita punasaviastioiden valmistuksesta uuden ajan alun Turussa – Tutkimusmateriaalina Turun tuomikirkon ympärysmuurirakennuksen kellarin keramiikka löydöt.* Master's thesis, University of Turku.

Tuovinen, T. 2004. *Turku VI/2/9 Turun kaupunginkirjasto. Kaupunkiarkeologinen kaivaus II-vaihe: kirjastotalon kellarikerros ja uudisrakennusosa 2004–2005.* Excavation report, Archives of Museum Centre of Turku.

Uotila, K. 1991. *Turun raatihuoneen rakennushistoria keskiajalta vuoteen 1734, Licentiate thesis*, Department of Finnish History, University of Turku.

Published

Ailio, J. 1913. Hattulan kirkko Hämeen emäkirkko, *Kaikuja Hämeestä* VIII: 2–10.

Andersson, K. et Hildebrand, A. 2002. *Byggnadsarkeologisk undersökning: det murade huset*. Första upplagan gavs ut 1980 under titeln: Handledning vid byggnadsarkeologisk undersökning av Karin Andersson och Angneta Rosenqvist, Stockholm: Riksantikvarieämbetet.

Ankarberg, C.-H. et Nyström, B. 2007. *Rörstrand i Stockholm: tegelbruk, fajansmanufaktur och keramisk storindustri 1270–1926*, Stockholm: Stockholmia.

Antell, O. 1986. *Taktegel, tegeltak*, Byggforskningsrådet: Riksantikvarieämbetet.

Blair, J. et Ramsay, N. 1991. *English Medieval Industries: Craftsmen, Techniques, Products*, London: The Hambledon press.

Bonizzoni, L., Galli, A., Gondola, M. et Martini, M., 2013. Comparison between XRF, TXRF, and PXRF analyses for provenance classification of archaeological bricks, X-Ray *Spectrometry* vol 42, issue 4: 262–267.

Brusila, H. 1984. Turun tuomiokirkon pohjois-koillispuolen rakennusjäännöksistä, in: *Historiallisen ajan arkeologia Suomessa: Den historiska tidens arkeologi i Finland*. Turku: Turun maakuntamuseo 108–111.

Donais, M.K. et George, D. 2013. Case study 2: Differentiation of tiles in a hypocaust, in: Shugar A.N. et Mass J.L. (eds), *Handheld XRF for Art and Archaeology*, Leuven: Leuven University Press, 364–369.

Drake, K. 2007. Gotische Backsteinbaukunst in Finnland, in: *Backstein Baukunst. Zur Denkmalkultur des Ostseeraums*, Bonn: Deutsche Stiftung Denkmalschutz, 106–115.

Drake, K. 2009. Kalkstenkonsoerna i Åbo domkyrkas sakristia, Kirkearkæologi i Norden 9, Kalundborg, Danmark, 2007, *Hikuin* 36: 121–128.

Egan, G. 2012. *The Medieval Household: Daily Living c.1150–c.1450*, London, Museum of London.

Frosterus, B. 1922. Geologisen komissionin agrogeologiset tutkimukset – Opas – Geologisen komissionin osastossa XII:ssa yleisessä maanviljelysnäyttelyssä Tampereella 1922 – *Geoteknillisiä tiedonantoja* 35.

Gardberg, C.J. 1957. *Med murslev och timmerbila : drag ur det finländska byggnadshantverkets historia*, Helsingfors.

Gardberg, C. J. 1959. *Åbo slott under den äldre vasatiden: En byggnadshistorisk undersökning.* Helsingfors: [tekijä].

Gardberg, C. J. 1971. Turun kaupungin historia 1100-luvun puolivälistä vuoteen 1366, *Turun kaupungin historia* 1, Turku, 115–338.

Hall, G. Bucharv, A. et Bonham-Carter, G. 2013. Quality Control Assessment of Portable XRF Analysers: Development of Standard Operating Procedures, Performance on Variable Media and Recommended Uses, *Canadian Mining Industry Research Organization (CAMIRO) Exploration Division*.

Hiekkanen, M. 1996. Uusia tutkimuksia Hattulan Pyhän Ristin kirkossa, *Arx Tavastica* 10: 47–76.

Hiekkanen, M. 2003. *Suomen kivikirkot keskiajalla*, Helsinki: Otava.

Hiekkanen, M. 2014. *Suomen keskiajan kivikirkot*. Helsinki: Suomalaisen Kirjallisuuden Seura.

Holmqvist, E. 2017. Handheld Portable Energy-Dispersive X-Ray Fluorescence Spectrometry (pXRF), in: Hunt A.M.W. (ed.), *The Oxford Handbook of Archaeological Ceramic Analysis*, Oxford, University Press, 363–381.

Holmqvist-Saukkonen, E., Koivisto A. et Väisänen R. 2013. Keskiajan suomalainen käyttökeramiikka: tuontitavaraa vai paikallista valmistusta?, *Historiallinen aikakauskirja* vol. 111, issue 4: 441–454.

Holmqvist-Saukkonen, E., Koivisto A. et Väisänen R. 2014. Redwares from Gubbacka's medieval village. Regional and inter-regional views on ceramic networks and technology (SEM-EDX), *SKAS* 2013: 1–2, 3–15.

Innov-X Systems 2005. *Instruction manual Innov-X Systems Alpha Series™ X-Ray Fluorescence Spectrometers*. http://www.equipcoservices.com/pdf/manuals/innov-x_alpha_series.pdf

Janoušek, V. Farrow, C.M. et Erban, V. 2006. Interpretation of whole-rock geochemical data in igneous geochemistry: introducing Geochemical Data Toolkit (GCDkit), *Journal of Petrology* vol 47, issue 6: 1255–1259.

Järvenpää, V. 1949, *Poltettujen savitiilien valmistus koti- ja pienteollisuutena*, Helsinki: Rakentajain kustannus.

Kinnunen, J. et Seppänen, L. in print. Geoarchaeology, bedrock surveys, and geochemical analysis – Tracing the provenance of medieval building stones, in: *Monographs of the Archaeological Society of Finland*, Archaeological Society of Finland.

Knapas, R.1974. Tiilen historiaa, *Tiili* 4: 10–17.

Koivunen, P. 2003. Koroisten piispanistuimen ja asutuksen tutkimushistoriaa, in: *Koroinen eläväksi*. Raportteja Turun maakuntamuseo 19: 35–65.

Kuokkanen, R. 1981. Tiilen lyönti ja käyttö ristiretkiajalta 1850-luvulle, in: *Suomen tiiliteollisuuden historia*, [Helsinki]: Suomen tiiliteollisuusliitto, 13–62. .

Lamm, J.P. et Lindahl, A. 2014. A Recently Excavated Medieval Brick Kiln at Saltsjö Boo, Sweden and the HXRF Analyses of its Products, in: Ratilainen T., Bernotas R. et Herrmann C. (eds), Fresh Approaches to Brick Production and Use in the Middle Ages. Proceedings of the session Utilization of Brick in the Medieval Period – Production, Construction, Destruction held at the European Association of Archaeologists (EAA) Meeting, 29 August to 1 September 2012 in Helsinki, Finland, Oxford, *Archaeological Reports: International Series* 2611: 81–92. .

Lejoneke, P. et Kistner, J. 2002. Vrak med last av medeltida tegel, *Marinarkeologisk tidskrift* 2: 22–25.

Lejoneke, P. 2004. Kungshamnsbåten – ett fartyg lastat med tegel, *Bottnisk Kontakt* XI: Maritimhistorisk Konferens, Länsmuseet Västernorrland 1–3 Februari 2002: Huvudtema: Båtar Och Skepp I äldre Tid (förhistoria-medeltid), Härnösand: Länsmuseet Västernorrland, 132–139.

Lindahl, A. 1988. Teknisk undersökning av taktegel från Kastelholms slott, Kastelholms slott. *Arkeologiska undersökningar 1982 och 1983*; KS 1–KS14 Taktegelanalys, Kastelholm: Museibyrån.

Lindberg, C. 1919. *Om teglets användning i finska medeltida gråstenskyrkor*, Helsingfors: H. Schildt.

Lindgren, J. et Moeschlin, J. 1985. *Tegel: tillverkning, konstruktion, gestaltning*, Stockholm: Svensk byggtjänst.

Majantie, K. 2007. Ceramic Stove Tiles and the Start of Local Production in Turku, in: Majantie, Kirsi (ed.), *Pots and princes: ceramic vessels and stove tiles from 1400–1700*, Archaeologia Medii Aevii Finlandiae XII, 93–96, Turku: Aboa Vetus et Ars Nova, Suomen keskiajan arkeologinen seura.

Majantie, K. 2010. *Muotia, mukavuutta ja mielipiteitä: Kaakeliuuni yhteiskunnallisten muutosten ilmentäjänä keskiajan ja uuden ajan alun Suomessa*, Archaeologia Medii Aevii Finlandiae XVII, Turku: Suomen keskiajan arkeologian seura.

Manninen, S. et Willamo, R.1993. Ympäristön laadun ohjearvot Suomessa: Arvoja ja arvioita. *Environmentalica Fennica* 17. Helsinki.

Middleton, W.D. et Price, D.T. 1996. Identification of Activity Areas by Multi-element Characterization of Sediments from Modern and Archaeological House Floors Using Inductively Coupled Plasma-atomic Emission Spectroscopy – Science Direct, *Journal of Archaeological Science* Vol. 23, issue 5: 673–687.

Newlander, K., Goodale, N., Jones, J.T., et Bailey, D.G., 2015. Empirical study of the effect of count time on the precision and accuracy of pXRF data, *Journal of Archaeological Science Reports* 3: 534–548.

Nikula, O. 1971. *Turun kaupungin historia 1721–1809*, Turku.

Nikula, O. 1985. *Turun kaupungin historia 1521–1600*, Turku.

Olympus 2011. *DELTA_Handheld XRF R and D Configuration Guide DS*_103-09-11. https://gwm-engineering.fi/files/8914/4491/4100/DELTA_XRF__Research_and_Discovery.pdf

Olympus 2012. *DELTA Family Handheld XRF Analyzer User Interface Guide*. https://d272z0j70hk1vf.cloudfront.net/downloads/5876c30e49740-103202-01en-rev-a1-delta-family-ui-guide-international.pdf

Olympus 2016. *How HandHeld XRF Works as Part of the Reasonable Testing Program for Regulation Markets*. http://www.olympus-ims.com/en/webinars/xrf-for-regulaton/

Ose, I. 2015. *Turaidas pils 13. – 17. gadsimta būvkeramika*, Katalogs, Riga, Latvijas vēstures institūta apgāds.

Paulsson, G., Engkvist O., Hansson S., Thunström O. et Lind S.I.1936. *Mureri*, Stockholm: Lindfors bokförlag.

Pihlman, A. 1989. Saviastiat – Lerkärl, in: Ikäheimo, M., Kostet, J., Pihlman, A., Lindberg, H., Löflund, B. & Swanljung, H. (eds) *Turun Mätäjärvi: Mätäjärvi i Åbo*, Turku, Turun maakuntamuseo, 83–122.

Pihlman, A. 2002. Medieval Pottery in the River Aura Valley in SW Finland, in: Helmig G., Scholkmann B. et Untermann M. (eds), *Centre, Region, Periphery*, Medieval Europe Basel 1, Hertigen, 339–344.

Pihlman, A. 2003a. Från Korois till Åbo Stad – De importerade lerkärlen i Aurajokidalen på 1200- och 1300-talen, in: Brusila H., Appelgren K., Kostet J. et Räty J. (eds), *Koroinen eläväksi*, Raportteja 19, Turku: Turun maakuntamuseo, 101–103. .

Pihlman, A. 2003b. Kaupunki, maaseutu ja keskiaikaiset saviastiat, in: Seppänen L. (ed.), *Kaupunkia pintaa syvemmältä: arkeologisia näkökulmia Turun historiaan*, Archaeologia Medii Aevii Finlandiae IX, Turku: Suomen keskiajan arkeologian seura, 195–206.

Pihlman, A. 2007a. The Archaeology of Early Turku and the Extent of the town, in: Pihlman, A., Söderström, M., Rantanen, A. & Kivijärvi, R. (eds) *Eurooppalainen Hansa: The European Hansa*. Raportteja 21, Turku: Turun maakuntamuseo, 85–94.

Pihlman, A. 2007b. Varhainen Turku -tutkimushanke. Uusia arkeologisia tulkintoja Turun kaupungin muodostumisesta. *HIT History in Turku: Tietoja, taitoja ja löytöjä*. Näyttely Turun linnassa 15.6.–23.9.2007, Turun maakuntamuseon näyttelyesite, Turku, 10–15.

Pihlman, A. 2010a. Tuontisaviastiat: eroavatko Turun kaupunginosat toisistaan 1300-luvulla tuontitavaroiden kuluttajina?, in: Söderström M. (ed.), *Varhainen Turku*, Raportteja 23, Turku: Turun museokeskus, 79–94.

Pihlman, A. 2010b. Turun kaupungin muodostuminen ja kaupunkiasutuksen laajeneminen 1300-luvulla, in: Söderström M. (ed.), *Varhainen Turku*, Raportteja 23, Turku: Turun museokeskus, 9–29.

Pihlman, A. 2018. Saviastiat ja alueen kronologia vallin sisäpuolisella alueella, in: Harjula, J., Hukantaival, S., Immonen, V., Ratilainen, T., Salonen, K., (eds) *Koroinen Suomen ensimmäinen kirkollinen keskus*. Turun historiallinen arkisto 71. Turku: Turun historiallinen yhdistys, 232–252.

Pihlman, A. et Savolainen, P. in print. Ruukuntekijän tontti – 1700-luvun savenvalajien arki historiallisen arkeologian valossa, in: Mustonen, R. et Ratilainen, T. (eds) *Pitkin poikin Aurajokea – Arkeologisia tutkimuksia*, Raportteja 23, Turku: Turun museokeskus.

Rantataro, J. 1996. Anthropogenic impact on recent sediment in Jätkäsaari harbour basin, Helsinki, Finland: A comparison with the geochemistry of unpolluted glacial clay. *Tutkimusraportti* 134, Geologian tutkimuskeskus: Espoo. http://tupa.gtk.fi/julkaisu/tutkimusraportti/tr_134.pdf

Ratilainen, T. 2010. Tiilen käytöstä 1300-luvun Turussa, *Varhainen Turku*, Raportteja 23, Turku: Turun museokeskus, 31–55.

Ratilainen, T. 2014. Unfired Bricks Used for a Medieval Oven in Turku, Finland, in: Ratilainen T., Bernotas R. et Herrmann C. (eds), Fresh Approaches to Brick Production and Use in the Middle Ages. Proceedings of the session Utilization of Brick in the Medieval Period – Production, Construction, Destruction held at the European Association of Archaeologists (EAA) Meeting, 29 August to 1 September 2012 in Helsinki, Finland, British *Archaeological Reports: International Series* 2611: 93–101.

Ratilainen T., Harjula J., Immonen V. et Salonen K. Manuscript. Dating bricks with OSL and AMS methods – the Case of Koroinen, in: *Castella Maris Baltici*.

Ratilainen T., Immonen V., Salonen K. et Harjula J. 2017. The Bishop's Brick House: Remains of Medieval Buildings on the River Bank of Koroinen, Finland, *Lund Archaeological Review* 22/2016: 61–87.

REA, *Registrum Ecclesiae Aboensis eller Åbo domkyrkas Svartbok med tillägg ur Skoklosters Codex Aboensis*. I tryck utg. genom Reinhold Hausen. Helsingfors 1890.

Rizzutto, M.A. et Tabacniks, M.H. 2017. Particle Induced X-ray Emission (PIXE) and Its Aplications for Ceramic Analysis, in: Hunt A.M.W. (ed.), *The Oxford Handbook of Archaeological Ceramic Analysis*, Oxford: University Press, 382–398.

Ruuth, J. W. 1909. *Åbo stads historia under medeltiden och 1500-talet: Första häftet*. Helsingfors.

Salminen, R., Kukkonen, M., Paukola, T. et Töllikkö, S. 1997. Chemical composition of clays in southwestern Finland, Geological Survey of Finland, *Current Research 1995–1996*, vol. 23: 117–126.

Salonen, V.-P., Räsänen, M. et Terho, A. 1989. Mätäjärvis paleolimnologiska evolution, *Turun Mätäjärvi: Mätäjärvi i Åbo*, Raportteja 10, Turku: Turun maakuntamuseo, 174–176.

Schwedt, A., Mommsen H. et Zaccharias N. 2004. Post-depositional Elemental Alterations in Pottery: Neutron Activation Analyses of Surface and Core Samples, *Archaeometry* vol. 46, issue 1: 85–101.

