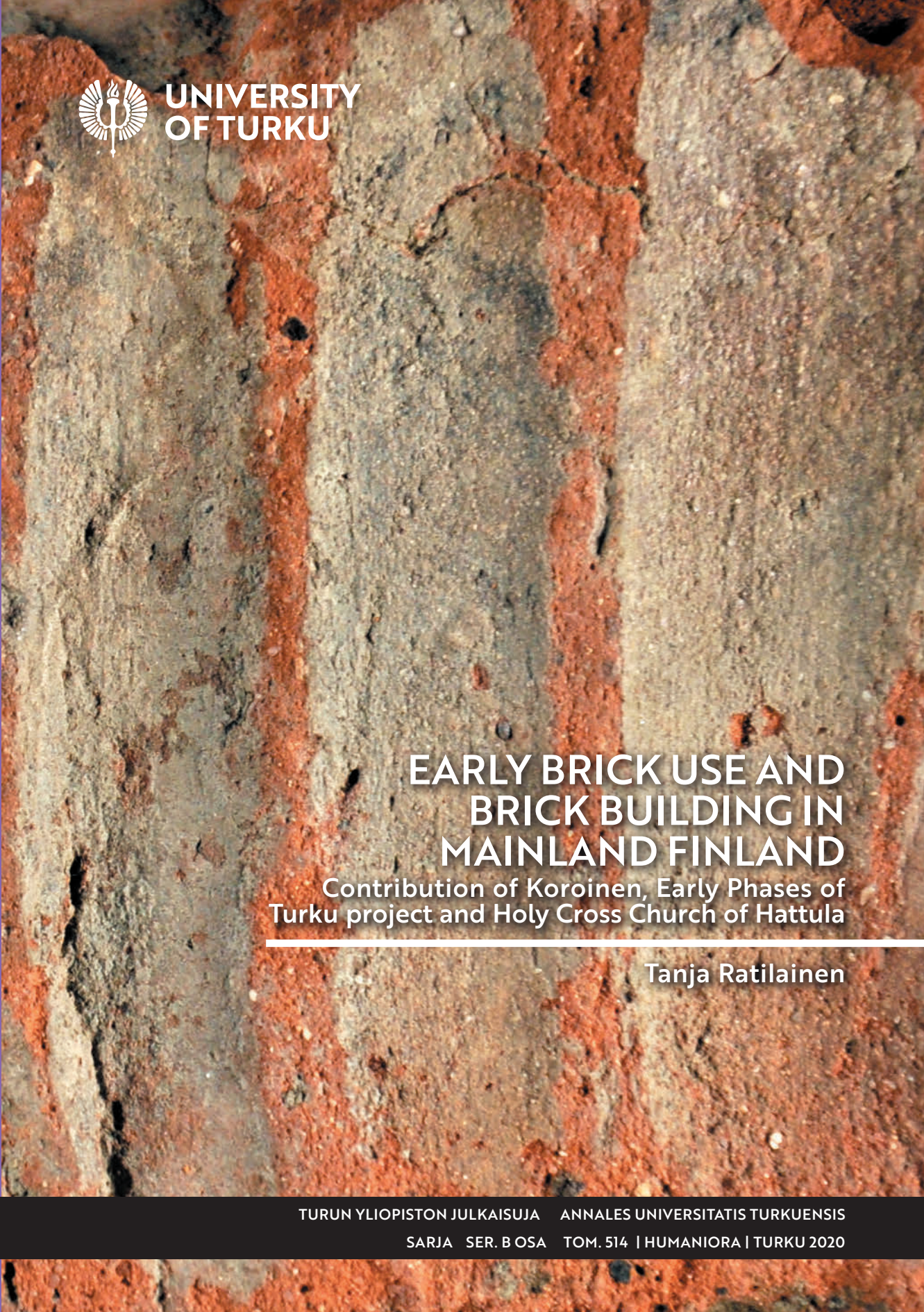

UNIVERSITY OF TURKU

EARLY BRICK USE AND BRICK BUILDING IN MAINLAND FINLAND

Contribution of Koroinen, Early Phases of Turku project and Holy Cross Church of Hattula

Tanja Ratilainen

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University of Turku

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To Joose, Saima and Harri

"Data! Data! Data! I can't make bricks without clay."

Sherlock Holmes
in The Adventure of Copper Beeches (1892)
by Sir Arthur Conan Doyle

UNIVERSITY OF TURKU
Faculty of Humanities
Department of Archaeology
Medieval Archaeology
TANJA Ratilainen: Early brick use and brick building in mainland Finland. Contribution of Koroinen, Early Phases of Turku project and Holy Cross Church of Hattula
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ABSTRACT

This dissertation focuses on the earliest traces of brick use on the mainland of medieval Finland, when and where the brick use and brick building started, the form in which it first appeared, and how it seems to have developed. In addition, the actors behind the building projects as well as meaning of the brick is shortly discussed. This study goes through three different sites, along with their brick materials and structures: the Koroinen site, where the bishop's see was located in the 13th century; the Early Phases of Turku excavation site around Turku Cathedral; and a standing brick building in the Häme region, the Holy Cross Church of Hattula. All of these sites, excavated or studied through archaeology and building archaeology, are unique and are the first in medieval Finland in their own way; Koroinen was the first ecclesiastical centre and Turku the oldest town. Holy Cross Church is the only—and thus, the first—parish church built in brick. This material will be discussed in light of new scientific dating and pXRF results and in the context of other sites with brick structures and buildings, as well as in a larger perspective in the Baltic Sea Region. The dating methods applied are dendrochronology, optically stimulated luminescence, radiocarbon dating and wiggle matching. Materials dated are brick, wood, burnt bone and mortar.