Seppänen, L. 2012a, Brick Buildings, Chimneys and Windows with Glass – A Chain of Changes in Medieval Housing in Turku, *Finskt museum*, 2012: 6–27.

Seppänen, L. 2012b. *Rakentaminen ja kaupunkikuvan muutokset keskiajan Turussa: erityistarkastelussa Åbo Akademin päärakennuksen tontin arkeologinen aineisto*, Turku: Turun yliopisto. http://urn.fi/URN:ISBN:978-951-29-5231-1

Smith, T.P. 1985. *The medieval brickmaking industry in England 1400–1450*, Oxford.

Suna, A. 1994. Maanalaisten rakenteiden jäännökset linnan alueella, in: Suna A. (ed.), *Kuusiston linna: tutkimuksia 1985–1993*. Helsinki: Museovirasto, 10–23.

Svanberg, J. 2013. *Medeltida byggmästare i Norden*, Stockholm: Bokförlaget Signum.

Thomsen, V. 2007. Basic Fundamental Parameters in X-Ray Fluorescence, *Spectroscopy* Vol. 22, issue 5: 46–50.

Tite, M.S. 2008. Ceramic production, provenance and use - A review, *Archaeometry* vol. 50, issue 2: 216–231.

Tjernström, S. 2003. *Keramik i arkitekturen*, Stockholm: Byggförl.

Tulkki, C. 2002. Savenvalajan jäljillä Turun tuomiokirkon kupeessa, *SKAS* 4: 43–54.

Tulkki, C. 2003. Oliko punasaviastioiden valmistus mahdollista uuden ajan alun Turussa?, in: Seppänen L. (ed.), *Kaupunkia pintaa syvemmältä*, Archaeologia Medii Aevii Finlandiae IX, Turku: Suomen keskiajan arkeologian seura, 207–222.

Tulkki, C. Majantie, K. et Uotila, K. 2002. Kokenhus project, in: Helmig, G. Scholkmann, B. et Untermann, M. (eds), Centre, *Region, Periphery, Medieval* Europe Basel 1, Hertigen, 396–401.

Uotila, K. 2000. Tiili rakennusmateriaalina, in: Uotila K. (ed.), *Vesilahden Laukko: linna, kartano, koti*, Archaeologia Medii Aevii Finlandiae IV, Turku: Suomen keskiajan arkeologian seura, 121–122.

Uotila, K. 2003. Kivitaloja keskiajan Turussa, in: Seppänen L. (ed.), *Kaupunkia pintaa syvemmältä*. Arkeologisia näkökulmia Turun historiaan. Archaeologia Medii Aevi Finlandiae IX. Turku: Suomen keskiajan arkeologian seura, 121–134.

Uotila, K. 2009. Keskiajan arkeologia, in: Lamberg, M. Lahtinen, A. et Niiranen, S. (eds), *Keskiajan avain*, Helsinki: Suomalaisen Kirjallisuuden Seura, 300–315.

Valonen, N. 1958. Turun viemärikaivantolöydöistä. *Turun kaupungin historiallinen museo* 20–21: 12–110.

Venhe, L. 1994. Irtaimet tiililöydöt, in: Suna A. (ed.), *Kuusiston linna : tutkimuksia 1985–1993*, Helsinki: Museovirasto, 32–39.

Venhe, L. 2000. Laukon kattotiilimateriaali, in: Uotila K. (ed.), *Vesilahden Laukko: linna, kartano, koti*, Archaeologia Medii Aevii Finlandiae IV, Turku: Suomen keskiajan arkeologian seura, 113–122.

Verma, H.R. 2007. X-ray Fluorescence (XRF) and Particle-Induced X-ray Emission (PIXE), *Atomic and Nuclear Analytical Methods*, Springer: Berlin, Heidelberg, 1–90.

Wahlberg, J. 2000. Keraamisen materiaalin pixe-analyysi – Laukon kartanon, Kuusiston linnan ja Aboa Vetus -museon näytteet, *Vesilahden Laukko. Linna, kartano, koti,* Archaeologia Medii Aevi Finlandiae IV, Turku: Suomen keskiajan arkeologian seura 123–130.

Winnari, E. 1925. *Tiiliteollisuus yleispiirtein: alan tietopuoleen ja käytäntöön viittoen 264 kuvalla valaisten*, Tekijä.

Ympäristöministeriö, 2007. Maaperän pilaantuneisuuden ja puhdistustarpeen arviointi. *Ympäristöhallinnon ohjeita* 2, Ympäristönsuojeluosasto, Ympäristöministeriö: Helsinki. www.ymparisto.fi/julkaisut

APPENDIX 1.
pXRF results. All appendices by Tanja Ratilainen.

Date	Time	Reading	Id	Si	Si +/-	Si%	SiO2	Ti	Ti +/-	Ti%	TiO2	Al	Al +/-	Al%	Al2O3	Fe	Fe +/-	Fe%	FeOt	Fe2O3t	Mn	Mn +/-	Mn%	MnO	Ca	Ca +/-	Ca%	CaO	K	K +/-	K%	K2O
4.3.2016	10.57.08	#76	1	436482,32	4131,12	43,65	93,37	6932,71	208,84	0,69	1,16	128862,25	5932,20	12,89	24,35	59759,76	561,22	5,98	7,69	8,54	591,18	35,37	0,06	0,08	16018,29	174,15	1,60	2,24	54526,54	520,89	5,45	6,57
4.3.2016	11.01.51	#77	2	419671,96	3940,48	41,97	89,78	5476,03	181,05	0,55	0,91	120900,85	5766,37	12,09	22,84	72320,86	647,59	7,23	9,30	10,34	774,76	38,04	0,08	0,10	14341,87	154,43	1,43	2,01	51338,36	477,51	5,13	6,18
4.3.2016	11.03.22	#78	3	384746,23	4015,44	38,47	82,30	5904,04	195,02	0,59	0,98	108814,69	6201,74	10,88	20,56	58843,93	566,39	5,88	7,57	8,41	1467,73	50,96	0,15	0,19	23247,33	237,54	2,32	3,25	53691,49	524,53	5,37	6,47
4.3.2016	11.05.02	#79	4	363184,59	4045,45	36,32	77,69	5860,15	193,67	0,59	0,98	98558,52	6423,87	9,86	18,62	67030,73	658,57	6,70	8,62	9,58	814,04	40,03	0,08	0,11	16348,71	182,21	1,63	2,29	50692,18	513,05	5,07	6,11
4.3.2016	11.06.41	#80	5	285993,89	3921,00	28,60	61,18	6172,95	201,20	0,62	1,03	104428,12	7278,22	10,44	19,73	73648,37	783,27	7,36	9,47	10,53	615,51	36,88	0,06	0,08	20843,93	239,67	2,08	2,92	62768,52	675,85	6,28	7,56
4.3.2016	11.08.19	#81	6	391361,74	3940,07	39,14	83,72	6095,71	192,61	0,61	1,02	110174,97	5922,74	11,02	20,82	60846,61	567,43	6,08	7,83	8,70	840,46	39,39	0,08	0,11	16227,93	172,06	1,62	2,27	47521,70	457,31	4,75	5,72
4.3.2016	11.09.59	#82	7	384273,15	4314,07	38,43	82,20	6470,98	209,72	0,65	1,08	113188,86	6769,27	11,32	21,39	82014,41	829,96	8,20	10,55	11,73	1610,63	55,69	0,16	0,21	11682,47	149,43	1,17	1,63	58255,83	606,86	5,83	7,02
4.3.2016	11.12.00	#83	8	431515,15	4131,37	43,15	92,31	6323,90	198,08	0,63	1,05	112541,12	6025,75	11,25	21,26	71986,59	669,52	7,20	9,26	10,29	781,95	39,20	0,08	0,10	7856,85	109,76	0,79	1,10	54546,74	523,33	5,45	6,57
4.3.2016	11.13.33	#84	9	380005,69	4149,84	38,00	81,29	5656,59	193,52	0,57	0,94	120771,59	6233,18	12,08	22,82	62198,17	614,25	6,22	8,00	8,89	792,85	39,92	0,08	0,10	17451,62	191,62	1,75	2,44	40728,90	423,09	4,07	4,91
4.3.2016	11.14.59	#85	10	355554,89	3984,26	35,56	76,06	5488,10	185,62	0,55	0,92	83178,06	6210,01	8,32	15,72	61158,72	598,87	6,12	7,87	8,74	596,91	35,11	0,06	0,08	17879,58	191,46	1,79	2,50	38345,47	396,24	3,83	4,62
4.3.2016	11.16.21	#86	11	328831,47	4086,31	32,88	70,34	5992,21	197,63	0,60	1,00	119485,14	6820,62	11,95	22,58	79180,28	810,15	7,92	10,19	11,32	861,09	41,80	0,09	0,11	20486,00	228,88	2,05	2,87	51393,89	544,86	5,14	6,19
4.3.2016	11.18.08	#87	12	289107,26	3922,58	28,91	61,85	4540,74	179,47	0,45	0,76	85229,06	6790,28	8,52	16,10	49109,64	527,18	4,91	6,32	7,02	650,31	37,29	0,07	0,08	25629,39	279,71	2,56	3,59	38856,60	429,88	3,89	4,68
4.3.2016	11.19.54	#88	13	397983,18	4126,37	39,80	85,14	5615,11	192,62	0,56	0,94	96233,53	6161,96	9,62	18,18	50983,12	502,44	5,10	6,56	7,29	736,60	38,29	0,07	0,10	13397,24	154,52	1,34	1,87	46239,48	464,98	4,62	5,57
4.3.2016	11.21.52	#89	14	355174,30	3497,63	35,52	75,98	5064,45	171,04	0,51	0,84	84940,15	5400,12	8,49	16,05	42656,58	381,21	4,27	5,49	6,10	804,55	36,58	0,08	0,10	25774,89	232,33	2,58	3,61	40459,95	367,92	4,05	4,87
4.3.2016	11.23.44	#90	15	367418,67	3980,96	36,74	78,60	5197,14	185,16	0,52	0,87	92966,32	6158,91	9,30	17,57	45590,49	452,77	4,56	5,87	6,52	854,01	40,14	0,09	0,11	19910,53	208,78	1,99	2,79	44448,73	446,77	4,44	5,35
4.3.2016	11.25.23	#91	16	371435,71	4257,00	37,14	79,46	6285,71	206,00	0,63	1,05	128319,22	6586,30	12,83	24,25	65133,70	665,84	6,51	8,38	9,31	842,30	41,96	0,08	0,11	13718,10	165,94	1,37	1,92	51153,36	537,11	5,12	6,16
4.3.2016	11.26.58	#92	17	387857,09	4126,90	38,79	82,97	5907,43	197,97	0,59	0,99	111468,95	6321,21	11,15	21,06	63879,50	624,80	6,39	8,22	9,13	1416,74	51,02	0,14	0,18	24493,92	253,32	2,45	3,43	50718,59	509,38	5,07	6,11
4.3.2016	11.29.03	#93	18	304181,55	4059,67	30,42	65,07	4478,30	182,42	0,45	0,75	60433,47	7351,41	6,04	11,42	55904,35	615,01	5,59	7,19	7,99	1649,36	56,86	0,16	0,21	23241,55	267,23	2,32	3,25	57921,05	638,09	5,79	6,98
4.3.2016	11.30.37	#94	19	369425,74	4189,79	36,94	79,03	5640,68	195,58	0,56	0,94	94388,04	6813,39	9,44	17,83	58257,93	599,23	5,83	7,49	8,33	998,14	44,20	0,10	0,13	13129,84	161,35	1,31	1,84	64630,37	663,06	6,46	7,79
4.3.2016	11.32.30	#95	20	340476,53	4515,98	34,05	72,83	5441,80	210,56	0,54	0,91	107493,65	7852,57	10,75	20,31	66470,07	761,91	6,65	8,55	9,50	931,16	47,28	0,09	0,12	14053,19	191,51	1,41	1,97	78583,77	894,51	7,86	9,47
4.3.2016	11.34.30	#96	21	331057,74	4135,97	33,11	70,82	5354,13	198,22	0,54	0,89	109141,40	6935,79	10,91	20,62	66338,53	697,96	6,63	8,53	9,48	1178,22	49,48	0,12	0,15	10761,80	145,14	1,08	1,51	59863,65	638,29	5,99	7,21
4.3.2016	11.36.28	#97	22	396663,08	3999,13	39,67	84,85	4257,08	172,19	0,43	0,71	89808,51	5732,40	8,98	16,97	40729,12	399,22	4,07	5,24	5,82	618,11	35,88	0,06	0,08	9581,78	120,21	0,96	1,34	37436,70	378,06	3,74	4,51
4.3.2016	11.39.55	#98	23	303706,69	3490,66	30,37	64,97	3287,82	152,09	0,33	0,55	70586,62	5247,53	7,06	13,34	32197,83	317,38	3,22	4,14	4,60	478,87	32,34	0,05	0,06	3694,69	72,97	0,37	0,52	26298,42	277,29	2,63	3,17
4.3.2016	11.42.04	#99	24	382617,48	3874,16	38,26	81,85	5157,46	191,66	0,52	0,86	80821,05	5576,56	8,08	15,27	38488,87	375,48	3,85	4,95	5,50	373,85	31,21	0,04	0,05	16700,78	176,66	1,67	2,34	32530,20	333,53	3,25	3,92
4.3.2016	11.44.30	#100	25	345977,50	4095,41	34,60	74,01	4148,68	187,05	0,41	0,69	92088,31	6214,07	9,21	17,40	37395,48	401,55	3,74	4,81	5,35	644,02	40,25	0,06	0,08	2857,42	82,31	0,29	0,40	37902,86	416,98	3,79	4,57
4.3.2016	11.46.19	#101	26	358081,66	3468,94	35,81	76,60	5155,35	176,07	0,52	0,86	94182,77	5008,33	9,42	17,80	40858,44	362,43	4,09	5,26	5,84	626,84	34,72	0,06	0,08	20077,51	186,11	2,01	2,81	27006,86	261,61	2,70	3,25
4.3.2016	11.48.22	#102	27	322695,49	3648,86	32,27	69,03	3352,97	157,55	0,34	0,56	95594,87	5571,29	9,56	18,06	32748,73	328,94	3,27	4,21	4,68	424,46	32,21	0,04	0,05	5711,87	92,47	0,57	0,80	36446,39	369,65	3,64	4,39
4.3.2016	11.50.21	#103	28	313872,66	3905,85	31,39	67,14	4058,61	178,51	0,41	0,68	68055,88	5983,72	6,81	12,86	31216,61	339,57	3,12	4,02	4,46	450,97	34,00	0,05	0,06	28974,24	300,30	2,90	4,05	25235,04	291,56	2,52	3,04
4.3.2016	11.52.17	#104	29	301846,62	4092,06	30,18	64,57	4140,02	179,32	0,41	0,69	67373,93	6911,51	6,74	12,73	38121,23	429,99	3,81	4,90	5,45	891,62	43,38	0,09	0,12	22080,28	252,03	2,21	3,09	37562,97	429,53	3,76	4,52
4.3.2016	11.54.05	#105	30	332071,09	4215,93	33,21	71,04	4941,67	193,96	0,49	0,82	72150,95	6630,62	7,22	13,63	35450,90	397,91	3,55	4,56	5,07	590,12	37,20	0,06	0,08	10329,30	137,19	1,03	1,45	34810,26	399,05	3,48	4,19
4.3.2016	11.56.13	#106	31	269226,55	3330,89	26,92	57,59	3066,32	146,51	0,31	0,51	58316,73	5288,48	5,83	11,02	25981,54	264,37	2,60	3,34	3,71	391,37	29,38	0,04	0,05	11778,32	131,65	1,18	1,65	24159,48	258,04	2,42	2,91
4.3.2016	11.58.23	#107	32	442860,35	3660,08	44,29	94,74	5926,54	185,91	0,59	0,99	89367,83	5051,96	8,94	16,89	35657,69	316,38	3,57	4,59	5,10	455,15	29,96	0,05	0,06	6823,06	93,52	0,68	0,95	43601,21	383,15	4,36	5,25
4.3.2016	12.00.19	#108	33	459065,16	4081,03	45,91	98,20	6355,06	203,97	0,64	1,06	101225,02	5490,99	10,12	19,13	40903,24	389,05	4,09	5,26	5,85	869,85	40,68	0,09	0,11	4611,59	83,43	0,46	0,65	37047,11	363,96	3,70	4,46
4.3.2016	12.02.28	#109	34	274390,32	3313,00	27,44	58,70	3836,12	159,11	0,38	0,64	59974,85	5231,67	6,00	11,33	31620,79	308,88	3,16	4,07	4,52	382,13	29,43	0,04	0,05	18146,97	181,23	1,81	2,54	23962,46	252,76	2,40	2,89
4.3.2016	12.04.20	#110	35	393761,53	4045,79	39,38	84,23	5443,31	196,96	0,54	0,91	80510,48	5846,94	8,05	15,21	40064,13	400,24	4,01	5,15	5,73	443,00	32,87	0,04	0,06	25057,01	251,33	2,51	3,51	33986,29	353,43	3,40	4,09
4.3.2016	12.06.28	#111	36	347068,11	3586,08	34,71	74,24	3748,00	158,14	0,37	0,63	83218,34	5213,15	8,32	15,72	32342,90	308,59	3,23	4,16	4,62	476,62	31,26	0,05	0,06	10423,83	119,01	1,04	1,46	26960,40	273,13	2,70	3,25
4.3.2016	12.08.29	#112	37	445576,19	3673,86	44,56	95,32	5035,13	179,26	0,50	0,84	90646,50	4883,60	9,06	17,13	32485,01	294,46	3,25	4,18	4,64	491,01	32,10	0,05	0,06	5655,73	86,90	0,57	0,79	32926,86	306,68	3,29	3,97
4.3.2016	13.26.58	#121	38	422188,10	4576,65	42,22	90,31	5303,95	208,77	0,53	0,88	92759,54	6511,58	9,28	17,53	42717,32	464,79	4,27	5,50	6,11	996,30	47,84	0,10	0,13	11754,25	152,48	1,18	1,64	38404,73	430,24	3,84	4,63
4.3.2016	13.29.30	#122	39	486627,56	4152,65	48,66	104,10	5096,66	188,63	0,51	0,85	105619,90	5509,97	10,56	19,96	47840,69	447,14	4,78	6,15	6,84	814,69	40,40	0,08	0,11	9330,37	118,35	0,93	1,31	39764,08	386,76	3,98	4,79
4.3.2016	13.31.11	#123	40	449850,37	4145,48	44,99	96,23	4294,69	178,74	0,43	0,72	81372,50	5594,74	8,14	15,38	31703,19	320,19	3,17	4,08	4,53	863,37	41,60	0,09	0,11	11787,25	137,25	1,18	1,65	33410,52	342,29	3,34	4,02
4.3.2016	13.32.42	#124	41	386747,89	4216,75	38,67	82,73	4608,96	182,49	0,46	0,77	87478,54	6157,32	8,75	16,53	51863,95	525,70	5,19	6,67	7,41	1126,66	47,21	0,11	0,15	11636,76	141,06	1,16	1,63	33450,44	361,84	3,35	4,03
4.3.2016	13.34.24	#125	42	326202,72	4600,20	32,62	69,78	5455,50	214,39	0,55	0,91	78206,62	7722,91	7,82	14,78	65625,94	773,12	6,56	8,44	9,38	855,31	46,66	0,09	0,11	16342,25	213,53	1,63	2,29	43907,23	537,65	4,39	5,29
4.3.2016	13.46.47	#130	43	356551,53	4162,34	35,66	76,27	5503,85	192,40	0,55	0,92	102558,02	6499,76	10,26	19,38	65685,71	668,09	6,57	8,45	9,39	954,82	43,38	0,10	0,12	10355,23	132,34	1,04	1,45	42333,19	450,77	4,23	5,10
4.3.2016	13.48.03	#131	44	380759,44	4327,58	38,08	81,45	5307,32	196,21	0,53	0,89	100799,45	6476,94	10,08	19,05	57813,38	599,94	5,78	7,44	8,27	707,71	39,95	0,07	0,09	8929,90	122,37	0,89	1,25	39533,43	430,51	3,95	4,76
4.3.2016	13.49.35	#132	45	346045,21	4938,94	34,60	74,03	5620,41	227,47	0,56	0,94	95185,63	8008,31	9,52	17,99	67153,82	823,86	6,72	8,64	9,60	815,18	47,96	0,08	0,11	10220,67	157,42	1,02	1,43	45661,67	581,97	4,57	5,50
4.3.2016	13.51.07	#133	46	425782,14	4654,65	42,58	91,08	3938,84	189,55	0,39	0,66	85500,13	6617,60	8,55	16,16	40749,28	452,99	4,07	5,24	5,83	708,77	42,68	0,07	0,09	10549,60	144,97	1,05	1,48	41153,26	464,42	4,12	4,96
4.3.2016	13.53.18	#134	47	322881,27	3768,90	32,29	69,07	3497,99	156,86	0,35	0,58	64015,61	5879,61	6,40	12,10	31270,38	322,23	3,13	4,02	4,47	927,89	40,91	0,09	0,12	22217,93	225,12	2,22	3,11	28941,53	307,20	2,89	3,49
4.3.2016	13.55.12	#135	48	367346,34	4623,27	36,73	78,58	3846,32	189,31	0,38	0,64	47919,04	6760,67	4,79	9,05	29843,67	360,23	2,98	3,84	4,27	727,53	42,94	0,07	0,09	12756,40	166,57	1,28	1,78	26503,36	335,41	2,65	3,19
4.3.2016	13.56.44	#136	49	402519,67	4642,64	40,25	86,11	5376,83	209,67	0,54	0,90	120274,32	6902,78	12,03	22,73	65177,46	704,04	6,52	8,39	9,32	858,30	45,90	0,09	0,11	14882,43	186,95	1,49	2,08	47644,56	533,43	4,76	5,74
4.3.2016	13.58.26	#137	50	420135,55	4616,32	42,01	89,88	6124,69	221,44	0,61	1,02	117789,38	6832,79	11,78	22,26	67193,20	710,05	6,72	8,64	9,61	1022,37	48,95	0,10	0,13	13733,17	175,56	1,37	1,92	55882,02	604,10	5,59	6,73
4.3.2016	14.00.44	#138	51	363515,48	4171,46	36,35	77,76	5784,53	201,41	0,58	0,96	119060,92	6550,33	11,91	22,50	63042,74	640,41	6,30	8,11	9,01	838,16	42,10	0,08	0,11	20542,93	226,18	2,05	2,87	50761,03	528,41	5,08	6,11
4.3.2016	14.02.10	#139	52	346440,57	4501,73	34,64	74,11	4358,33	191,82	0,44	0,73	80705,90	7232,53	8,07	15,25	48096,51	551,42	4,81	6,19	6,88	1100,12	50,00	0,11	0,14	19461,18	235,51	1,95	2,72	42729,05	499,51	4,27	5,15
4.3.2016	14.03.50	#140	53	363627,35	4225,89	36,36	77,79	5965,74	205,77	0,60	1,00	110202,95	6715,60	11,02	20,82	64719,02	666,40	6,47	8,33	9,25	841,70	42,68	0,08	0,11	30514,62	322,14	3,05	4,27	51135,56	538,71	5,11	6,16
4.3.2016	14.05.57	#141	54	288204,88	4732,65	28,82	61,65	5752,08	233,34	0,58	0,96	74489,81	8413,25	7,45	14,07	61780,79	796,73	6,18	7,95	8,83	985,32	52,73	0,10	0,13	23738,58	317,77	2,37	3,32	39363,23	529,50	3,94	4,74
4.3.2016	14:08:52	#142	55	309018,10	4798,74	30,90	66,11	6263,59	232,67	0,63	1,04	105864,59	8035,56	10,59	20,00	74455,28	922,73	7,45	9,58	10,64	879,84	48,59	0,09	0,11	7964,61	131,80	0,80	1,11	37894,31	499,39	3,79	4,56
4.3.2016	14:10:15	#143	56	415936,79	4820,57	41,59	88,98	5395,73	216,97	0,54	0,90	109764,03	7077,70	10,98	20,74	59693,06	665,80	5,97	7,68	8,53	719,04	44,22	0,07	0,09	10817,71	153,84	1,08	1,51	48802,54	559,98	4,88	5,88
4.3.2016	14.12.27	#144	57	383534,57	4417,46	38,35	82,05	6358,21	213,61	0,64	1,06	116223,73	6689,76	11,62	21,96	77259,46	800,02	7,73	9,94	11,05	1010,56	46,97	0,10	0,13	10920,83	143,12	1,09	1,53	43939,89	480,19	4,39	5,29
4.3.2016	14.16.32	#145	58	340229,32	4055,54	34,02	72,78	5173,10	185,59	0,52	0,86	119257,14	6486,54	11,93	22,53	59578,12	604,93	5,96	7,66	8,52	934,14	42,50	0,09	0,12	25255,54	266,32	2,53	3,53	43584,41	457,58	4,36	5,25
4.3.2016	14.19.04	#146	59	342914,32	4203,37	34,29	73,36	5214,10	191,12	0,52	0,87	113667,29	6730,35	11,37	21,48	56004,75	591,17	5,60	7,21	8,01	648,25	37,87	0,06	0,08	18593,63	212,14	1,86	2,60	44984,28	487,44	4,50	5,42
4.3.2016	14.22.59	#147	60	412303,18	4123,47	41,23	88,20	5008,67	186,27	0,50	0,84	102025,21	5915,19	10,20	19,28	51151,38	496,55	5,12	6,58	7,31	706,70	38,50	0,07	0,09	16178,06	175,64	1,62	2,26	39057,78	396,08	3,91	4,70
4.3.2016	14.24.30	#148	61	504427,61	4050,69	50,44	107,91	4771,59	182,14	0,48	0,80	93289,49	5296,54	9,33	17,63	34058,89	322,85	3,41	4,38	4,87	427,96	31,38	0,04	0,06	9299,59	116,22	0,93	1,30	41997,32	393,32	4,20	5,06
4.3.2016	14.26.16	#149	62	425904,60	4199,57	42,59	91,11	4908,65	187,08	0,49	0,82	107648,25	5948,97	10,76	20,34	45735,12	452,12	4,57	5,88	6,54	589,89	36,06	0,06	0,08	12088,71	144,02	1,21	1,69	41928,85	424,62	4,19	5,05
4.3.2016	14.28.04	#150	63	243602,14	3962,57	24,36	52,11	3238,38	180,17	0,32	0,54	50125,18	7414,52	5,01	9,47	27087,83	341,39	2,71	3,48	3,87	347,62	33,81	0,03	0,04	116970,89	1278,75	11,70	16,37	22279,71	285,15	2,23	2,68
4.3.2016	14.29.22	#151	64	464807,69	4187,39	46,48	99,43	4183,55	176,46	0,42	0,70	85344,70	5709,09	8,53	16,13	33769,01	337,45	3,38	4,34	4,83	475,41	33,22	0,05	0,06	9517,51	121,89	0,95	1,33	43987,82	431,18	4,40	5,30
4.3.2016	14.30.56	#152	65	369973,07	4973,29	37,00	79,14	5269,77	223,23	0,53	0,88	81727,07	7658,24	8,17	15,44	53378,90	650,13	5,34	6,87	7,63	587,68	42,40	0,06	0,08	6921,15	121,47	0,69	0,97	39892,79	506,67	3,99	4,81
4.3.2016	14.32.20	#153	66	373761,53	4144,57	37,38	79,96	4946,76	185,60	0,49	0,83	97657,59	6399,23	9,77	18,45	58864,00	590,63	5,89	7,57	8,42	549,85	35,44	0,05	0,07	18095,63	199,62	1,81	2,53	46429,03	479,89	4,64	5,59
4.3.2016	14.34.12	#154	67	190272,73	3331,36	19,03	40,70	3721,25	161,10	0,37	0,62	61182,87	6800,26	6,12	11,56	67662,69	723,85	6,77	8,70	9,67	616,56	36,33	0,06	0,08	31560,95	342,56	3,16	4,42	29461,67	341,90	2,95	3,55
4.3.2016	14.36.11	#155	68	367189,08	4108,99	36,72	78,55	5879,20	199,81	0,59	0,98	114025,15	6364,16	11,40	21,55	59369,02	593,68	5,94	7,64	8,49	677,54	38,25	0,07	0,09	27323,68	281,72	2,73	3,82	45070,20	464,95	4,51	5,43
4.3.2016	14.39.12	#156	69	355895,07	4380,56	35,59	76,13	5726,86	208,17	0,57	0,96	100125,57	6996,83	10,01	18,92	67098,12	720,66	6,71	8,63	9,59	682,37	40,63	0,07	0,09	20984,93	242,54	2,10	2,94	47715,91	529,85	4,77	5,75
4.3.2016	14.40.43	#157	70	294862,88	3541,70	29,49	63,08	3737,80	163,29	0,37	0,62	56696,13	5898,04	5,67	10,71	39247,93	388,32	3,92	5,05	5,61	420,49	31,06	0,04	0,05	46086,02	427,93	4,61	6,45	33059,87	337,08	3,31	3,98
4.3.2016	14.42.38	#158	71	359736,53	4034,86	35,97	76,95	5002,05	185,23	0,50	0,83	95088,47	6564,70	9,51	17,97	41580,19	429,19	4,16	5,35	5,94	659,77	36,80	0,07	0,09	17277,95	193,57	1,73	2,42	62447,85	625,01	6,24	7,52
4.3.2016	14.44.16	#159	72	295660,22	3833,32	29,57	63,25	4520,41	180,51	0,45	0,75	60936,58	6489,93	6,09	11,51	39047,43	417,08	3,90	5,02	5,58	545,10	34,85	0,05	0,07	45857,56	462,28	4,59	6,42	31061,51	343,25	3,11	3,74
4.3.2016	14.46.35	#160	73	363973,33	4263,03	36,40	77,86	4626,31	191,49	0,46	0,77	87039,82	6638,91	8,70	16,45	54483,91	573,16	5,45	7,01	7,79	807,09	43,08	0,08	0,10	29238,15	312,11	2,92	4,09	41969,31	456,96	4,20	5,06
4.3.2016	14.48.04	#161	74	443846,62	4161,62	44,38	94,95	4836,18	184,13	0,48	0,81	95200,15	5793,74	9,52	17,99	42048,48	410,54	4,20	5,41	6,01	700,51	37,91	0,07	0,09	11555,58	137,04	1,16	1,62	41930,13	415,77	4,19	5,05
4.3.2016	14.49.38	#162	75	430140,76	4082,91	43,01	92,02	4336,27	174,86	0,43	0,72	94487,57	5697,23	9,45	17,85	32506,27	325,39	3,25	4,18	4,65	487,96	32,66	0,05	0,06	15381,20	165,43	1,54	2,15	37631,26	375,36	3,76	4,53
17.3.2016	9.16.51	#2	77	432948,48		43,29	43,29	3984,39		0,40	0,66	82997,40		8,30	15,68	32712,22		3,27	4,21	4,68	1206,41		0,12	0,16	86170,77		8,62	12,06	23415,31		2,34	2,82
17.3.2016	9.19.58	#3	78	345415,11		34,54	34,54	3383,37		0,34	0,56	37816,43		3,78	7,15	20706,31		2,07	2,66	2,96	1617,58		0,16	0,21	75887,15		7,59	10,62	12745,44		1,27	1,54