Brick use started on the mainland of medieval Finland in the second half of the 13th century at Koroinen. Bricks were applied in various ways in several different structures, but the first brick buildings were erected only in the second half of the 14th century. Not only roof tiles but also ordinary wall bricks and moulded bricks were imported, but all of them were also locally produced. The bishop was the first to employ brick, likely because he wanted to promote Koroinen as an ecclesiastical centre. Right after founding Turku, brick was applied in the hearths and floors of wooden buildings, which suggests that it was also available to other actors in town. On the other hand, bricks, including the special raw bricks dealt with in this study, were hardly acquired for just a few modest structures, but it seems likely that a large-scale building project was going on in town in the early 14th century. In Häme, brick use also probably started in the 14th century. The main building material of the Häme Castle may have been brick already at the end of the 14th century or early 15th century. The Crown seems to have launched brick use in Häme since the Holy Cross Church of Hattula was built only in the second half of the 15th century at the earliest. In the Åland Islands, brick may have been introduced only in the early 14th century. Compared to the Baltic Sea region, brick building was launched modestly in medieval Finland, but as seen in the overview of the known traces and remains, it is richer, more varied and earlier than recently believed.

KEYWORDS: Buildings archaeology, church archaeology, medieval archaeology, medieval bricks, medieval roof tiles, optically stimulated luminescence, radiocarbon dating of mortar, raw bricks, scientific dating, town archaeology, tree-ring-wiggle-matching, unfired bricks

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TIIVISTELMÄ

Tämän tutkimuksen aiheena on varhainen tiilen käyttö ja tiilirakentaminen keskiajan Suomessa. Siinä selvitetään, missä ja milloin tiilen käyttö alkoi, mitä tiilestä aluksi rakennettiin ja miten käyttö kehittyi ja laajeni. Lisäksi tarkastellaan tahoja, jotka vaikuttivat tiilirakentamiseen ja pohditaan lyhyesti, mikä tiilen merkitys rakennusmateriaalina varhaisimmassa vaiheessa oli. Aihetta lähestytään kolmen erilaisen arkeologisen ja rakennusarkeologisen aineiston kautta. Yksi aineistoista on Turun Koroisista, toinen Turun tuomiokirkon ympäristöstä (Varhainen Turku -hanke) ja kolmas Hattulasta (Pyhän Ristin kirkko). Koroinen ja Turku edustavat tiilen käyttöä varhaisessa kirkollisessa keskuksessa ja kaupungissa, ja Hattulan Pyhän Ristin kirkko ainoaa kokonaan tiilestä muurattua seurakuntakirkkoa keskiajan Suomessa. Tutkimuksessa on teetetty ajoituksia tiilestä, puusta, palaneesta luusta ja laastista eri luonnontieteellisin menetelmin. Lisäksi pXRF-menetelmän avulla tarkastellaan tiilien alkuperää Koroisissa ja Turussa. Tutkimustuloksia verrataan muihin mantereen sekä Ahvenanmaan rakennusarkeologisiin ja arkeologisiin kohteisiin sekä peilataan yleiseen tiilirakentamisen kehitykseen Itämeren piirissä.

Tutkimuksen perusteella tiilen käyttö alkoi mantereella 1200-luvun toisella puoliskolla. Tiiliä käytettiin monipuolisesti erilaisissa rakenteissa, tosin ensimmäiset tiilirakennukset rakennettiin vasta 1300-luvun toisen puoliskon aikana. Kattotiiliä, mutta myös tavallisia rakennus- ja muototiiliä tuotiin ulkomailta. Niitä kaikkia valmistettiin myös paikallisesti. Ensimmäisenä tiiltä käytti piispa, jonka tarkoituksena oli todennäköisesti korostaa kirkon hallinnollisen keskuksen merkitystä ja mahtia Koroistenniemellä. Heti Turun kaupungin perustamisen jälkeen tiiltä käytettiin myös puurakennusten tulisijoissa ja lattioissa, mikä viittaa siihen, että rakennusmateriaali oli myös muiden tahojen saatavilla. Toisaalta tiiliä tuskin hankittiin ainoastaan vaatimattomia rakenteita varten, vaan todennäköisesti kaupungissa oli jo 1300-luvun alkupuolella meneillään suuri tiilirakennushanke. Hämeessä tiilen käyttö lienee alkanut 1300-luvulla. Hämeen linnan päärakennusmateriaalina se on voinut olla jo 1300-luvun lopulla tai 1400-luvun alussa, joten siellä ensimmäisenä näyttää liikkeellä olleen kruunu. Hattulan Pyhän Ristin kirkko rakennettiin aikaisintaan 1400-luvun toisella puoliskolla. Muualla mantereella tiilen käyttö ja muuraaminen näyttää käynnistyneen 1300-luvun lopulla. Ahvenanmaalla tiiltä käytettiin mahdollisesti vasta 1300-luvun alusta lähtien. Itämeren piiriin verrattuna tiilirakentaminen käynnistyi melko vaatimattomasti keskiajan Suomessa, mutta tässä tutkimuksessa tehty katsaus osoittaa, että se on varhain ollut runsaampaa ja monipuolisempaa kuin viime vuosina on ajateltu.

ASIASANAT: Kattotiili, kaupunkiarkeologia, keskiajan arkeologia, kirkkoarkeologia, luonnontieteelliset ajoitusmenetelmät, rakennusarkeologia, tiili, polttamattomat tiilet, raakatiilet

Acknowledgements

When it was that my fascination with brick walls began, I have no idea. Maybe it was during my high school years, when I passed the factory buildings of Finlayson every day, or maybe after starting my studies at Turku and seeing the mighty Cathedral, or perhaps when I was living in one of the medieval brick buildings of Siena for six months. Nevertheless, my first encounter with building archaeology was in the autumn of 1996 when Professor Markus Hiekkanen gave his series of lectures about the building of the stone churches in the diocese of Turku. At the same time, I was looking for a topic for my BA thesis, and thanks to him, I got involved with the bricks of Häme Castle. In my studies, I was still aiming towards classical archaeology and was into Etruscans, but then, work opportunities in historical archaeology came up and led me in another direction. I guess after doing the church archaeological excavations at Hämeenkoski, studying building archaeology in Siena and participating in town archaeological excavations in Turku, there was no turning back. Bricks, stratigraphy and medieval times took over me. I would like to thank Professor Markus Hiekkanen for leading me into that world. Professor emeritus Jussi-Pekka Taavitsainen had his hands in the process, too, and I thank him for that.

Docent Kari Uotila stepped into the academic picture in my master's phase, when BA Ratilainen was searching for herself as a building archaeologist. From then on, Kari has been a great mentor to me. His hands-on innovative attitude, practical help with the equipment and many fruitful discussions on building archaeology helped and taught me a lot. Kari has always pushed me to reach further in my research, and I cannot thank him enough for that.

In 2007, I started to work on my PhD. My original idea was to study the building process and the builders of the Holy Cross Church of Hattula and Häme Castle and to make comparisons between the two with aid of 3D technology. I finished with my licentiate thesis on Holy Cross Church in 2012. However, during this time, it became clear that the topic was too time-consuming for a PhD, and I decided to concentrate only on Holy Cross Church. At the same time, I got involved with the At the Dawn of the Middle Ages project, for which I eventually worked for six months. In the project, my task was to re-analyse the building archaeological material of the Koroinen site. In 2014, however, I started my current job at the Museum Centre of

Turku. This intensive work as a town archaeologist made me soon realise that it would be impossible to deliver for both the Koroinen projects and my PhD on the side. Thus, re-arrangements had to be made once again. Thanks to the understanding of the Kone Foundation, it was possible to change the topic as well as the outcome to a set of articles.

In 2016, I took a year off and was able to fully concentrate on my dissertation work. Since then, the work has gone forward in the evenings and weekends and some days off, except for a three-month period in autumn 2018. I managed to submit the manuscript for pre-examination in June 2019 and got very positive reviews back in September 2019. Due to an exhibition project at work, I could only get back to the corrections in December 2019. At the same time, I got the reviews on my sixth article. The last one of the trials was certainly the Corona pandemic, which closed Finland in mid-March 2020. It not only gave me more time to put the final touches on the dissertation but also produced many consuming worries and concerns. Writing this, on the D-day, there probably can be no traditional dissertation followed by "karonkka" party. Thus, the possibility of saying thank you to those involved in this almost everlasting project is even more important than usual.

I would like to express my gratitude to the foundations who have made my full-time PhD work possible: the Finnish Cultural Foundation, the Häme Regional Fund (2006), the Turku University Foundation (2008), the Kone Foundation (2010, 2011, 2013) and the doctoral program Juno at the University of Turku (2018). With the travel grant by the Finnish Academy of Science and Letters, the Emil Öhman Foundation (2008), I was able to become familiar with many brick buildings in Northern Germany and Poland. In 2011, the Nordenskiöld-samfundet i Finland Foundation supported my trip to the Lake Mälaren area in Sweden. The dating project of the Holy Cross Church would not have been possible without financial support from the Hämeen Wanhan Linnan Kilta (2011), Knut Drake (2012), the Finnish Graduate School in Archaeology (2013) and the Turku Centre for Medieval and Early Modern Studies (2016). Thank you all for supporting my work.

Tireless supervisors of my work have been Docent Kari Uotila, Professor emeritus Jussi-Pekka Taavitsainen and, since 2018, Professor Visa Immonen. Docent emeritus Knut Drake and Professor Markus Hiekkanen examined my licentiate thesis. Docent Georg Haggrén and Senior research fellow Andres Tvauri, PhD were pre-examiners of the dissertation. My warmest thanks to You for all the valuable comments, insights and support. I am especially grateful for the opportunity to have conversations with Knut during his last research years at Juslenia, and I certainly wish I had done it more often.

During the Hattula years, I was always welcome to visit the church. I thank janitor Arto Hasari, Financial Manager Leena Nieminen, and gardener Kustaa Niini for their kind help. My warmest thanks to Martti Lampila, MA Päivi Luppi, my

father Tapani and my husband Harri for flying Kari's Zeppelin in the hardest of spring winds. Thank you, Päivi, for valuable discussions (and laughs) since the first day we met. I would also like to thank GM Seppo Kokkonen (Ukri Oy), who let me use the Dino and scaffoldings, and conservator Teemu Kajaste for great co-operation during the renovation works of the church in 2008. The guys at the former Helsinki University of Technology, Institute of Photogrammetry and Remote Sensing and the Institute of Geomatics (presently Aalto University, Department of Built Environment) deserve a big thank you also, especially archaeologist Nina Heiska and research manager Hannu Hyyppä. I truly appreciate the time and effort you put into the photogrammetry and laser scanning materials as well as your guidance in the 3D techniques. Furthermore, I thank Docent Tapani Tuovinen for helping me with statistics relating to brick measurements and Docent Auli Bläuer for the survival with Excel charts. I would also like to thank architect Marko Huttunen (Livady Oy) for the valuable observations concerning the roof trusses as well as PhD Rivo Bernotas and Professor Christofer Herrmann for organizing a session with me at the European Association of Archaeologists meeting in Helsinki in 2012.

Thanks a million to Professor Visa Immonen and Docent Janne Harjula, who invited me to the Koroinen project. It has been a rewarding journey. Co-operation with the whole team working on Koroinen has been fruitful in many ways. My warmest thanks also to university lecturer emeritus Pentti Koivunen who kindly shared information and materials about Koroinen and to Lic.Phil. Aki Pihlman, who wisely commented on my writings and with whom I have had many rewarding and fruitful discussions about archaeology during these years. Furthermore, many thanks to Docent Markku J. Oinonen and Docent Alf Lindroos. I truly appreciate the time you spent answering my endless questions about the dating methods, especially Markku for helping me with the coding of OxCal. Docent Pentti Zetterberg, thank you kindly for your contribution as well.

I would also like to thank my co-writers Kari O. Eskola, Janne Harjula, Visa Immonen, Jussi Kinnunen, Alf Lindroos, Markku J. Oinonen, Kirsi Salonen and Kari Uotila.