Date	Time	Reading	Id	P	P +/-	P%	P2O5	V	V +/-	V%	Ni	Ni +/-	Ni%	Cu	Cu +/-	Cu%	Zn	Zn +/-	Zn%	As	As +/-	As%	S	S +/-	S%	Cl	Cl +/-	Cl%	Zr	Zr +/-	Zr%	Nb	Nb +/-
4.3.2016	10.57.08	#76	1	3880,35	490,79	0,39	0,89	522	76	0	314	24	0	121	11	0	298	9	0	ND		ND	2058	243	0	ND		ND	197	4	0		
4.3.2016	11.01.51	#77	2	18165,77	694,07	1,82	4,16	547	69	0	363	24	0	ND		ND	267	9	0	ND		ND	ND		ND	ND		ND	280	4	0		
4.3.2016	11.03.22	#78	3	20384,62	762,30	2,04	4,67	907	81	0	292	24	0	48	9	0	628	14	0	ND		ND	2826	261	0	ND		ND	290	5	0		
4.3.2016	11.05.02	#79	4	19185,41	731,59	1,92	4,40	718	76	0	341	25	0	49	10	0	387	11	0	ND		ND	ND		ND	ND		ND	230	4	0		
4.3.2016	11.06.41	#80	5	34082,22	920,17	3,41	7,81	640	76	0	312	25	0	ND		ND	291	10	0	ND		ND	1771	236	0	ND		ND	194	4	0		
4.3.2016	11.08.19	#81	6	17367,51	691,69	1,74	3,98	814	77	0	358	24	0	ND		ND	563	13	0	ND		ND	2438	242	0	ND		ND	265	4	0		
4.3.2016	11.09.59	#82	7	3686,29	470,46	0,37	0,84	499	75	0	372	27	0	ND		ND	235	9	0	ND		ND	5945	314	1	ND		ND	200	4	0		
4.3.2016	11.12.00	#83	8	4639,86	460,90	0,46	1,06	583	74	0	294	24	0	ND		ND	315	10	0	ND		ND	ND		ND	ND		ND	224	4	0		
4.3.2016	11.13.33	#84	9	5056,54	523,03	0,51	1,16	801	79	0	298	24	0	74	10	0	233	8	0	ND		ND	2377	250	0	ND		ND	165	3	0		
4.3.2016	11.14.59	#85	10	5166,45	503,61	0,52	1,18	592	72	0	309	24	0	166	12	0	229	8	0	ND		ND	1667	223	0	ND		ND	202	4	0		
4.3.2016	11.16.21	#86	11	17179,66	719,77	1,72	3,94	481	72	0	367	26	0	67	10	0	217	8	0	ND		ND	2658	256	0	ND		ND	176	4	0		
4.3.2016	11.18.08	#87	12	13112,84	673,73	1,31	3,00	480	70	0	263	24	0	ND		ND	185	8	0	ND		ND	14817	439	1	ND		ND	179	4	0		
4.3.2016	11.19.54	#88	13	3312,24	462,31	0,33	0,76	687	77	0	309	24	0	74	10	0	207	8	0	ND		ND	2930	255	0	ND		ND	199	4	0		
4.3.2016	11.21.52	#89	14	3175,53	453,68	0,32	0,73	425	65	0	318	22	0	ND		ND	225	7	0	ND		ND	52934	744	5	ND		ND	234	4	0		
4.3.2016	11.23.44	#90	15	5079,22	515,44	0,51	1,16	616	74	0	279	23	0	ND		ND	193	7	0	ND		ND	12567	398	1	ND		ND	228	4	0		
4.3.2016	11.25.23	#91	16	3506,93	477,59	0,35	0,80	743	80	0	322	25	0	ND		ND	204	8	0	ND		ND	1690	236	0	ND		ND	171	4	0		
4.3.2016	11.26.58	#92	17	10857,04	644,45	1,09	2,49	828	80	0	336	25	0	129	11	0	487	12	0	ND		ND	ND		ND	ND		ND	169	4	0		
4.3.2016	11.29.03	#93	18	18510,90	744,89	1,85	4,24	557	73	0	309	26	0	397	17	0	690	16	0	ND		ND	11074	391	1	ND		ND	235	4	0		
4.3.2016	11.30.37	#94	19	1681,01	412,95	0,17	0,39	509	73	0	280	25	0	134	12	0	937	18	0	ND		ND	6838	318	1	ND		ND	259	4	0		
4.3.2016	11.32.30	#95	20	2971,97	479,25	0,30	0,68	656	83	0	265	27	0	69	13	0	361	12	0	189	21	0	15727	478	2	ND		ND	199	4	0		
4.3.2016	11.34.30	#96	21	1755,63	407,86	0,18	0,40	527	76	0	295	27	0	ND		ND	405	12	0	559	37	0	40198	730	4	555	39	0	203	4	0		
4.3.2016	11.36.28	#97	22	3104,79	435,54	0,31	0,71	501	70	0	280	24	0	ND		ND	139	7	0	695	37	0	23641	536	2	610	38	0	287	5	0		
4.3.2016	11.39.55	#98	23	ND		ND	ND	305	62	0	163	23	0	ND		ND	141	7	0	2918	63	0	106864	1229	11	2334	59	0	191	4	0		
4.3.2016	11.42.04	#99	24	ND		ND	ND	299	70	0	238	24	0	ND		ND	82	6	0	980	36	0	67442	952	7	1202	49	0	244	4	0		
4.3.2016	11.44.30	#100	25	ND		ND	ND	346	73	0	231	26	0	ND		ND	135	7	0	1456	50	0	89946	1229	9	2480	67	0	187	4	0		
4.3.2016	11.46.19	#101	26	1544,32	406,79	0,15	0,35	251	64	0	307	23	0	ND		ND	204	8	0	1481	45	0	77098	938	8	2416	54	0	242	4	0		
4.3.2016	11.48.22	#102	27	1388,12	350,33	0,14	0,32	283	64	0	168	24	0	ND		ND	105	7	0	2632	68	0	94286	1149	9	1787	54	0	158	4	0		
4.3.2016	11.50.21	#103	28	4207,46	546,19	0,42	0,96	360	71	0	224	25	0	ND		ND	112	7	0	1448	49	0	53897	868	5	989	46	0	204	4	0		
4.3.2016	11.52.17	#104	29	12712,36	688,23	1,27	2,91	535	74	0	229	24	0	77	10	0	254	9	0	ND		ND	13523	441	1	ND		ND	202	4	0		
4.3.2016	11.54.05	#105	30	ND		ND	ND	385	73	0	206	24	0	ND		ND	127	7	0	475	28	0	21373	545	2	461	38	0	285	5	0		
4.3.2016	11.56.13	#106	31	2326,72	380,66	0,23	0,53	426	63	0	182	21	0	ND		ND	87	5	0	1631	42	0	111239	1258	11	2229	57	0	198	4	0		
4.3.2016	11.58.23	#107	32	2652,20	390,56	0,27	0,61	703	75	0	261	21	0	160	13	0	146	6	0	ND		ND	39276	642	4	416	35	0	289	4	0		
4.3.2016	12.00.19	#108	33	4937,63	468,41	0,49	1,13	452	74	0	243	23	0	ND		ND	120	6	0	ND		ND	ND		ND	ND		ND	297	4	0		
4.3.2016	12.02.28	#109	34	2304,29	401,78	0,23	0,53	361	64	0	147	21	0	ND		ND	78	5	0	1819	46	0	108794	1222	11	2500	59	0	207	4	0		
4.3.2016	12.04.20	#110	35	5394,59	570,66	0,54	1,24	389	73	0	259	23	0	ND		ND	98	6	0	312	20	0	24585	565	2	ND		ND	225	4	0		
4.3.2016	12.06.28	#111	36	5116,84	451,70	0,51	1,17	351	63	0	270	22	0	ND		ND	130	6	0	1208	36	0	71649	935	7	1249	46	0	237	4	0		
4.3.2016	12.08.29	#112	37	1161,57	363,73	0,12	0,27	442	70	0	234	22	0	ND		ND	91	5	0	652	39	0	60359	834	6	726	41	0	348	5	0		
4.3.2016	13.26.58	#121	38	ND		ND	ND	470	79	0	227	25	0	ND		ND	124	7	0	ND		ND	ND		ND	ND		ND	363	6	0		
4.3.2016	13.29.30	#122	39	1488,79	424,32	0,15	0,34	480	73	0	339	24	0	ND		ND	116	6	0	ND		ND	ND		ND	ND		ND	350	5	0		
4.3.2016	13.31.11	#123	40	ND		ND	ND	495	73	0	222	22	0	ND		ND	92	5	0	ND		ND	6302	326	1	ND		ND	467	6	0		
4.3.2016	13.32.42	#124	41	2182,29	441,80	0,22	0,50	349	68	0	226	23	0	ND		ND	167	7	0	ND		ND	3001	262	0	ND		ND	347	5	0		
4.3.2016	13.34.24	#125	42	ND		ND	ND	435	79	0	252	27	0	ND		ND	177	9	0	ND		ND	7665	374	1	ND		ND	171	4	0		
4.3.2016	13.46.47	#130	43	1278,98	392,84	0,13	0,29	444	71	0	324	25	0	ND		ND	153	7	0	ND		ND	3122	253	0	ND		ND	196	4	0		
4.3.2016	13.48.03	#131	44	1646,74	415,22	0,16	0,38	481	74	0	300	25	0	ND		ND	141	7	0	ND		ND	ND		ND	ND		ND	196	4	0		
4.3.2016	13.49.35	#132	45	ND		ND	ND	405	82	0	235	28	0	ND		ND	182	9	0	ND		ND	ND		ND	ND		ND	173	4	0		
4.3.2016	13.51.07	#133	46	1813,80	481,07	0,18	0,42	495	78	0	273	26	0	ND		ND	121	7	0	ND		ND	2344	282	0	ND		ND	259	5	0		
4.3.2016	13.53.18	#134	47	ND		ND	ND	373	63	0	229	21	0	ND		ND	101	5	0	ND		ND	31327	607	3	ND		ND	293	4	0		
4.3.2016	13.55.12	#135	48	ND		ND	ND	386	75	0	211	25	0	ND		ND	79	6	0	ND		ND	ND		ND	ND		ND	340	6	0		
4.3.2016	13.56.44	#136	49	ND		ND	ND	701	84	0	290	27	0	ND		ND	156	8	0	ND		ND	ND		ND	ND		ND	194	4	0		
4.3.2016	13.58.26	#137	50	ND		ND	ND	517	82	0	315	27	0	ND		ND	166	8	0	ND		ND	7186	365	1	ND		ND	171	4	0		
4.3.2016	14.00.44	#138	51	1453,69	461,19	0,15	0,33	631	78	0	328	25	0	ND		ND	283	10	0	ND		ND	18618	490	2	ND		ND	178	4	0		
4.3.2016	14.02.10	#139	52	ND		ND	ND	427	74	0	225	25	0	ND		ND	116	7	0	ND		ND	ND		ND	ND		ND	187	4	0		
4.3.2016	14.03.50	#140	53	2340,42	527,28	0,23	0,54	450	75	0	345	26	0	ND		ND	176	8	0	ND		ND	3532	282	0	ND		ND	222	4	0		
4.3.2016	14.05.57	#141	54	ND		ND	ND	474	86	0	331	30	0	ND		ND	179	9	0	ND		ND	8662	415	1	ND		ND	172	4	0		
4.3.2016	14:08:52	#142	55	ND		ND	ND	651	87	0	233	28	0	ND		ND	198	10	0	ND		ND	ND		ND	ND		ND	196	5	0		
4.3.2016	14:10:15	#143	56	ND		ND	ND	509	83	0	301	28	0	ND		ND	154	8	0	ND		ND	ND		ND	ND		ND	176	4	0		
4.3.2016	14.12.27	#144	57	1613,68	432,63	0,16	0,37	685	81	0	333	27	0	ND		ND	182	8	0	ND		ND	ND		ND	ND		ND	182	4	0		
4.3.2016	14.16.32	#145	58	6033,71	558,18	0,60	1,38	615	73	0	313	24	0	ND		ND	149	7	0	ND		ND	ND		ND	ND		ND	139	3	0		
4.3.2016	14.19.04	#146	59	2048,46	465,08	0,20	0,47	442	71	0	333	25	0	ND		ND	150	7	0	ND		ND	ND		ND	ND		ND	150	3	0		
4.3.2016	14.22.59	#147	60	13718,39	680,38	1,37	3,14	597	74	0	312	24	0	ND		ND	133	6	0	ND		ND	ND		ND	ND		ND	309	5	0		
4.3.2016	14.24.30	#148	61	ND		ND	ND	421	70	0	251	22	0	ND		ND	104	6	0	ND		ND	ND		ND	ND		ND	326	5	0		
4.3.2016	14.26.16	#149	62	5072,67	515,03	0,51	1,16	461	72	0	303	24	0	ND		ND	130	6	0	ND		ND	5401	310	1	ND		ND	294	5	0		
4.3.2016	14.28.04	#150	63	ND		ND	ND	446	77	0	217	25	0	ND		ND	73	5	0	ND		ND	ND		ND	ND		ND	257	5	0		
4.3.2016	14.29.22	#151	64	1765,45	431,99	0,18	0,40	431	70	0	247	23	0	ND		ND	254	8	0	ND		ND	ND		ND	ND		ND	301	5	0		
4.3.2016	14.30.56	#152	65	ND		ND	ND	470	84	0	251	28	0	ND		ND	135	8	0	ND		ND	ND		ND	ND		ND	204	5	0		
4.3.2016	14.32.20	#153	66	8259,65	582,44	0,83	1,89	505	72	0	323	24	0	82	10	0	183	8	0	ND		ND	4051	281	0	ND		ND	165	4	0		
4.3.2016	14.34.12	#154	67	55110,94	1144,11	5,51	12,63	524	66	0	276	24	0	ND		ND	155	7	0	145	19	0	22406	524	2	336	32	0	156	4	0		
4.3.2016	14.36.11	#155	68	4449,93	546,63	0,44	1,02	446	73	0	284	24	0	ND		ND	357	11	0	ND		ND	5781	311	1	ND		ND	183	4	0		
4.3.2016	14.39.12	#156	69	4722,35	553,97	0,47	1,08	597	80	0	302	26	0	ND		ND	160	8	0	ND		ND	3570	287	0	ND		ND	169	4	0		
4.3.2016	14.40.43	#157	70	16296,29	719,66	1,63	3,73	431	66	0	276	22	0	ND		ND	119	6	0	ND		ND	51351	782	5	526	36	0	174	3	0		
4.3.2016	14.42.38	#158	71	16568,81	692,23	1,66	3,80	311	67	0	291	23	0	68	9	0	455	12	0	ND		ND	7876	335	1	ND		ND	217	4	0		
4.3.2016	14.44.16	#159	72	11070,52	706,90	1,11	2,54	491	72	0	303	23	0	ND		ND	231	8	0	ND		ND	6075	321	1	ND		ND	239	4	0		
4.3.2016	14.46.35	#160	73	18679,65	817,65	1,87	4,28	519	76	0	299	25	0	ND		ND	270	10	0	ND		ND	6166	343	1	ND		ND	196	4	0		
4.3.2016	14.48.04	#161	74	4656,42	502,36	0,47	1,07	530	73	0	241	22	0	ND		ND	134	6	0	ND		ND	ND		ND	ND		ND	278	4	0		
4.3.2016	14.49.38	#162	75	4577,60	512,62	0,46	1,05	496	71	0	284	22	0	ND		ND	123	6	0	ND		ND	ND		ND	ND		ND	270	4	0		
17.3.2016	9.16.51	#2	77					387		0	280		0				84		0				6198		1				307				
17.3.2016	9.19.58	#3	78					314		0	214		0				61		0				2540		0				277				