Auli, Elina, Janne, Kirsi, Mia, Mirva, Sari and Sonja, many thanks for being there for me and sharing my academic and less academic problems (and some of you also a room). A huge thanks also goes to the guys at the department, especially Anne-Mari, George, Henkka, Joonas, Juha and Jussi K., as well as to the whole group for silly talks and silly walks. I appreciate your help, advice and sharing. My warmest thanks also to my non-archaeologist friends, who keep my thoughts above the ground, especially Angela, Johanna, Marianne and Vera. I would also like to thank my boss, Maarit Talamo-Kemiläinen, and my colleagues at work for their understanding.

I cannot give enough thanks to my parents, Marketta and Tapani, for their support during all these years. I thank my children Joose and Saima and my husband Harri for their patience, support and understanding while having a mother and a spouse that was sometimes all too absent. You mean the world to me. I hope you've learnt that archaeology and science can also be fun (at least watching the Big Bang Theory show) and exciting.

It's still not perfect, but it's time to let go.

on a rainy day in Katariinanlaakso, on the 16th of May, 2020

Tanja Katariina Ratilainen

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Figures

List of Original Publications and Author Contributions

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Ratilainen, T. Unfired bricks used for a medieval oven in Turku, Finland. In: Ratilainen, T., Bernotas, R. and Herrmann, C. (Eds). *Fresh Approaches to the Brick Production and Use in the Middle Ages. Proceedings of the Session "Utilization of Brick in the Medieval Period – Production, Construction, Destruction," held in the European Association of Archaeologists (EAA) Meeting 29 August to 1 September, 2012 in Helsinki, Finland*, 2014; British Archaeological Reports International Series, 2611: 93–101.

II Ratilainen, T. At the dawn of masonry architecture – Church remains and associated brick structures at Koroinen, Turku. *Estonian Journal of Archaeology*, 2016; 20/1: 54–80, doi: 10.3176/arch.2016.1.03, peer-reviewed.

III Ratilainen, T., Immonen, V., Salonen, K. and Harjula, J. The bishop's brick house: Remains of medieval buildings on the river bank of Koroinen, Finland. *Lund Archaeological Review*, 2017; 22/2016: 61–87, peer-reviewed.

IV Ratilainen, T., Eskola, Kari O., Uotila, K. and Oinonen, M. How and when the brick church of the Holy Cross Church of Hattula in Finland was built. *Bebyggelsehistoriskt tidskrift*, 2017; 73: 69–99, peer-reviewed.

V Ratilainen, T. and Kinnunen, J. Identifying the origin of bricks and roof tiles with pXRF – A case study from medieval Turku, Finland. In: Mustonen, R. and Ratilainen, T. (Eds). *Pitkin poikin Aurajokea – Arkeologisia tutkimuksia omistettu Kaisa Lehtosen muistolle*, 2019; Turun museokeskus raportteja 23: 135–159.

VI Ratilainen, T., Oinonen, M., Lindroos, A., Harjula, J., Immonen, V. and Salonen, K. The contribution of bricks and mortar in the chronology of the fortified site of Koroinen, Finland. In: Biermann, F., Crettaz, E. and Herrmann, C. (Eds). *Burgen im Ostseeraum und ihre Verbindungen zum*

Westen, in print, Castella Maris Baltici XIV, Archaeologia Medii Aevi Finlandiae XXVII, Beiträge zur Ur- und Frühgeschichte, peer-reviewed.

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The author's contribution to publications III–VI:

III Ratilainen analysed the brick material and composed the original manuscript, while others made revisions and commented on it.

IV Ratilainen analysed the church (building archaeological study) and composed the documentation material (if not mentioned otherwise in the article) and wrote the section on the building archaeology. All of the original data can be found in Ratilainen's unpublished licentiate thesis in Finnish (Ratilainen 2012b), available at: https://www.academia.edu/2970089/. Kari Eskola analysed the OSL samples and composed the chapter on OSL sampling. The phase model analysis was performed by Markku Oinonen. Kari Uotila provided the digital measuring equipment and software and commented on the manuscript. The results and conclusions on the OSL were composed together by Oinonen and Ratilainen. The results and conclusions on the WM were composed by Ratilainen. The discussion on dating results and the final conclusions were composed by Ratilainen.

V Jussi Kinnunen made the analyses with the pXRF equipment and wrote the chapter on analysing methods and instrumentation and made revisions on the manuscript. In the conclusions, the last two paragraphs were written together; otherwise, it was composed by Ratilainen.

VI The manuscript was written by Ratilainen except for the paragraphs on modelling the dating results with OxCal and on OSL laboratory procedures at Luomus, which were written by Oinonen. Oinonen helped also with OxCal software and made revisions to the manuscript. Lindroos contributed to the section on Principles and restrictions of AMS dating of mortar and made revisions to the manuscript. Others commented and made revisions to the manuscript.

1 Introduction

1.1 Brick as a building material in medieval Finland

Traditionally, brick was considered a rare and an expensive building material in medieval Finland. It was mostly used in detailing work, such as window jambs, portals, pillars, vaults and gables of masonry buildings.[1] The few buildings erected entirely in brick were Häme Castle, Holy Cross Church of Hattula and Turku Cathedral. In addition to these, only some parts of stone churches would have been originally brick-built, such as the choir of Nousiainen, the porch of Isokyrö and the nave of Kirkkonummi.[2] However, since the 1990s, building and town archaeological research results from Turku have shown that the use of brick was more common and varied in the medieval period than previously believed. The town hall of Turku was probably a brick building, while burghers of the town also erected private brick houses.[3] Moreover, it seems that many masonry buildings in the area of the Dominican Convent were brick-built.[4] In wooden buildings, bricks were applied in hearths and floor structures. Some streets and paths were paved with re-used bricks and roof tiles.[5] Brick use seems to have flourished in 15th-century Turku.[6]

The same kind of tendency can be seen outside of Turku. For example, recent church archaeological studies in Naantali have indicated that the western choir and the related corridor were completely built in brick.[7] In Hattula, it was discovered that the walls of Holy Cross Church were constructed using a double-shell wall structure (article IV). In Raseborg Castle, a great amount of brick waste shows that brick was applied there more than just in detailing.[8] In several medieval village plots, brick has