Date	Time	Reading	Id	Nb%	Mo	Mo +/-	Mo%	Sn	Sn +/-	Sn%	Sb	Sb +/-	Sb%	Pb	Pb +/-	Pb%	Bi	Bi +/-	Bi%	Cd	Cd +/-	Cd%	Co	Co +/-	Co%	Ag	Ag +/-	Ag%	Hf	Hf +/-	Hf%	W	W +/-
4.3.2016	10.57.08	#76	1	0	ND		ND	104	6	0	164	8	0	33	3	0	50	4	0	91	10	0	ND		ND	ND		ND	53	10	0	ND	
4.3.2016	11.01.51	#77	2	0	ND		ND	112	6	0	183	8	0	44	3	0	54	4	0	122	10	0	ND		ND	ND		ND	55	9	0	ND	
4.3.2016	11.03.22	#78	3	0	ND		ND	115	6	0	194	8	0	38	3	0	55	4	0	118	10	0	ND		ND	ND		ND	ND		ND	56	10
4.3.2016	11.05.02	#79	4	0	ND		ND	122	6	0	183	8	0	38	3	0	61	4	0	112	10	0	ND		ND	ND		ND	54	10	0	ND	
4.3.2016	11.06.41	#80	5	0	ND		ND	111	6	0	180	9	0	44	3	0	56	4	0	101	11	0	ND		ND	ND		ND	54	10	0	ND	
4.3.2016	11.08.19	#81	6	0	ND		ND	110	6	0	185	8	0	42	3	0	48	3	0	127	10	0	ND		ND	ND		ND	46	9	0	ND	
4.3.2016	11.09.59	#82	7	0	ND		ND	122	7	0	173	9	0	41	3	0	64	4	0	101	11	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	11.12.00	#83	8	0	ND		ND	116	6	0	181	8	0	46	3	0	51	4	0	94	10	0	ND		ND	ND		ND	52	9	0	ND	
4.3.2016	11.13.33	#84	9	0	ND		ND	116	6	0	188	8	0	43	3	0	42	3	0	116	10	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	11.14.59	#85	10	0	ND		ND	101	6	0	179	8	0	37	3	0	53	4	0	93	10	0	ND		ND	ND		ND	59	11	0	ND	
4.3.2016	11.16.21	#86	11	0	ND		ND	97	6	0	171	9	0	44	3	0	57	4	0	88	11	0	ND		ND	ND		ND	54	10	0	ND	
4.3.2016	11.18.08	#87	12	0	ND		ND	101	6	0	166	8	0	36	3	0	44	4	0	111	10	0	ND		ND	ND		ND	56	10	0	ND	
4.3.2016	11.19.54	#88	13	0	ND		ND	109	6	0	193	8	0	37	3	0	50	4	0	110	10	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	11.21.52	#89	14	0	ND		ND	122	5	0	171	7	0	32	3	0	45	3	0	103	9	0	ND		ND	ND		ND	48	8	0	ND	
4.3.2016	11.23.44	#90	15	0	ND		ND	120	6	0	179	8	0	35	3	0	48	4	0	129	10	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	11.25.23	#91	16	0	ND		ND	117	6	0	193	9	0	35	3	0	62	4	0	109	11	0	ND		ND	ND		ND	63	10	0	ND	
4.3.2016	11.26.58	#92	17	0	ND		ND	121	6	0	194	8	0	54	4	0	46	4	0	116	10	0	ND		ND	ND		ND	ND		ND	54	10
4.3.2016	11.29.03	#93	18	0	ND		ND	119	7	0	193	9	0	2642	35	0	70	7	0	122	11	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	11.30.37	#94	19	0	ND		ND	107	6	0	181	9	0	1014	17	0	65	5	0	100	10	0	ND		ND	ND		ND	ND		ND	64	12
4.3.2016	11.32.30	#95	20	0	ND		ND	113	7	0	182	9	0	1401	23	0	71	6	0	118	12	0	ND		ND	ND		ND	125	19	0	ND	
4.3.2016	11.34.30	#96	21	0	ND		ND	124	7	0	202	9	0	4644	55	0	90	9	0	132	11	0	ND		ND	ND		ND	148	26	0	ND	
4.3.2016	11.36.28	#97	22	0	ND		ND	112	6	0	183	8	0	5632	58	1	70	8	0	132	10	0	ND		ND	ND		ND	133	25	0	ND	
4.3.2016	11.39.55	#98	23	0	ND		ND	118	6	0	157	9	0	14883	136	1	133	13	0	147	11	0	ND		ND	ND		ND	651	41	0	ND	
4.3.2016	11.42.04	#99	24	0	ND		ND	112	6	0	149	8	0	4865	51	0	ND		ND	114	10	0	ND		ND	ND		ND	255	26	0	ND	
4.3.2016	11.44.30	#100	25	0	ND		ND	129	7	0	212	9	0	8070	86	1	ND		ND	160	11	0	ND		ND	ND		ND	267	33	0	ND	
4.3.2016	11.46.19	#101	26	0	ND		ND	129	6	0	183	8	0	8860	78	1	76	10	0	143	10	0	ND		ND	ND		ND	414	32	0	ND	
4.3.2016	11.48.22	#102	27	0	ND		ND	144	7	0	164	9	0	18271	169	2	178	15	0	149	11	0	ND		ND	ND		ND	491	44	0	ND	
4.3.2016	11.50.21	#103	28	0	ND		ND	134	7	0	188	9	0	8357	88	1	80	11	0	142	11	0	ND		ND	ND		ND	288	33	0	ND	
4.3.2016	11.52.17	#104	29	0	ND		ND	90	6	0	163	9	0	151	6	0	40	4	0	118	11	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	11.54.05	#105	30	0	ND		ND	121	7	0	177	9	0	2836	36	0	51	7	0	124	11	0	ND		ND	ND		ND	106	20	0	ND	
4.3.2016	11.56.13	#106	31	0	ND		ND	98	6	0	150	8	0	7098	69	1	66	9	0	116	10	0	ND		ND	ND		ND	390	29	0	ND	
4.3.2016	11.58.23	#107	32	0	ND		ND	102	5	0	165	7	0	3074	31	0	59	6	0	117	9	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	12.00.19	#108	33	0	ND		ND	114	6	0	176	8	0	190	6	0	36	3	0	112	10	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	12.02.28	#109	34	0	ND		ND	99	6	0	137	8	0	8439	80	1	92	10	0	114	10	0	ND		ND	ND		ND	446	32	0	ND	
4.3.2016	12.04.20	#110	35	0	ND		ND	87	6	0	143	8	0	1512	21	0	36	5	0	87	10	0	ND		ND	ND		ND	112	16	0	ND	
4.3.2016	12.06.28	#111	36	0	ND		ND	131	6	0	198	8	0	5363	52	1	76	8	0	140	10	0	ND		ND	ND		ND	324	26	0	ND	
4.3.2016	12.08.29	#112	37	0	ND		ND	119	6	0	189	8	0	7379	65	1	77	9	0	135	10	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	13.26.58	#121	38	0	ND		ND	99	7	0	161	9	0	33	3	0	50	4	0	79	11	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	13.29.30	#122	39	0	ND		ND	119	7	0	196	8	0	28	3	0	43	3	0	118	10	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	13.31.11	#123	40	0	ND		ND	121	7	0	161	8	0	28	3	0	38	3	0	120	10	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	13.32.42	#124	41	0	ND		ND	126	7	0	185	9	0	59	4	0	47	4	0	116	11	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	13.34.24	#125	42	0	ND		ND	129	8	0	173	10	0	40	4	0	55	4	0	92	12	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	13.46.47	#130	43	0	ND		ND	134	7	0	214	9	0	45	3	0	54	4	0	144	11	0	ND		ND	ND		ND	62	10	0	ND	
4.3.2016	13.48.03	#131	44	0	ND		ND	135	7	0	180	9	0	41	3	0	46	4	0	122	11	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	13.49.35	#132	45	0	ND		ND	107	8	0	190	10	0	42	4	0	49	4	0	100	13	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	13.51.07	#133	46	0	ND		ND	127	8	0	182	9	0	29	3	0	33	4	0	104	11	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	13.53.18	#134	47	0	ND		ND	123	6	0	180	8	0	24	3	0	22	3	0	105	10	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	13.55.12	#135	48	0	ND		ND	132	8	0	188	9	0	20	3	0	28	3	0	136	12	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	13.56.44	#136	49	0	ND		ND	130	8	0	172	9	0	36	3	0	48	4	0	111	12	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	13.58.26	#137	50	0	ND		ND	123	8	0	179	9	0	44	4	0	56	4	0	96	11	0	ND		ND	ND		ND	61	11	0	ND	
4.3.2016	14.00.44	#138	51	0	ND		ND	123	7	0	197	9	0	44	3	0	50	4	0	116	11	0	ND		ND	ND		ND	65	10	0	ND	
4.3.2016	14.02.10	#139	52	0	ND		ND	119	8	0	186	9	0	42	4	0	40	4	0	129	12	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14.03.50	#140	53	0	ND		ND	145	7	0	193	9	0	47	4	0	51	4	0	121	11	0	ND		ND	ND		ND	56	10	0	ND	
4.3.2016	14.05.57	#141	54	0	ND		ND	138	9	0	212	11	0	34	4	0	59	5	0	139	13	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14:08:52	#142	55	0	ND		ND	80	8	0	125	10	0	42	4	0	60	5	0	ND		ND	ND		ND	ND		ND	81	13	0	ND	
4.3.2016	14:10:15	#143	56	0	ND		ND	138	8	0	184	10	0	37	4	0	55	4	0	107	12	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14.12.27	#144	57	0	ND		ND	131	8	0	183	9	0	42	3	0	56	4	0	103	11	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14.16.32	#145	58	0	ND		ND	126	7	0	193	8	0	39	3	0	51	4	0	134	10	0	ND		ND	ND		ND	54	9	0	ND	
4.3.2016	14.19.04	#146	59	0	ND		ND	121	7	0	172	9	0	36	3	0	54	4	0	114	11	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14.22.59	#147	60	0	ND		ND	137	7	0	184	8	0	49	3	0	39	3	0	118	10	0	ND		ND	ND		ND	50	9	0	ND	
4.3.2016	14.24.30	#148	61	0	ND		ND	111	6	0	169	8	0	44	3	0	38	3	0	114	10	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14.26.16	#149	62	0	ND		ND	136	7	0	196	8	0	655	12	0	46	4	0	121	10	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14.28.04	#150	63	0	ND		ND	154	8	0	200	10	0	34	3	0	27	4	0	128	12	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14.29.22	#151	64	0	ND		ND	125	7	0	191	8	0	32	3	0	33	3	0	117	10	0	ND		ND	ND		ND	46	9	0	ND	
4.3.2016	14.30.56	#152	65	0	ND		ND	127	8	0	189	10	0	35	4	0	49	4	0	104	12	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14.32.20	#153	66	0	ND		ND	116	7	0	187	9	0	62	4	0	50	4	0	118	11	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14.34.12	#154	67	0	ND		ND	127	7	0	186	9	0	1301	21	0	55	5	0	98	11	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14.36.11	#155	68	0	ND		ND	147	7	0	189	9	0	186	6	0	46	4	0	131	11	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14.39.12	#156	69	0	ND		ND	121	8	0	190	9	0	140	6	0	57	4	0	123	11	0	ND		ND	ND		ND	58	11	0	ND	
4.3.2016	14.40.43	#157	70	0	ND		ND	131	7	0	184	8	0	337	8	0	38	4	0	98	10	0	ND		ND	ND		ND	53	10	0	ND	
4.3.2016	14.42.38	#158	71	0	ND		ND	124	7	0	186	8	0	33	3	0	36	3	0	121	10	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14.44.16	#159	72	0	ND		ND	124	7	0	181	8	0	48	3	0	32	3	0	118	10	0	ND		ND	ND		ND	47	9	0	ND	
4.3.2016	14.46.35	#160	73	0	ND		ND	128	7	0	192	9	0	52	4	0	46	4	0	117	11	0	ND		ND	ND		ND	ND		ND	ND	
4.3.2016	14.48.04	#161	74	0	ND		ND	107	7	0	180	8	0	36	3	0	36	3	0	86	10	0	ND		ND	ND		ND	56	9	0	ND	
4.3.2016	14.49.38	#162	75	0	ND		ND	130	7	0	193	8	0	30	3	0	30	3	0	104	10	0	ND		ND	ND		ND	ND		ND	ND	
17.3.2016	9.16.51	#2	77					105		0	175		0	37		0	38		0	98		0							48				
17.3.2016	9.19.58	#3	78					97		0	162		0	26		0			0	93		0											

Date	Time	Reading	Id	W%	Au	Au +/-	Au%	Rh	Rh +/-	Rh%	Pd	Pd +/-	Pd%	Ir	Ir +/-	Ir%	LE	LE +/-	Light elements%
4.3.2016	10.57.08	#76	1	ND			0			0			0			0	288940,48	3166,28	28,89
4.3.2016	11.01.51	#77	2	ND			0			0			0			0	294982,98	3141,60	29,50
4.3.2016	11.03.22	#78	3	0			0			0			0			0	337333,79	3623,79	33,73
4.3.2016	11.05.02	#79	4	ND			0			0			0			0	376028,35	4008,94	37,60
4.3.2016	11.06.41	#80	5	ND			0			0			0			0	407692,88	4569,56	40,77
4.3.2016	11.08.19	#81	6	ND			0			0			0			0	344569,22	3575,22	34,46
4.3.2016	11.09.59	#82	7	ND			0			0			0			0	331065,27	3865,89	33,11
4.3.2016	11.12.00	#83	8	ND			0			0			0			0	307851,42	3352,41	30,79
4.3.2016	11.13.33	#84	9	ND			0			0			0			0	362885,28	3908,99	36,29
4.3.2016	11.14.59	#85	10	ND			0			0			0			0	428944,16	4274,61	42,89
4.3.2016	11.16.21	#86	11	ND			0			0			0			0	372113,56	4188,49	37,21
4.3.2016	11.18.08	#87	12	ND			0			0			0			0	477327,05	4861,80	47,73
4.3.2016	11.19.54	#88	13	ND			0			0			0			0	380593,79	3938,69	38,06
4.3.2016	11.21.52	#89	14	ND			0			0			0			0	387291,48	3555,38	38,73
4.3.2016	11.23.44	#90	15	ND			0			0			0			0	404142,98	4066,43	40,41
4.3.2016	11.25.23	#91	16	ND			0			0			0			0	355894,75	4000,99	35,59
4.3.2016	11.26.58	#92	17	0			0			0			0			0	340865,20	3732,85	34,09
4.3.2016	11.29.03	#93	18	ND			0			0			0			0	457272,68	4949,77	45,73
4.3.2016	11.30.37	#94	19	0			0			0			0			0	381360,62	4171,34	38,14
4.3.2016	11.32.30	#95	20	ND			0			0			0			0	364102,15	4559,07	36,41
4.3.2016	11.34.30	#96	21	ND			0			0			0			0	366467,42	4268,56	36,65
4.3.2016	11.36.28	#97	22	ND			0			0			0			0	385384,85	3909,16	38,54
4.3.2016	11.39.55	#98	23	ND			0			0			0			0	430743,83	4141,86	43,07
4.3.2016	11.42.04	#99	24	ND			0			0			0			0	367326,55	3781,86	36,73
4.3.2016	11.44.30	#100	25	ND			0			0			0			0	375369,05	4246,76	37,54
4.3.2016	11.46.19	#101	26	ND			0			0			0			0	360661,69	3481,07	36,07
4.3.2016	11.48.22	#102	27	ND			0			0			0			0	382821,78	4038,84	38,28
4.3.2016	11.50.21	#103	28	ND			0			0			0			0	457505,08	4587,39	45,75
4.3.2016	11.52.17	#104	29	ND			0			0			0			0	499889,62	5083,03	49,99
4.3.2016	11.54.05	#105	30	ND			0			0			0			0	482928,21	4931,08	48,29
4.3.2016	11.56.13	#106	31	ND			0			0			0			0	480844,07	4230,27	48,08
4.3.2016	11.58.23	#107	32	ND			0			0			0			0	327888,21	3125,53	32,79
4.3.2016	12.00.19	#108	33	ND			0			0			0			0	343244,05	3471,99	34,32
4.3.2016	12.02.28	#109	34	ND			0			0			0			0	462149,32	4140,05	46,21
4.3.2016	12.04.20	#110	35	ND			0			0			0			0	387493,46	3950,26	38,75
4.3.2016	12.06.28	#111	36	ND			0			0			0			0	409318,34	3822,81	40,93
4.3.2016	12.08.29	#112	37	ND			0			0			0			0	315270,31	3133,49	31,53
4.3.2016	13.26.58	#121	38	ND			0			0			0			0	384268,90	4288,68	38,43
4.3.2016	13.29.30	#122	39	ND			0			0			0			0	301629,23	3197,94	30,16
4.3.2016	13.31.11	#123	40	ND			0			0			0			0	378671,90	3771,14	37,87
4.3.2016	13.32.42	#124	41	ND			0			0			0			0	416281,25	4285,44	41,63
4.3.2016	13.34.24	#125	42	ND			0			0			0			0	454214,23	5335,40	45,42
4.3.2016	13.46.47	#130	43	ND			0			0			0			0	409886,41	4356,66	40,99
4.3.2016	13.48.03	#131	44	ND			0			0			0			0	402859,79	4350,34	40,29
4.3.2016	13.49.35	#132	45	ND			0			0			0			0	427814,12	5392,17	42,78
4.3.2016	13.51.07	#133	46	ND			0			0			0			0	385838,67	4367,12	38,58
4.3.2016	13.53.18	#134	47	ND			0			0			0			0	493470,45	4454,05	49,35
4.3.2016	13.55.12	#135	48	ND			0			0			0			0	509538,99	5262,86	50,95
4.3.2016	13.56.44	#136	49	ND			0			0			0			0	341428,40	4131,37	34,14
4.3.2016	13.58.26	#137	50	ND			0			0			0			0	309205,04	3801,12	30,92
4.3.2016	14.00.44	#138	51	ND			0			0			0			0	354367,88	3970,80	35,44
4.3.2016	14.02.10	#139	52	ND			0			0			0			0	455636,38	5052,78	45,56
4.3.2016	14.03.50	#140	53	ND			0			0			0			0	365314,12	4104,77	36,53
4.3.2016	14.05.57	#141	54	ND			0			0			0			0	495284,51	6067,88	49,53
4.3.2016	14:08:52	#142	55	ND			0			0			0			0	455992,70	5682,66	45,60
4.3.2016	14:10:15	#143	56	ND			0			0			0			0	347210,53	4280,66	34,72
4.3.2016	14.12.27	#144	57	ND			0			0			0			0	357241,80	4147,85	35,72
4.3.2016	14.16.32	#145	58	ND			0			0			0			0	398142,32	4228,43	39,81
4.3.2016	14.19.04	#146	59	ND			0			0			0			0	414353,78	4473,43	41,44
4.3.2016	14.22.59	#147	60	ND			0			0			0			0	357922,78	3748,10	35,79
4.3.2016	14.24.30	#148	61	ND			0			0			0			0	310149,28	3135,59	31,01
4.3.2016	14.26.16	#149	62	ND			0			0			0			0	348379,44	3700,13	34,84
4.3.2016	14.28.04	#150	63	ND			0			0			0			0	534812,33	5531,89	53,48
4.3.2016	14.29.22	#151	64	ND			0			0			0			0	354371,66	3611,73	35,44
4.3.2016	14.30.56	#152	65	ND			0			0			0			0	440686,28	5331,62	44,07
4.3.2016	14.32.20	#153	66	ND			0			0			0			0	385593,46	4107,04	38,56
4.3.2016	14.34.12	#154	67	ND			0			0			0			0	534644,10	5191,37	53,46
4.3.2016	14.36.11	#155	68	ND			0			0			0			0	368265,78	3980,34	36,83
4.3.2016	14.39.12	#156	69	ND			0			0			0			0	391561,81	4490,02	39,16
4.3.2016	14.40.43	#157	70	ND			0			0			0			0	455874,08	4244,75	45,59
4.3.2016	14.42.38	#158	71	ND			0			0			0			0	391921,85	4102,17	39,19
4.3.2016	14.44.16	#159	72	ND			0			0			0			0	503411,99	4813,09	50,34
4.3.2016	14.46.35	#160	73	ND			0			0			0			0	391197,19	4323,58	39,12
4.3.2016	14.48.04	#161	74	ND			0			0			0			0	353542,30	3641,90	35,35
4.3.2016	14.49.38	#162	75	ND			0			0			0			0	378790,96	3751,92	37,88
17.3.2016	9.16.51	#2	77				0			0			0			0	328808,92		32,88
17.3.2016	9.19.58	#3	78				0			0			0			0	498646,43		49,86

APPENDIX 2.