[1] See, e.g., Ailio 1913, pp. 1, 6; Lindberg 1919, pp. 15–16; Gardberg 1957, pp. 4–5, 20, 31; Valonen 1958, p. 21.
[2] Hiekkanen 1996, p. 47, note 1. See also: Mäntylä 1976, p. 293.
[3] Uotila 2002; 2003a; 2006; 2009a; Ratilainen 2010.
[4] Hiekkanen 2003d, pp. 91–92; Immonen et al. 2014, p. 553 and references therein.
[5] Ratilainen 2010; Seppänen 2012a; 2012b.
[6] Uotila 2009b, pp. 306–307; Ratilainen 2010.
[7] Uotila et al. 2011
[8] Drake 1991, pp. 94–95; Uotila 2009c, p. 82.

been found in the oven structures, too.[9] However, the earliest phases of brick use and brick building, when and where it actually started, and in what forms it first appeared have not been the focus of recent research.

1.2 Aims of the research

The scope of this research is to answer the following main questions:

1) When did brick start to be used as a building material on the mainland of medieval Finland? Was Koroinen the first site where brick use emerged? When was brick technology introduced inland, to Häme?

2) What kinds of bricks were applied in the early phases? Are there only bricks used for building the walls, or were moulded bricks used, too? Were roof tiles already used in the early phases?

3) In which kinds of structures and buildings were bricks applied in the early phases and how?

4) Were the first bricks locally produced or imported?

Answering these questions may change our conception about the scale and quality of early brick technology in medieval Finland and may give ideas about how brick building was organised, which institutions may have been behind it and, furthermore, why it was chosen.

1.3 Definitions and outline

According to a Finnish expert dictionary (Vanhan rakentajan sanakirja), "brick" (tiili) is defined as an artificial, rectangular hexahedron building block made of clay or clay and sand hardened by firing.[10] In medieval times, bricks were produced in a much more varied way since pieces of bone and other materials were mixed into them.[11] Furthermore, they were also moulded and glazed for decorative purposes.[12] In general, bricks belong to a group of ceramic building materials, which also

[9] Väisänen 2016; Mikkanen 2017.
[10] Helamaa 2004, p. tiili, 258.
[11] E.g., Dahlbäck 1982, p. 142; article III.
[12] See, e.g., Andersson and Hildebrand 2002.

includes all kinds of tiles, terracotta, faience and mosaic.[13] In this study, brick is understood as a solid block for building walls and is also used, e.g., in hearths, floors and pavements. They are referred to here as bricks or wall bricks. Moulded bricks, which were used to make decorative details in masonry, are also included in this study and are referred to as moulded bricks or bricks. From the category of tiles, only some roof tiles are included in this study, referred to here as roof tiles or tiles.

The general chronological outline of this study is set to circa 1250–1430. This is because, during this time, bricks and roof tiles were introduced to medieval Finland. From a local perspective, both in the town of Turku and at Koroinen, either at the cape or the estate, there was probably a fire in 1429.[14] In the case of Koroinen, the possible fire, along with the sudden land slide to the river, seems to be the end of the active use of the cape.[15] In Turku, the fire of 1429 may be seen as a turning point, after which the number of brick and masonry buildings seems to have increased.[16] In addition, according to Hiekkanen, the 1420s–1430s also mark the launch of stone church building on the mainland of the diocese of Turku.[17] Thus, the general chronological framework of this study is between 1250 and 1430.

Geographically, medieval Finland is defined here according to the castle provinces, towns, manors and counties existing in the late medieval period (1475) and presented in the map by Georg Haggrén (Fig. 1).[18] Naturally, this outline does not directly reflect the situation in the earliest phase, in the 13th and 14th centuries. For example, the castle province of Kastelholm was not founded until the end of the 14th century.[19] Furthermore, the area of Savo was under the castle province of Viipuri until 1535, even if the Castle of St Olav was built at the end of the 15th century.[20] Vast areas of modern-day Kainuu belonged to the castle province of Korsholm. According to C. J. Gardberg, even areas from the west side of the Gulf of Bothnia belonged in the county of Korsholm.[21] Moreover, our understanding of the early borders of the administrative areas are not without ambiguities due to the scarcity of written sources.[22] In addition, the use of brick was not spread all over the inhabited area,

[13] van Lemmen 2013, p. 7.
[14] Aspelin 1898, p. 12; Gardberg 1971, p. 166; Kuujo 1981, p. 180. Gardberg mistakenly mentions the year 1423. Heininen 1988, p. 60.
[15] Ratilainen 2018; Ratilainen and Immonen 2018.
[16] Hiekkanen 2003d; Uotila 2003b; 2009b, pp. 306–307; Ratilainen 2010.
[17] Hiekkanen 1994; 2007; 2014.
[18] Haggrén 2015, p. 436. See also: Kivistö 2007, pp. 80–81.
[19] Gardberg 1993, p. 93.
[20] Gardberg 1993, p. 113.
[21] Gardberg 1993, p. 105.
[22] See maps in Kivistö 2007, pp. 80–81.