Medians of imported reference material.

	Id	Si%	Ti%	Al%	Fe%	Mn%	Ca%	K%	P%	V	Ni	Cu	Zn	As	S	Cl	Zr	Sn	Sb	Pb	Bi	Cd	Hf	W	LE
	22	39,66631	0,425708	8,980851	4,072912	0,061811	0,958178	3,74367	0,310479	501,18	279,5	0	139,44	694,81	23641,2	610,19	286,53	112,24	183,08	5632,38	70,07	131,97	133,44	0	385384,9
	23	30,37067	0,328782	7,058662	3,219783	0,047887	0,369469	2,629842	0	304,84	163,32	0	141,13	2917,85	106864	2333,79	191,06	117,62	157,43	14883,46	132,93	147,14	650,81	0	430743,8
	24	38,26175	0,515746	8,082105	3,848887	0,037385	1,670078	3,25302	0	299,41	238,47	0	82	980,1	67441,9	1202,08	244,43	111,65	149,26	4865,23	0	114,17	255,09	0	367326,6
	25	34,59775	0,414868	9,208831	3,739548	0,064402	0,285742	3,790286	0	346,1	230,8	0	134,68	1456,27	89946,1	2479,54	186,57	128,6	211,59	8069,82	0	159,57	267,01	0	375369,1
	26	35,80817	0,515535	9,418277	4,085844	0,062684	2,007751	2,700686	0,154432	250,82	306,76	0	203,93	1481,11	77098,2	2415,8	241,77	128,9	183,3	8860,34	76,26	142,94	414,4	0	360661,7
	27	32,26955	0,335297	9,559487	3,274873	0,042446	0,571187	3,644639	0,138812	282,58	168,17	0	105,41	2632,08	94286,1	1786,88	158,05	143,75	163,57	18270,82	178,37	148,94	490,58	0	382821,8
	28	31,38727	0,405861	6,805588	3,121661	0,045097	2,897424	2,523504	0,420746	360,3	223,94	0	111,89	1447,67	53897,5	988,75	204,46	134,42	187,95	8356,65	80,28	141,78	287,88	0	457505,1
	29	30,18466	0,414002	6,737393	3,812123	0,089162	2,208028	3,756297	1,271236	535,13	228,56	77,41	253,88	0	13522,5	0	202,33	89,52	163,34	150,94	40,09	117,65	0	0	499889,6
	30	33,20711	0,494167	7,215095	3,54509	0,059012	1,03293	3,481026	0	384,61	206,35	0	127,33	474,58	21372,8	461,45	285,26	120,67	177,29	2836,07	51,18	124,24	105,7	0	482928,2
	31	26,92266	0,306632	5,831673	2,598154	0,039137	1,177832	2,415948	0,232672	425,98	181,59	0	87,38	1631,28	111239	2228,77	198,23	98,19	149,59	7097,51	65,93	116,06	389,63	0	480844,1
	32	44,28604	0,592654	8,936783	3,565769	0,045515	0,682306	4,360121	0,26522	702,85	260,63	160,49	146,36	0	39275,8	416,2	289,48	102,11	164,64	3073,8	58,6	116,77	0	0	327888,2
	33	45,90652	0,635506	10,1225	4,090324	0,086985	0,461159	3,704711	0,493763	452,01	243,43	0	120,2	0	0	0	296,96	114,44	176,07	190,09	35,63	112,46	0	0	343244,1
	34	27,43903	0,383612	5,997485	3,162079	0,038213	1,814697	2,396246	0,230429	360,76	146,64	0	77,57	1819,24	108794	2499,77	207,22	99,16	136,98	8439,04	91,91	114,4	446,2	0	462149,3
	35	39,37615	0,544331	8,051048	4,006413	0,0443	2,505701	3,398629	0,539459	388,99	258,78	0	98,13	311,73	24585,4	0	225,32	87,33	142,99	1511,76	35,94	87,48	112,33	0	387493,5
	37	44,55762	0,503513	9,06465	3,248501	0,049101	0,565573	3,292686	0,116157	441,81	234,13	0	91,42	652,14	60359,4	726,46	347,99	118,99	188,54	7379,38	76,61	134,8	0	0	315270,3
	77	43,29485	0,398439	8,29974	3,271222	0,120641	8,617077	2,341531	0	386,92	279,61	0	84,02	0	6197,98	0	307,21	104,96	174,75	36,95	37,82	98,22	47,67		328808,9
	78	34,54151	0,338337	3,781643	2,070631	0,161758	7,588715	1,274544	0	313,85	213,69	0	60,86	0	2539,78	0	276,5	96,7	162,08	26,06	0	92,65	0	0	498646,4
Number	17																								
Max		45,90652	0,635506	10,1225	4,090324	0,161758	8,617077	4,360121	1,271236	702,85	306,76	160,49	253,88	2917,85	111239	2499,77	347,99	143,75	211,59	18270,82	178,37	159,57	650,81	0	499889,6
Min		26,92266	0,306632	3,781643	2,070631	0,037385	0,285742	1,274544	0	250,82	146,64	0	60,86	0	0	0	158,05	87,33	136,98	26,06	0	87,48	0	0	315270,3
Median		34,59775	0,414868	8,082105	3,54509	0,049101	1,177832	3,292686	0,154432	384,61	230,8	0	111,89	694,81	53897,5	726,46	241,77	112,24	164,64	5632,38	58,6	117,65	133,44	0	385384,9

APPENDIX 3.
Medians of local reference material.

Formulas	Id	Si%	Ti%	Al%	Fe%	Mn%	Ca%	K%	P%	V	Ni	Cu	Zn	As	S	Cl	Zr	Sn	Sb	Pb	Bi	Cd	Hf	W	LE
	1	43,64823	0,693271	12,88623	5,975976	0,059118	1,601829	5,452654	0,388035	521,85	313,54	121,24	298,03	0	2058,47	0	197,19	104,27	163,85	33,09	50,4	91,2	52,99	0	288940,5
	2	41,9672	0,547603	12,09009	7,232086	0,077476	1,434187	5,133836	1,816577	546,58	362,6	0	266,91	0	0	0	280,46	111,56	182,81	44,16	54,27	122,09	55,12	0	294983
	3	38,47462	0,590404	10,88147	5,884393	0,146773	2,324733	5,369149	2,038462	907,48	292,25	47,94	627,91	0	2825,5	0	290,06	115,49	193,57	37,81	54,86	117,58	0	55,7	337333,8
	4	36,31846	0,586015	9,855852	6,703073	0,081404	1,634871	5,069218	1,918541	718,27	341,48	49,09	387,39	0	0	0	230,1	122,31	182,95	38,36	60,77	112,16	54,45	0	376028,4
	5	28,59939	0,617295	10,44281	7,364837	0,061551	2,084393	6,276852	3,408222	640,48	312,21	0	291	0	1770,59	0	193,8	111,24	179,94	43,6	56,13	100,69	53,93	0	407692,9
	6	39,13617	0,609571	11,0175	6,084661	0,084046	1,622793	4,75217	1,736751	813,63	357,73	0	562,68	0	2437,53	0	264,81	109,87	185,39	41,74	47,67	127,22	45,87	0	344569,2
	7	38,42732	0,647098	11,31889	8,201441	0,161063	1,168247	5,825583	0,368629	499,34	372,12	0	235,24	0	5944,87	0	199,54	122,34	172,68	40,59	64,2	101,17	0	0	331065,3
	8	43,15152	0,63239	11,25411	7,198659	0,078195	0,785685	5,454674	0,463986	583,47	293,79	0	315,16	0	0	0	223,7	116,47	180,56	45,88	50,79	94,22	52,36	0	307851,4
	9	38,00057	0,565659	12,07716	6,219817	0,079285	1,745162	4,07289	0,505654	800,68	297,62	73,51	233,17	0	2377,41	0	165,38	115,84	188,02	43,28	41,87	116,01	0	0	362885,3
	10	35,55549	0,54881	8,317806	6,115872	0,059691	1,787958	3,834547	0,516645	592,32	308,77	166,44	229,14	0	1667,2	0	201,99	100,69	179,05	37,11	52,78	92,95	59,24	0	428944,2
	11	32,88315	0,599221	11,94851	7,918028	0,086109	2,0486	5,139389	1,717966	481,18	367,28	66,56	216,83	0	2657,67	0	175,82	97,04	170,99	44,21	57,24	87,54	54,33	0	372113,6
	12	28,91073	0,454074	8,522906	4,910964	0,065031	2,562939	3,88566	1,311284	479,79	262,91	0	185,46	0	14817,4	0	178,65	100,72	166,27	35,66	43,69	110,72	55,84	0	477327,1
	13	39,79832	0,561511	9,623353	5,098312	0,07366	1,339724	4,623948	0,331224	687,39	309,14	73,63	207,3	0	2930,31	0	199,17	108,61	193,25	36,57	50,02	110,31	0	0	380593,8
	14	35,51743	0,506445	8,494015	4,265658	0,080455	2,577489	4,045995	0,317553	424,71	318,13	0	224,98	0	52934,1	0	234,2	121,68	171,25	32,23	45,02	103,3	48,46	0	387291,5
	15	36,74187	0,519714	9,296632	4,559049	0,085401	1,991053	4,444873	0,507922	615,96	278,63	0	193,05	0	12566,7	0	227,73	119,74	178,65	34,76	48,18	128,56	0	0	404143
	16	37,14357	0,628571	12,83192	6,51337	0,08423	1,37181	5,115336	0,350693	743,27	322,05	0	203,98	0	1690,28	0	171,4	117,25	193,2	35,3	62,09	108,52	62,88	0	355894,8
	17	38,78571	0,590743	11,1469	6,38795	0,141674	2,449392	5,071859	1,085704	828,16	336,38	129,35	486,57	0	0	0	168,65	121,27	194,1	54,28	46,42	115,91	0	54,45	340865,2
	18	30,41816	0,44783	6,043347	5,590435	0,164936	2,324155	5,792105	1,85109	556,67	308,72	397,32	689,91	0	11074,1	0	234,51	118,54	193,35	2641,79	69,58	122,34	0	0	457272,7
	19	36,94257	0,564068	9,438804	5,825793	0,099814	1,312984	6,463037	0,168101	508,65	279,54	134,49	936,75	0	6837,88	0	258,79	107,49	181,47	1014,05	64,75	99,77	0	64,02	381360,6
	20	34,04765	0,54418	10,74937	6,647007	0,093116	1,405319	7,858377	0,297197	656,01	264,75	69,28	360,98	188,66	15726,7	0	198,65	113,21	181,98	1401,38	71,02	117,84	125,2	0	364102,2
	21	33,10577	0,535413	10,91414	6,633853	0,117822	1,07618	5,986365	0,175563	526,69	295,17	0	404,53	558,71	40197,6	554,96	203,16	124,32	202,4	4644,21	89,99	132,18	147,53	0	366467,4
	58	34,02293	0,51731	11,92571	5,957812	0,093414	2,525554	4,358441	0,603371	614,93	312,98	0	148,64	0	0	0	139,29	125,8	192,9	39,46	50,53	134,08	53,57	0	398142,3
	59	34,29143	0,52141	11,36673	5,600475	0,064825	1,859363	4,498428	0,204846	442,13	332,58	0	149,99	0	0	0	149,77	121,22	172,18	35,53	54,13	113,61	0	0	414353,8
Number	23																								
Maks		43,64823	0,693271	12,88623	8,201441	0,164936	2,577489	7,858377	3,408222	907,48	372,12	397,32	936,75	558,71	52934,1	554,96	290,06	125,8	202,4	4644,21	89,99	134,08	147,53	64,02	477327,1
Min		28,59939	0,44783	6,043347	4,265658	0,059118	0,785685	3,834547	0,168101	424,71	262,91	0	148,64	0	0	0	139,29	97,04	163,85	32,23	41,87	87,54	0	0	288940,5
Median		36,74187	0,564068	10,91414	6,115872	0,084046	1,745162	5,115336	0,507922	592,32	312,21	0	266,91	0	2437,53	0	199,54	115,84	181,98	40,59	54,13	112,16	52,36	0	372113,6

APPENDIX 4.
Medians of bricks and tiles under study.