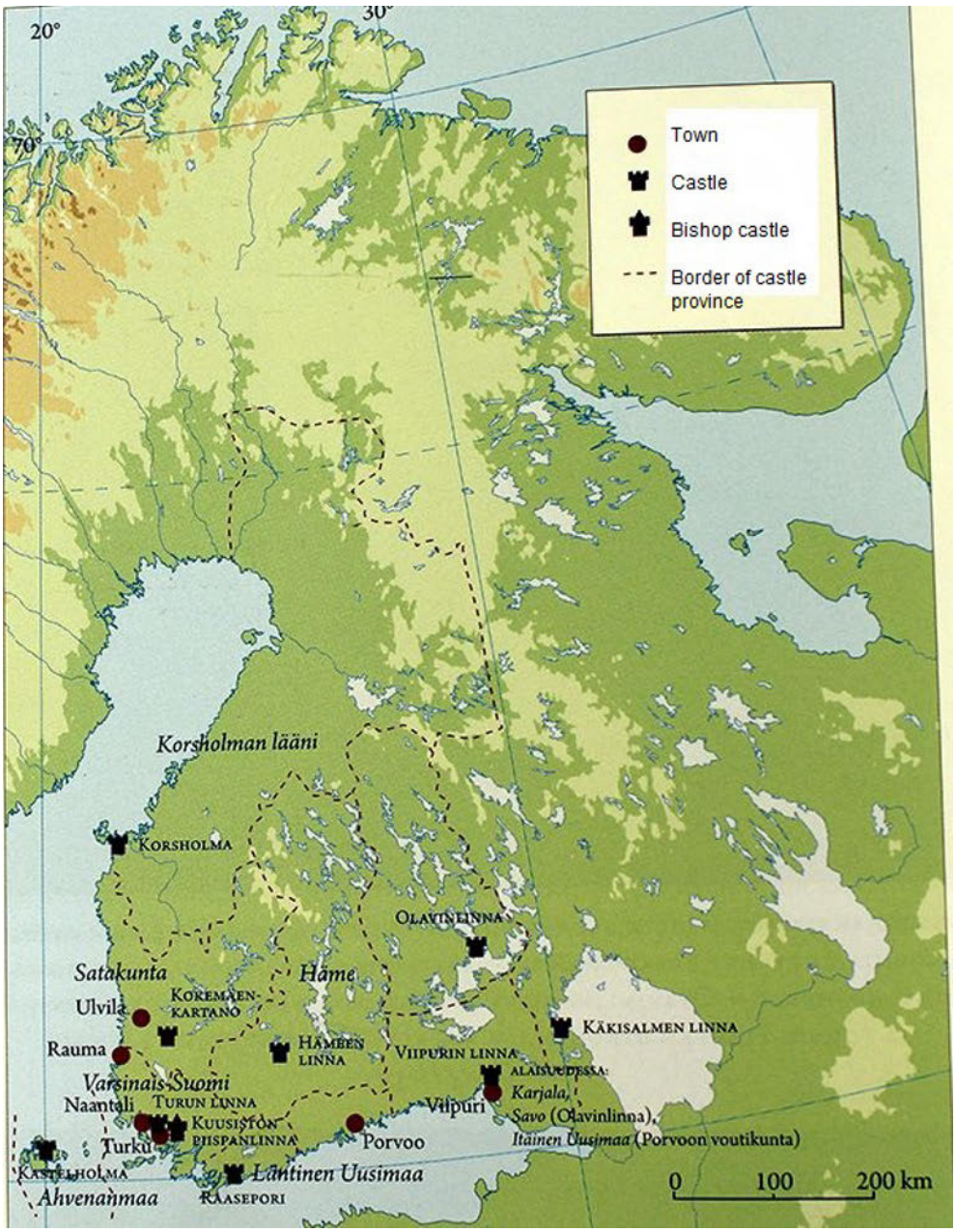

Figure 1. The castle provinces, Porvoo County, Kokemäki manor and medieval towns in 1475, defining Medieval Finland. HCCH is located near Häme Castle; two other materials of this study originate from the SW coast of Finland in Turku. Kartano = Manor, Voutikunta = County, Turun linna = Turku Castle, Hämeen linna = Häme Castle, Viipurin linna = Viipuri Castle, Raasepori = Raseborg Castle, Kastelholma = Kastelholm Castle, Olavinlinna = Castle of St Olav, Ahvenanmaa = Åland Islands. Original map in Haggrén 2015, 436, modified by Tanja Ratilainen.

even in the late medieval period. Nevertheless, the late medieval administrative area of Eastern medieval Sweden creates reasonable geographical limits for this study.

The administrative entities indicated in Figure 1 are: the castle province of Turku, Kastelholm, Raasepori, Häme, Viipuri, Korsholma and Olavinlinna. These are sites of the Crown's main castles. In contrast, Porvoo was actually a county that belonged to the castle province of Viipuri,[23] but it is handled here as a separate entity because it was an important factor in the region. Moreover, in Satakunta, there was no castle belonging to the Crown; rather, there was the manor of Kokemäki. Thus, in this study, the entity is called the Kokemäki area.

Certain areas or towns on the mainland fall out of the discussion due to their dating or research situation. The castle province of Korsholm is excluded from this study since the only site in the area, which might relate to the period in question, is a wooden castle probably built in the 1360s, but there is no actual data on brick remains.[24] There is no archaeological evidence on brick use from the castle province of St Olav prior to 1430, either; the construction of the castle began only in the 1470s.[25] The village plots are handled only in connection with the castle province of Raseborg since there are no published data from other areas.

In medieval Finland, the towns existing before 1430 are Turku (circa 1300), Viipuri (1316/1403), Ulvila (1340s/1365) and Porvoo (1380/1387).[26] The first known town rights of Rauma are from 1442, but it was probably already a town-like community in the early 15th century. However, the town of Rauma is excluded from this study since no archaeological contexts dating to the medieval period—and thus, relating to brick use—have been detected so far.[27] In addition, the ecclesiastical stone buildings in connection with the town, the Franciscan convent and the church of the Holy Spirit, were built only in the Late Middle Ages.[28] The research situation in Porvoo is similar; so far, no structures and deposits older than the end of 15th century have been found.[29] Thus, only the church and the fortress of Porvoo will be discussed. The sites included in the discussion are listed in Appendix 1.

[23] Gardberg 1996, pp. 147–148.
[24] Gardberg 1993, pp. 104–107; Suhonen 2003. Earlier, it was assumed to be the northernmost brickwork castle in Europe (Kuokkanen 1981, p. 35), but there are no grounds for this interpretation.
[25] See, e.g., Gardberg 1993, p. 109; Uotila 1998, p. 135.
[26] Harjula 2014, pp. 20–25 and references therein; Niukkanen et al. 2014, pp. 36–43 and references therein.
[27] Niukkanen et al. 2014, p. 42; However, cfr. Haggrén 2015, p. 463. Apparently, 15th-century material is sporadic.
[28] Hiekkanen 2014, pp. 247, 253.
[29] Hakanpää 2008; Niukkanen et al. 2014, pp. 40–42; Haggrén 2015, pp. 461–462.