Formula	Id	Si%	Ti%	Al%	Fe%	Mn%	Ca%	K%	P%	V	Ni	Cu	Zn	As	S	Cl	Zr	Sn	Sb	Pb	Bi	Cd	Hf	W	LE
	38	42,21881	0,530395	9,275954	4,271732	0,09963	1,175425	3,840473	0	470,4	227,08	0	123,78	0	0	0	363,32	98,74	161,48	33,15	49,52	79,44	0	0	384268,9
	39	48,66276	0,509666	10,56199	4,784069	0,081469	0,933037	3,976408	0,148879	479,67	339,34	0	115,73	0	0	0	349,52	118,59	196,36	28,34	42,81	117,67	0	0	301629,23
	40	44,98504	0,429469	8,13725	3,170319	0,086337	1,178725	3,341052	0	494,97	221,96	0	91,75	0	6301,84	0	467,14	120,64	161,24	27,99	38,42	120,26	0	0	378671,9
	41	38,67479	0,460896	8,747854	5,186395	0,112666	1,163676	3,345044	0,218229	348,93	225,68	0	167,09	0	3001,43	0	347,2	126,41	184,9	58,69	47,42	115,53	0	0	416281,25
	42	32,62027	0,54555	7,820662	6,562594	0,085531	1,634225	4,390723	0	435,07	252,14	0	177,41	0	7665,14	0	171,14	129,14	172,72	40,42	54,67	92,34	0	0	454214,23
	43	35,65515	0,550385	10,2558	6,568571	0,095482	1,035523	4,233319	0,127898	444,27	323,58	0	153,11	0	3122,27	0	195,89	133,55	213,9	44,82	54,11	144,42	62,35	0	409886,41
	44	38,07594	0,530732	10,07995	5,781338	0,070771	0,89299	3,953343	0,164674	481,2	300,04	0	141,09	0	0	0	196,38	135,49	180,2	41,12	45,81	121,5	0	0	402859,79
	45	34,60452	0,562041	9,518563	6,715382	0,081518	1,022067	4,566167	0	404,78	235,15	0	182,15	0	0	0	172,99	106,85	190,11	42,27	49,4	99,59	0	0	427814,12
	46	42,57821	0,393884	8,550013	4,074928	0,070877	1,05496	4,115326	0,18138	494,5	273,37	0	120,61	0	2344,19	0	258,72	126,51	182,1	29,08	32,62	103,8	0	0	385838,67
	47	32,28813	0,349799	6,401561	3,127038	0,092789	2,221793	2,894153	0	372,58	228,9	0	100,98	0	31326,6	0	293,05	123,48	180,37	23,79	22,47	104,79	0	0	493470,45
	48	36,73463	0,384632	4,791904	2,984367	0,072753	1,27564	2,650336	0	385,69	211,28	0	78,67	0	0	0	339,66	132,17	187,79	19,68	27,9	135,51	0		509538,99
	49	40,25197	0,537683	12,02743	6,517746	0,08583	1,488243	4,764456	0	701,38	289,98	0	156,18	0	0	0	193,77	129,8	171,81	36,49	47,62	111	0		341428,4
	50	42,01356	0,612469	11,77894	6,71932	0,102237	1,373317	5,588202	0	516,77	315,47	0	166,07	0	7186,11	0	171,24	123,27	178,93	43,9	56,18	95,68	60,98		309205,04
	51	36,35155	0,578453	11,90609	6,304274	0,083816	2,054293	5,076103	0,145369	631,19	327,78	0	283,45	0	18618,5	0	177,7	122,89	197,22	43,83	49,58	115,82	64,74		354367,88
	52	34,64406	0,435833	8,07059	4,809651	0,110012	1,946118	4,272905	0	427,1	225,45	0	116,31	0	0	0	187,09	118,61	185,67	42,16	40,18	129,38	0		455636,38
	53	36,36274	0,596574	11,0203	6,471902	0,08417	3,051462	5,113556	0,234042	450,1	344,76	0	175,91	0	3532,05	0	222,44	144,82	192,93	47,47	51,14	121,01	55,9		365314,12
	54	28,82049	0,575208	7,448981	6,178079	0,098532	2,373858	3,936323	0	474,1	331,25	0	178,94	0	8662,33	0	172,27	138,32	212,08	33,74	59,11	138,65	0		495284,51
	55	30,90181	0,626359	10,58646	7,445528	0,087984	0,796461	3,789431	0	651,04	233,34	0	198,4	0	0	0	195,97	80,12	125,23	41,61	59,96	0	81,3		455992,7
	56	41,59368	0,539573	10,9764	5,969306	0,071904	1,081771	4,880254	0	508,65	300,64	0	153,8	0	0	0	175,79	137,81	183,87	37,41	55,12	107,49	0		347210,53
	57	38,35346	0,635821	11,62237	7,725946	0,101056	1,092083	4,393989	0,161368	684,97	332,98	0	181,97	0	0	0	181,6	131,03	183,29	42,4	56,08	102,96	0		357241,8
	60	41,23032	0,500867	10,20252	5,115138	0,07067	1,617806	3,905778	1,371839	597,34	311,66	0	132,86	0	0	0	309	137,08	184,26	49,26	38,86	117,85	49,68		357922,78
	61	50,44276	0,477159	9,328949	3,405889	0,042796	0,929959	4,199732	0	421,45	250,64	0	103,52	0	0	0	326,27	111,26	169,11	44,26	38,16	113,59	0		310149,28
	62	42,59046	0,490865	10,76483	4,573512	0,058989	1,208871	4,192885	0,507267	461,41	302,97	0	129,51	0	5400,5	0	294,49	136,44	196,39	655,03	45,99	121,1	0		348379,44
	63	24,36021	0,323838	5,012518	2,708783	0,034762	11,69709	2,227971	0	445,89	217,05	0	73,16	0	0	0	256,52	154,33	200,28	33,84	26,58	128,26	0		534812,33
	64	46,48077	0,418355	8,53447	3,376901	0,047541	0,951751	4,398782	0,176545	431,4	246,91	0	253,86	0	0	0	300,6	124,78	190,78	32,17	33,09	117,13	46,48		354371,66
	65	36,99731	0,526977	8,172707	5,33789	0,058768	0,692115	3,989279	0	469,83	250,53	0	134,6	0	0	0	203,82	127,26	188,95	34,93	49,45	103,92	0		440686,28
	66	37,37615	0,494676	9,765759	5,8864	0,054985	1,809563	4,642903	0,825965	505,23	323,29	81,87	182,99	0	4051,12	0	165,45	115,96	187,05	62,11	49,5	117,91	0		385593,46
	67	19,02727	0,372125	6,118287	6,766269	0,061656	3,156095	2,946167	5,511094	524,25	275,74	0	154,5	145,3	22406,4	336,28	155,96	127,11	186,46	1300,99	55,29	98	0		534644,1
	68	36,71891	0,58792	11,40252	5,936902	0,067754	2,732368	4,50702	0,444993	446,23	284,08	0	357,25	0	5780,74	0	183,01	146,56	188,92	185,81	46,35	131,47	0		368265,78
	69	35,58951	0,572686	10,01256	6,709812	0,068237	2,098493	4,771591	0,472235	596,76	301,61	0	160,38	0	3569,81	0	168,58	121,46	189,88	140,44	57,37	122,98	57,75		391561,81
	70	29,48629	0,37378	5,669613	3,924793	0,042049	4,608602	3,305987	1,629629	431,2	276,4	0	118,9	0	51350,7	525,58	174,32	131,43	184,02	336,97	38,16	98,26	52,55		455874,08
	71	35,97365	0,500205	9,508847	4,158019	0,065977	1,727795	6,244785	1,656881	310,72	291,08	67,82	455,25	0	7875,54	0	216,95	124,05	185,95	32,67	35,72	120,79	0		391921,85
	72	29,56602	0,452041	6,093658	3,904743	0,05451	4,585756	3,106151	1,107052	490,61	302,89	0	230,74	0	6075,29	0	239,48	124,09	181,16	47,84	31,7	117,9	46,96		503411,99
	73	36,39733	0,462631	8,703982	5,448391	0,080709	2,923815	4,196931	1,867965	519,32	299,34	0	269,56	0	6165,57	0	196,45	127,77	191,64	52,09	46,2	117,31	0		391197,19
	74	44,38466	0,483618	9,520015	4,204848	0,070051	1,155558	4,193013	0,465642	529,57	240,74	0	134,38	0	0	0	278,31	106,6	179,95	35,53	36,47	86,32	16,68547101	0	353542,3
	75	43,01408	0,433627	9,448757	3,250627	0,048796	1,53812	3,763126	0,45776	495,55	283,53	0	123,47	0	0	0	270,39	130,02	193,15	29,96	29,77	104,32	16,29917536	0	378790,96
Number	36																								
Min		19,02727	0,323838	4,791904	2,708783	0,034762	0,692115	2,227971	0	310,72	211,28	0	73,16	0	0	0	155,96	80,12	125,23	19,68	22,47	0	0	0	301629,23
Maks		50,44276	0,635821	12,02743	7,725946	0,112666	11,69709	6,244785	5,511094	701,38	344,76	81,87	455,25	145,3	51350,7	525,58	467,14	154,33	213,9	1300,99	59,96	144,42	81,3	0	534812,33
Median		36,86597	0,500536	9,478802	5,262143	0,072329	1,43078	4,192949	0,155124	476,885	283,805	0	154,15	0	2672,81	0	200,135	126,81	185,81	41,885	46,275	116,475	0	0	388517,93

SUMMARIES

JOUKO PUKKILA

TURKU RÄNTÄMÄKI RIIHIVAINIO – ARCHAEOLOGICAL RESEARCH OF STONE AGE/EARLY METAL AGE (CA. 2500–1 BC) SETTLEMENT AND CULTIVATION SITE IN 2012

The Turku Museum Centre carried out archaeological surveys in the Riihivainio Stone Age settlement site in 2012. Although during the recent fieldwork the majority of the cultural layer was found to have been destroyed, there were some intact prehistoric layers, a few centimetres thick. Layers showed traces of an ancient field. On the cultural layer – and also outside of it –some 10 cm wide and mainly a few ten centimetres long ploughing traces were visible.

Riihivainio's settlement site area is extensive; observations have been made in an area about 170 m long and about 100 m wide. On the basis of the found material, the dates are clear; most have been Kiukainen ceramics (2500–1800 BC) and Morby ceramics (800 BC–AD 300). All observations were made about 23 m or more above sea level, which, according to the speed of shoreline displacement, tracks with the end of the Stone Age.

There were three kinds of ploughing traces: traces filled with dark gray culture soil, lighter gray sand-filled traces in the dark cultural layer and pale gray "ghosts" in light sand. The width of the traces was about 8 to 11 cm, and the cross section resembled the letter *U*. Depth ranged from a few cm to about 10 cm. The direction of the traces varied so that they went crosswise, but their shear angle was not rectangular. In a few places, it was seen that the plough was turned 90 degrees in a small distance so that about 20 to 30 cm was ploughed in a curve. Only one spot was found in the trace that curved from both ends. The distance between the turning angles of this track was just over two metres.

The area with the densest ploughing was about 27 m^2. In addition, at the south end of the excavation area, there was another ploughing area of about 10 m^2.

Finds consisted of pottery sherds, rock and quartz flakes, and few pieces of burnt bone. There were two main types of ceramics, Morby and Kiukainen pottery, on which basis the settlement site can be dated to the end of the Stone Age, Late Bronze Age and the Earliest Iron Age, i.e., about the time period 2500–1 BC.

No cereal grains were found in the soil samples but otherwise they were interesting. In them, among other things, two spruce (*Picea abies*) needles and small pieces of burnt fish bones were found.

Radiocarbon dating was made from charcoal. Samples were taken as well as from the cultural layer (sample 2: 1750 cal BC) and the plough trace (sample 26: 1900 cal BC). Dates are from the final stages of the Kiukainen culture and well matched to the dates of the finds.

JANI ORAVISJÄRVI

KAARINA'S KEETTERINMÄKI HOARD FROM THE LATE IRON AGE

Kaarina's Keetterinmäki hoard was found in 2014 by a local metal detectorist. It was the seventeenth-known Late Iron Age hoard discovered in Finland Proper. The find was made where coins were dispersed along a forest pathway. The hoard includes a total of twenty-six coins and fragments. There are three Anglo-Saxon coins and two Anglo-Scandinavian imitations; the rest are from the Holy Roman Empire, including a few very worn coins (see the catalogue). It was thus quite a typical silver hoard. Its terminus post quem is 1036. This article is dedicated to the memory of Kaisa Lehtonen.

JAANA RIIKONEN

GRAVE 31 AT KIRKKOMÄKI IN TURKU AND LOINCLOTH – NEW ACCESSORY TO WOMAN'S DRESS IN LATE IRON AGE FINLAND

There is a burial ground called Church Hill (Fi. *Kirkkomäki*) on the north side of St. Catherine's church (Fi. *Pyhän Katariinan kirkko*) in Turku which was excavated at the beginning of the 1990s. Parts of the woman's grave 31 were lifted with the help of plaster casts. The soil blocks were preserved frozen until 2006 when they were examined in the Museum Centre of Turku. It was then that the remains of an earlier unknown accessory to a woman's dress was found and named a loincloth. It was sewn of woollen fabric woven in twill and surrounded with a braid. On each corner, it had a fanlike spiral ornament such as aprons used to have in southwestern Finland in the Late Iron Age. The loincloth had been about 70 cm long and 10 cm wide and was probably attached with narrow bands on top of the apron to the left loin of the deceased. The article also discusses earlier interpretations of loincloths called *kaatterit* (Fi.).

According to the finds made, the grave is dated probably to the twelfth century. The deceased wore a necklace, and one finger had a silver ring. She was dressed in a shirt made of fine linen, held together by a small penannular bronze brooch. Her other clothes were made of wool. The woollen dress was fastened on the shoulders with bronze penannular brooches. A broad bronze-plated knife sheath had been hung from the apron band. On top of the knife sheath, there were fragments of mittens made using nålbinding technique. Under the dress hem were the remains of leg-bindings attached with plaited braids.

The fair-haired deceased was resting on deer skin with birch branches next to her in a coffin made of dug-out log. Before the cover of the coffin was nailed shut, the deceased was covered with two spiral-ornamented woollen cloaks, and a sickle was laid on them. Two containers made of birch-bark were laid at the foot of the coffin – at least one of them containing textile craft supplies. The deceased, dressed in her best clothes – and the carefully furnished grave – convey her valued position and the wealth of her family.

JANNE RANTANEN & JASSE TIILIKKALA

SPOTTING IRON AGE SETTLEMENT SITES FROM AERIAL PHOTOGRAPHS IN FINLAND PROPER: THE RIVER AURAJOKI AREA AS A CASE STUDY

A team of archaeologists from the University of Turku conducted an archaeological survey of Iron Age settlement sites in Finland Proper during 2014–2017. The research was funded by the society *Suomen muinaistutkimuksen tuki ry*. Orthoimagery was used for spotting soil marks which could indicate the presence of settlement sites dating to the Iron Age (ca. 500 BC–AD 1200). Survey work was focused on river valleys in the area of the following municipalities and cities: Mynämäki, Nousiainen, Masku, Rusko, Raisio, Turku, Lieto, Kaarina, Paimio and Salo. Ten previously unknown settlement sites were found in the survey and most of them were recognised in aerial photographs before conducting fieldwork at the sites. The perimeter of the known Iron Age and medieval settlement site of Lieto Vääntelä Uotila was also more accurately determined with the help of orthoimagery.

In the River Aurajoki area, three previously unknown Iron Age or multi-period settlement sites were found. The site of Lieto Sauvala Rantapelto is situated on the bank of the River Aurajoki, where the Lausteenoja tributary joins the river. The site of Lieto Pakurla Ylirihko is a kilometer northeast, on the bank of the Lausteenoja tributary. Another settlement site, Turku Paimala Yli-Junnila, is located on the bank of another tributary, the River Vähäjoki, and its artificial Paimala Basin. The sites were spotted as soil marks from orthoimagery of the National Land Survey of Finland and the city of Turku. Field survey was performed on each of the sites. Find material consisted mostly of potsherds and burnt clay daub. Animal bones were also found on the site of Yli-Junnila, whereas a considerable amount of iron slag was found on the site of Ylirihko. The potsherds from the three sites can be dated roughly to the younger phase of the Iron Age (ca. AD 550–1200), but some porphyritic stone flakes and a flint core from the site of Rantapelto might indicate an older, Bronze Age settlement period.

TIINA VASKO

A HORSE IN A PURSE - ARTEFACTS FROM THE MALE GRAVE NR 5 IN TASKULA INHUMATION CEMETERY (TURKU)

This article presents artefacts found from the male grave number 5 in Taskula inhumation cemetery. The Taskula inhumation cemetery was discovered in May 1938 by workmen digging a sewer ditch across the yard of the chaplain's house. A total of 20 inhumation graves were excavated the same year. Coins from the graves date it mainly to the 11th and 12th centuries. For various reasons the material from Taskula remained nearly unstudied.

A nine-faceted Facies Christi finger ring with nine picture frames was found from this grave. It was identified only recently by the author. It is the earliest Facies Christi finger ring in Finland, and possibly also in Scandinavia. As a ring type, the Taskula silver ring is unique so far. The ring is presented in a previous article (in Finskt Museum 2013–2015).

In the grave were also remains of a leather belt in Gotlandic style with animal fittings, a knife with silver thread on the handle, four weights, a padlock, and a key. Two silver coins were found near the waistline: one German (1056–84) and one English (1135–54) coin. One of the weights is in a shape of a tiny horse; it weights only 9,63 g. This object has been studied earlier and it was interpreted as Livonian. Author suggests a Latvian or Estonian origin. Still it remains unclear if this little horse was originally a pendant or a weight.

Also few badly corroded, at the time unidentified iron objects were found. One of these turned out to be a massive ring needle (length 16 cm) revealed by an X-ray in 2015. Similar needles are known in male graves from 12th and 13th century Novgorod. Another mystery was an iron "lump"; X-ray revealed six or seven iron rod chains. These were found near the waistline of the deceased, so the chains were probably part of the belt. The rods were very likely detached to a purse and also to a knife sheath and a padlock key that was also identified from the X-ray.

The establishment of the local parish was already close when the burial took place. The younger silver coin dates the burial not earlier than 1135 AD. The grave may also well date to the 13th century, because the rotation time of the coins was often very long. Also the Facies Christi finger ring points to the 13th century. The first common wooden church of the Maaria parish was probably built in the first half of the 13th century. We can at least assume, that after this people were buried beside the new church. It is very likely that the man in this grave was last ones buried to this cemetery in traditional way.

JUHA RUOHONEN

FROM TOURS TO EXCAVATIONS, FROM EXHIBITIONS TO WEBSITES. PUBLIC ARCHAEOLOGY OF THE MEDIEVAL RAVATTULA CHURCH SITE IN KAARINA.

In 2013, the well-preserved stone foundation of a church dated to the late twelfth century was found on Ristimäki hill in Ravattula village in Kaarina, Southwest Finland. This church was built before any known ecclesiastical organization was established in Finland. Excavations on the site were almost forced to end because of a lack of resources. However, this unique find received great visibility in the media, and as the location of the oldest church in Finland, the site quickly became a place of interest for both regular visitors and especially for enthusiasts of archaeology and history. New events and activities were created to gain publicity and ensure the continuity of the research project. In addition to scientific research, public excavations were arranged annually from 2014 to 2016. Researchers also organized guided tours of the church and, more widely, to archaeological sites around Ravattula village. Other events such as lectures, exhibitions, theme days with different activities, and ecumenical services have taken place; in addition, both popular and scientific articles have been published. The website that introduces the site has nearly broken the limit of 100 000 visitors, and approximately 15 000 people have visited the Ristimäki site personally. What makes this site so popular among the audience? Some of the methods and examples discussed in this article are traditional, but some of them have been tried for the very first time in the history of Finnish archaeology.

SANNA KUPILA & KAISA LEHTONEN

LOST AND FOUND VILLAGE PLOTS IN THE TURKU AREA

This article is based partly on the writings of the late archeologist Kaisa Lehtonen. She published her texts in the Turku Museum Centre´s blog *Kulperi* in 2015. Old village plots were of great interest to Ms Lehtonen. She and I surveyed those plots together in the Turku city area during autumn of 2014 and spring of 2015. Ms Lehtonen had plans to expand this kind of research and to write an article about it for this book. Alas, she passed away in February 2017, after a long and difficult illness.

The villages and village plots of medieval and modern times have sunk to the depths of Turku city. Of the many reasons for this, the biggest is the expansion of the city and with it, the disappearance of old settlements. However, the disappearance of medieval village plots cannot be explained by city expansion alone. The desertion of villages has happened for various reasons, including wars, famine and disease. Also, especially in the seventeenth century, heavy taxation led to houses being deserted.

The value of bygone village plots in Finland has been recognised only in the early twenty-first century as archaeologists started to examine these ancient remains of the medieval countryside. Consequently, they have become of special interest. Still, the remains of the ancient settlements are relatively little researched, and in the Turku area, there have been no excavations of these sites.

The village plots survey was done by the Turku Museum Centre as part of a background study to the Turku city zoning plan. Before the field work, building researcher studied seventeenth- and eighteenth-century maps. The surveyors visited village plots which were found in the old maps, which were no longer inhabited, and which, furthermore, had been saved from development.

All in all, eighteen village plots were examined. Undoubtedly, the most interesting one was Borgareböle village of the Kakskerta district. It had become uninhabited during the Middle Ages, but the location was still marked in a 1697 map. Other village plots which were examined had only been uninhabited since the eighteenth century or later.

LIISA SEPPÄNEN

THE ESTABLISHMENT OF TURKU

The establishment of Turku has attracted the interest of many researchers since the late eighteenth century. Despite new evidence unearthed in the 2000s, we are still drawing conclusions about the earliest phases of Turku on the basis of very limited material. According to our present knowledge, Turku was founded in the early fourteenth century in an area, which was previously used for cultivation and probably for religious and commercial activities.

In this article, I am examining the manifestations of urbanism and charting the beginning of urbanisation of Turku. On the basis of archaeological and historical evidence, it seems that the urbanisation of Turku started in the 1300s with the establishment of the cathedral, the town hall, administration and urban layout with streets and square(s). The construction of the cathedral, Turku Castle and the bishop's castle in Kuusisto took place simultaneously in the turn of the thirteenth and fourteenth century. In 1318, Novgorodians burned the bishop's castle in Kuusisto and the newly established town with its cathedral. Obviously, this attack halted the development of Turku for a couple of decades and it was not until the 1340s when the town was reconstructed on a larger scale. The next phase of urbanisation took place in the 1360s and 1370s when the town grew both in size and in population.

In this article, I have discussed the reasons why Turku was founded in the early fourteenth century and why Koroinen was not transformed into a town. According to circumstantial evidence, Turku was founded as a result of active power politics of the Swedish realm, which was initially intertwined with the missionary work of the Roman Catholic Church. Koroinen, with the bishop's seat from the thirteenth century, was not considered a suitable place for a town and for the urban functions related to administration and trade because of its primary function as a religious centre of the area. The crown needed to establish itself in a new area with a more neutral status, better connections and availability of land for activities of different kinds. Furthermore, the new site with visibility from the castle provided a better location for the defence. The role of the surrounding hills in defence might have supported the choice of the new area, too. Therefore the town was founded about 1.6. km downriver from Koroinen where the heart of the medieval town of Turku still situates today.

ELINA SALORANTA

CONSTRUCTING THE SHORE OF AURAJOKI RIVER IN THE OLD TOWN CENTRE OF TURKU BEFORE THE FIRE OF 1827

The Aurajoki River has played a central role in Turku town since the beginning and has long been associated with its development and livelihood. In the early fourteenth century, merchants settled on the eastern shore of the river, and the harbour of the town followed. After the cathedral was built, the bishop and the rest of the clergy settled down on the eastern shore as well. The Dominican convent was located in the southwestern area of the town, on the eastern slope of the riverside. Since the fifteenth century, the settlement has spread to the western riverside. The sawyers, especially, who needed water in their line of work, settled on the western riverside.

In the early stages of the town, the water level of the river was about three meters higher than it is now. The postglacial rebound has made the river shallower, while at the same time, the original ground has become compacted under the pressure of structures and filling soil. Old maps show that the curve of the river was once sharper than it is now. Running water has eroded the outer curve, and on the other hand, soil has accumulated along the inner curve, which has shallowed the western shore.

Archaeological excavations related to reparation of wharfs and other earthworks near the riverside have brought out old pilings, wharf constructions, foundations, pavements and filling strata. On this basis, the influence of human fabrication can be reconstructed until the beginning of the nineteenth century. Because of this, the river has become narrower in the vicinity of the curve than upstream or downstream.

The oldest remains of wharfs are from the middle of the fourteenth century. Supporting the shore with pilings began at the latest in the 1430s. The present stone wharf in the old core area of the town was built in the 1830–1860s. Older wharves precede it by at least 500 years.

JUSSI KINNUNEN

REAPPRAISAL OF THE SHORE-LEVEL DISPLACEMENT AND ITS COMPARISON OF DENDROCHRONOLOGICALLY DATED WOODEN BUILDING MATERIALS OF THE ARCHAEOLOGICAL EXCAVATIONS IN MEDIEVAL TURKU DOWNTOWN

Shore-level displacement is a commonly used dating method in Finland where land lifting has continued since the last ice age. In the Turku area, there are three different shore-level displacement curves. It is no-ticed that first shore level displacement curves don't fit with all archaeologically excavated structure da-ting. Some structures seem to have been underwater at the time they were constructed.

Contemporary mean water tables are based on very accurate geodetic data, and by using them, it is possi-ble to calculate shore-level displacement about 130 years back. Here, three different shore-level displace-ment curves were calculated: a) constant curve where shore-level displacement is 3,8 mm/year, b) curve where shore-level displacement is 3,8 mm/year + 1 % retardation/100 years and c) curve where shore-level displacement is 3,8 mm/year + 1,5 % retardation/100 years.

Aboa Vetus & Ars Nova Museum of History and Contemporary Art is situated on the eastern bank of the river Aurajoki. There are several medieval (mainly fourteenth- and fifteenth-century) building remains in the museum, consisting mainly of plaster-walled masonry, quarried dimension stones, natural loose stones and bricks. But there are also lots of wooden building remains and altogether about fifty dendrochrono-logically dated structures.

The main aim of this research was to compare different shore displacement curves – curves made back-wards in time from contemporary mareograph measurements and dendrochronologically dated structures. It is known that shore displacement becomes slower over time, so the constant curve based on mean water tables is the minimum curve for shore displacement.

The main results of this research were:
- The most valid shore-level displacement curve for at least the years 500 BCE–the present in the Turku area seems to be the Vuorela et al. 2009 curve, which is practically identical with the mean water 3,8 mm/year + 1,5 %/100 years -shore-level displacement curve. These two curves are derived using totally different methods, which supports their validity.

- When estimating subsidence of the soil, it was noticed that the medieval city of Turku seems to be founded by a relatively steady, wet, circa 0–20 m thick clay bed, far sturdier than the many other, more strongly sinking areas of Turku.

TANJA RATILAINEN & JUSSI KINNUNEN

TIILIEN JA KATTOTIILIEN ALKUPERÄN TUNNISTAMINEN pXRF-MENETELMÄLLÄ – TAPAUSTUTKIMUS KESKIAJAN TURUSTA

Tutkimuksessa selvitetään alkuaineanalyysien avulla, valmistettiinko muuri- ja muototiiliä 1200-luvun lopulla ja 1300-luvun alkupuoliskolla Turun seudulla vai tuotiinko niitä muualta Koroisten ja Turun kaupungin rakennushankkeisiin. Lisäksi tarkastellaan sitä, miten tiilien hankinta (muuritiilet, muototiilet, kattotiilet) kehittyi 1300- ja 1400-lukujen aikana. Kyseessä on ensimmäinen suomalainen tutkimus, jossa tiilien ja kattotiilien alkuainekoostumuksen tutkimiseen käytettiin kannettavaa röntgenfluoresenssianalysaattoria (pXRF).

Työssä analysoitiin 20 tiiltä Koroistenniemeltä sekä 17 tiiltä ja 3 kattotiiltä Turun kaupungin alueelta. Koroisten tiilet oli taltioitu Juhani Rinteen kaivauksissa (1900–1902) ja kaupungin tiilet Varhainen Turku -hankkeen kaivauksissa (2005–2006). Vertailuaineisto (40 kpl) koostui paikallisista ja tuoduista saviastioista ja tiilistä. Tuloksia verrattiin myös paikallisten savien geologisiin koostumusanalyyseihin.

Tulosten tulkinnassa otettiin huomioon mm. ympäröivien maakerrosten mahdollisesti korkeat raskasmetallipitoisuudet sekä kaliumin ja kalsiumin liukeneminen tiilen pinnasta. Tämän vuoksi useista alkuaineista koostuvien ryhmien katsottiin yhdessä osoittavan tiilen vierasta alkuperää. Vertailuaineiston perusteella ainoastaan raudan ja kalsiumin tulkittiin yksin osoittavan tuontia.

Aineistossa oli vähintään 9, mutta todennäköisesti kaikkiaan 13 tuotua tiiltä. Näiden joukossa oli muototiiliä, mutta myös tavallisia muuritiiliä. Tiiliä tuotiin tiilenkäytön varhaisvaiheista lähtien, 1200-luvun toiselta puoliskolta 1300-luvun alkupuoliskolle, mutta edelleen käytön yleistyessä 1300-luvun toisella puoliskolla ja 1400-luvulla. Tiiliä valmistettiin alusta lähtien myös paikallisesti.

Tutkimusaineistossa oli vain kolme kattotiiltä, minkä perusteella ei juurikaan voida tehdä luotettavia johtopäätöksiä kattotiilien hankinnasta. Vaikuttaa kuitenkin siltä, että 1400-luvulla kattotiiliä hankittiin sekä paikallisesti valmistamalla (73) että tuomalla muualta (66?,67). Kattotiilien pinnoitteena käytettiin luultavasti lyijy- ja kuparipohjaista (66, 67) sivelyä.

Tutkimuksen perusteella Turun seudulle ei keskiajalla saapunut ainoastaan tiilentekijöitä ja muurareita, vaan myös tiiliä. On mahdollista, että tiiliä tuotiin, koska tänne ei saatu tarpeeksi taitavia tiilenlyöjiä tai että paikallinen tuotanto ei riittänyt täyttämään tarvetta. Tiilien harvinaisuus tai kalleus ei liene ollut syynä tuontiin.

XRF-menetelmän käytön etuihin voidaan laskea se, että näytteitä ei tarvitse kuljettaa analysaattorin luo, mikä esimerkiksi mahdollistaa laitteen käytön kentällä. Näytteitä saadaan myös analysoitua suhteellisen nopeasti isoja määriä. Toisaalta kannettavat XRF-analysaattorit ovat edelleen melko hintavia, ja käyttäjän on toimittava Säteilyturvakeskuksen valvonnan alaisena. Lisäksi eri laitevalmistajien laitteiden tulokset eivät ole suoraan vertailukelpoisia keskenään.

HEINI KIRJAVAINEN

OLD SAMPLES, NEW RESULTS – COLOUR ANALYSIS OF TEXTILE FRAGMENTS FROM ÅBO AKADEMI MAIN BUILDING SITE

This article reviews the results of three different laboratory tests on medieval dyes detected from archaeological woolen textile fragments dated to the 1350–1400 AD. Textile fragments were excavated from a medieval urban dwelling site in the centre of Turku. Ten dye samples were studied at the *Textile Research in Archaeology in York* in 2001 and at the *Anglo-Saxon Laboratory incorporating Textile Research in York, the United Kingdom* in 2004. The research method used was thin layer chromatography (TLC). The other ten were analysed at the laboratory of the *Conservation science department, Netherlands Institute for Cultural Heritage in Amsterdam, the Netherlands* in 2011. A high-performance liquid chromatography (HPLC) was used for dye analyses. The visible colours on textiles discovered were red, blue, brown, and blackish brown. The results for dye indicated the use of purpurin and alizarin originating from madder (*Rubia tinctorum* L.) and possible local madder plants (*Galium verum* L. and *Galium odoratum* L.), indigotin from woad (*Isatis tinctorum* L.), tannins from tree/alder bark (*Alnus glutinosa* L.) and luteolin from weld (*Reseda luetola* L.). Furthermore, six unidentified yellows and two unidentified reds were detected. 'Yellow X' was analysed as a contamination of soil rather than a dye substance. Unidentified reds were analysed as a local dye plant and a tannin-based dye substance originating from unidentified tree bark. The results of dye analyses gave new information on the use of dyes and their combinations in dyeing processes used in medieval Finland.

AKI PIHLMAN & PANU SAVOLAINEN

THE HOUSE OF POTTERS – HISTORICAL ARCHAEOLOGY AND THE EVERYDAY LIFE OF POTTERS IN IN 18TH CENTURY TURKU (FINLAND)

In 2012, the remains of a pottery workshop were unearthed in the eastern fringes of the historical town area of Turku. The archaeological material comprised remarkable amounts of fragments of pottery, tiled stoves and other clay artefacts from 18th century and the beginning of 19th century. The ensemble of objects gave exceptional opportunities from the angle of historical archaeology, because the history of the workshop and the potter masters was unveiled in written records. The documents revealed, that the workshop functioned from 1680's to 1830's over four generations, and from the 1730's to 1760's the head of the workshop was a woman, Maria Sarcovia (1680–1771). The article highlights, how archaeological material and historical records and the methods of both fields can be combined and interlinked to form more elucidate and accurate conclusions that neither of the materials and disciplines could reveal alone.

SONJA HUKANTAIVAL, ANNE-MARI LIIRA & SOFIA PAASIKIVI

THE FORGOTTEN CHOLERA BURIAL GROUND IN TURKU – ARCHAEOLOGICAL EXCAVATIONS ON THE WEST SLOPE OF KAKOLA HILL

In 2011–14, the Museum Centre of Turku conducted archaeological excavations at the site of a 19th-century burial ground. The excavations were connected with building work done at the site. During the excavations, 45 graves were detected of which 37 were thoroughly documented. Eight of the observed graves did not coincide with the construction site and these where left untouched. The graves were preserved to different degrees: some were almost completely decomposed while others were quite well preserved. The bodies had been placed in simple wooden coffins. Some of the coffins were placed in the same pit side by side and on top of each other in two layers. Some of them included plant remains such as straw or twigs that had been placed under the body, especially under the head.

Three of the burials contained a small metal Orthodox cross pendant and two of the graves showed signs of amputated legs. One of these was a young man whose left lower leg (tibia) had been amputated. He had died before the amputation had begun to heal. Still, the off-cut part of the leg had not been included in the burial. The other case was an amputated femur that was found in a grave where the buried individual had two whole legs. It seems that the off-cut part was buried in another person's coffin. However, it is possible that the femur belonged in the coffin on top of the one it was found in, since this quite decomposed coffin had partly collapsed into the nether one.

This burial ground has not been marked on maps. Human bones and burials were first found there in the early 21th century, when the area was constructed into a residential zone. In the 1970s, when bones were again found, the museum was informed that this was a Cholera burial ground. Indeed, historical sources confirm that a Cholera burial ground had been founded somewhere in the area in 1831, during the first epidemic. However, two major questions remain. First, why was the burial ground forgotten so soon after its use period? In 1905 when the residential area was being built, newspapers reported the finds of mysterious human bones as if there was no recollection of a burial ground founded there only around 70 years earlier. Moreover, only ten years earlier, in 1895, a local newspaper reported that funds were appropriated for building a fence around the Cholera burial ground, since relatives of the deceased were distressed about the neglected state of the graves.

The second question might provide a clue for the first one. All 14 of the deceased whose sex was possible to estimate were male. All were adults, except one was juvenile. Moreover, the Orthodox cross pendants and amputated legs (together with earlier observations of soldier clothing) seem to point towards Russian soldiers. The Cholera burial ground of the Russian military hospital did indeed situate close to the area. However, if the area excavated was mainly in use by the Russian troops, it would mean that the burial ground of ordinary townspeople is still to be located. Continued excavations in the area may shed more light to this question.

Aurajokilaakson maisemaa Kaarinan Muikunvuoren laelta vuonna 1998. Kuva TYA 294:56 / Kaisa Lehtonen.

TURUN MUSEOKESKUS RAPORTTEJA 23

ISBN 978-951-595-207-3 (pdf)
ISBN 978-951-595-208-0 (painettu)
ISSN 1797-965X