1.4 Theoretical background

The theoretical background of this study lies in the building archaeological approach. As a discipline, building archaeology can be defined simply as a study of buildings in which buildings are the primary source of information.[30] It may be seen extensively from excavating Stone Age houses to investigating 21st-century layers of tapestry, but in the Finnish research tradition, the field has been narrower since it mainly includes the study of old masonry structures and buildings, both standing and underground. Both can be equally studied or "read" and equally excavated when necessary.[31]

Another important theoretical aspect of this study is stratigraphy and a context-related approach that derives from the Harris method.[32] The context excavation method has been used in Finland since the 1980s, but it was more systematically and commonly applied only in the 1990s onwards.[33] The same occurred in the study of standing buildings. Often, stratigraphic thinking was recognised or could be recognised through the interpretations of early scholars, but the point in the modern method is that the relative chronology, e.g., of the building phases, is documented with units in a systematic manner.[34] In an ideal situation, information gathered both above and underground are combined. The context-based approach naturally includes all the fragments, loose or sampled, and the finds directly related to buildings that need to be studied.[35]

The contexts should also be dated. For a long time, written sources, inscriptions and archaeological finds related to buildings were the only absolute means of dating.[36] Since the 1980s, scientific dating methods have provided more possibilities,[37] but the preservation of datable materials and what was saved from the excavations often set limits for choosing methods. In addition, taking samples from a standing building can be difficult or even denied by the heritage officials. Usually,

[30] Grenville 1999; Morriss 2000, pp. 8–10; Sundnér 2000, p. 26; Haedersdahl 2012.
[31] Drake 1984, pp. 13–17; Uotila 1998, p. 17; 1999, p. 28; 2000a, p. 83; Ratilainen 2012b; cfr. Seppänen 2012b, p. 29
[32] Harris 1979.
[33] Seppänen 2012b, pp. 36–45.
[34] Eriksdotter 1997; On the problems related to the method, e.g., Uotila 2000a; Eriksdotter 2005.
[35] See also: Haedersdahl 2012.
[36] See the dating methods applied: e.g., in church archaeology, Hiekkanen 1994, pp. 213–215; and in castle archaeology, Uotila 1998, pp. 17–19.
[37] See, e.g., a review: Holst 2010; Sanjurjo-Sánchez 2016.

dendrochronology provides the best means of dating both the town contexts and masonry buildings.[38]

Building archaeology can also be seen as a research method applied in church archaeology, castle archaeology and town archaeology, which, in turn, are part of historical archaeology.[39] In my view, the key here is the method in which the stratigraphic study of walls and structures, i.e., contexts, is acknowledged and is not limited "only" to the horizontal stratigraphy, which is all that is left when excavating underground in many cases. A building archaeologist aims to collect a three-dimensional set of information on a building or its remains and also tries to gain the fourth dimension, i.e., time. Through this basic method, insights regarding, e.g., the use of space or changes in the society can be reached.[40]

1.5 Methodological development

In the early days, bricks were measured, and their consistency and other qualities were studied visually, but the results were often handled very briefly in the publications. Many times, conclusions were drawn boldly and based on a small amount of material as well as references.[41] For decades, measuring bricks was also a means of dating.[42] In Finland, it was not until the 1970s and further in the 1990s that it was criticised, e.g., for circular reasoning: the expected age of the building was projected to bricks of a certain size, interpreted to be from a certain period. Other shortages were related to variations in brick size due to, e.g., shrinking.[43] However, measures and other qualities of bricks, together with the bonding technique, jointing and mortar quality, are good indicators of building phases in a single building and, thus, of relative chronology.[44] Furthermore, a lot of information, e.g., on the production and use of bricks can also be derived from the deposits including brick and other building waste.[45]

Former studies on masonry buildings were also based on styles, certain features and their evolution. For example, castles were dated according to their primitive

[38] E.g., Zetterberg 1999; Sanjurjo-Sánchez 2016.
[39] Taavitsainen 1999a; Lavento 2008, pp. 23–24; Rodwell 2012.
[40] Seppänen 2003, pp. 89–101; Eriksdotter 2005.
[41] See, e.g., Rinne 1914.
[42] Rinne 1914; Lindberg 1919; See also: Hiekkanen 1994, p. 214; Uotila 1998, p. 18 and references therein.
[43] Lilius 1971a; 1971b; 1976, p. 197; See also: Hiekkanen 1994, p. 214; Uotila 1998, p. 18 and references therein.
[44] Brogiolo 1988; See, e.g., Parenti 1988; Rodwell 1989, p. 75; Davies 1993.
[45] E.g., Palamarz 2002; Ratilainen 2010.

features, such as the use of stone, while the use of brick, embankments and moats were seen as more advanced and, therefore, younger. Furthermore, features considered to be Romanesque were seen as older than Gothic ones. Written sources were connected with buildings and their time of construction, even if the building was only indirectly mentioned in them.[46] Thus, source criticism in general, especially dating buildings, differed greatly compared to current times.

In addition, the relationship between a standing building, ruin or an underground structure and the deposits surrounding them were not the focus of previous archaeological research. The structures were mainly dug out in the open, and the finds were mostly neglected. Structures were not always documented, and many times, reports were not made. Primarily presenting only the interpretations and conclusions on the structures and not the observations and discoveries they were based on was common.[47] Sometimes, comments like 'I do not wish to bore the reader with details of the excavation' frustrates the modern researcher, who is left without information on what was really found.

Nowadays, studies on standing buildings and structures excavated underground are mainly well documented and reported. Moreover, since the 1980s, the use of scientific dating methods has considerably changed dating in archaeology as well as in building archaeology.[48] Furthermore, the use of digital 3D methods has remarkably improved the possibilities of presenting one's observations and interpretations compared to simple 2D plans and sections.[49] Lately, the use of scientific analysing methods, not just for dating, has also created new possibilities for brick research. For example, the method based on the Particle-Induced X-ray Emission (PIXE) has been used to analyse the chemical composition of bricks from Kastelholm Castle and Laukko Manor.[50] Furthermore, the Scanning Electron Microscope (SEM) method provided information on the origin of the ceramic materials found in Gubbacka village plot in Vantaa.[51]

[46] Lilius 1971a; 1971b. See, e.g., Rinne 1932, pp. 90–92; Drake 1968.
[47] Uotila 1998, p. 17.
[48] See, e.g., Aitken 1990; Zetterberg 1999; Sanjurjo-Sánchez 2016; Blain and Hall 2017.
[49] E.g., Uotila 1999; Uotila and Tulkki 2002; Ratilainen 2009; Uotila 2009c; Ratilainen 2011.
[50] Lindahl 1988; Wahlberg 2000.
[51] Holmqvist-Saukkonen et al. 2013; 2014.

1.6 Research history – general concepts on building with brick

According to Rinne, masonry arrived in medieval Finland during the second half of the 12th century and the use of brick at the end of the same century. The first stone building was in Masku, Stenberga, where the assumed Bishop's Castle was built before the see was moved from Nousiainen to Koroinen in the 12th century. The first bricks appeared at Koroinen.[52] Gardberg pointed out that this would have meant that brick arrived in Finland earlier than in the Mälaren region.[53] Another early site in which bricks were used was the hillfort of Vanhalinna, the assumed predecessor of Turku Castle. In Häme, according to Rinne, the first masonry and brick structures were erected in the mid-13th century at Hakoinen hillfort, the predecessor of Häme Castle.[54]

After Rinne, Iikka Kronqvist presented another chronological main framework which was generally accepted for a long time. According to Kronqvist, the stone choir of Koroinen and the stone sacristies of Turku Cathedral and Mynämäki were constructed in the early 13th century; brick was not yet applied in these structures. In the next phase, at the end of the 13th and the beginning of the 14th century, sacristies with brick vaults and other details were started in the parish churches of Finland Proper. The trigger for this development was the second building phase of Turku Cathedral, in which brick had started to be used, as well as the building of the Nousiainen and Mynämäki churches. Most of the churches in Uusimaa were built at the end of the 14th century and throughout the 15th century. However, the first phase of Inkoo Church, which was the oldest, was built at the end of the 13th century. Based on brick structures, Kronqvist dated the stone church of Kirkkonummi to the mid-13th century. The first stone churches in the Åland Islands were dated to the second half of the 13th century based on Romanesque or archaic features.[55]

According to Kronqvist, the building projects of medieval parish churches of stone usually started from the stone sacristy, which was built next to the north wall of an earlier wooden nave. In the next phase, when the economic situation was favourable, the stone nave was constructed, wooden vaults were replaced by brick ones, brick gables were erected, and a stone porch was built. Between the building phases, decades passed, and masons changed. Turku Cathedral was seen as an example which parish churches followed. The use of brick was one of the features

[52] Rinne 1914, p. 201; 1932, p. 90; 1941, pp. 41, 51–52; Gardberg 1957, pp. 6–8.
[53] Gardberg 1957; 1971.
[54] Rinne 1914, pp. 210, 227–228, 262, 280–281.
[55] Kronqvist 1979, pp. 11, 13.

showing a slightly younger age of the structures.[56] This chronological and evolutionary framework of building stone churches created by Kronqvist prevailed for many decades.

In the post-war era, the major castles of the Crown had begun being renovated and building archaeological studies made. The information gathered from the castles was mainly embedded in the same kind of chronological and evolutionary framework as in church archaeology.[57]

Based on the first systematic classification, as well as on scientific dating, Hiekkanen presented a completely new interpretation of stone church building in 1994. Stone churches were mainly built as a single building project, from the foundations to the wall paintings, by the same group of masons in a short period of time.[58] In the Åland Islands, stone church building started in the 1270s and ended in the early 16th century. In Finland Proper, the archipelago and Eastern Uusimaa, the parish churches of stone were erected mainly between the 1410s and 1480s, while in Western Uusimaa, building works began at Inkoo in the 1430s at the earliest but were mostly going on in the second half of the 15th century. In the Satakunta, Tavastland and Korsholm areas, stone churches were built from the mid-1490s until 1560.[59] Consequently, the dating of the masonry and brick structures at Koroinen was questioned by Hiekkanen. In his view, the assumed masonry choir could have been a late medieval memorial chapel built for the bishops. Also, the age and function of the masonry structures interpreted as the bishop's keep and a palace were suspected.[60]

After Hiekkanen's doctoral dissertation, the dating of the brick Turku Cathedral was problematic since it was a hundred years older than the parish churches of stone in the vicinity.[61] Knut Drake proposed a new chronological framework, according to which the brick cathedral was built at the end of 14th century or by 1425 at the latest.[62] Later, Drake preferred the period of 1370–1390.[63] Two preceding stone building projects were interrupted, but brick details were built in them. The first one was started in the early 14th century. The interpretation was also supported by the

[56] Kronqvist 1948; 1979.
[57] Gardberg 1959, p. 19; Sinisalo 1964; See, e.g., Drake 1968.
[58] Hiekkanen 1994, p. 248; On the research methods: 1994, p. 12; 2003b, pp. 28, 44; 2014, p. 24.
[59] Hiekkanen 1994, pp. 217–246, 248; 2000; 2014, pp. 24–26, 433, 364, 377, 407.
[60] Hiekkanen 1994, p. 246; 2002b, pp. 410–411; 2003b, p. 89; 2014, pp. 185–186.
[61] Kronqvist 1948, p. 34; Gardberg 1987a, p. 53; Hiekkanen 1994, pp. 225–227; Gardberg 2000, pp. 38–39.
[62] Drake 2003b, p. 138; 2003c, pp. 85–86; 2005, p. 483; 2006, pp. 17–21; 2009, pp. 182–191.
[63] Drake 2013.

fact that no urban archaeological deposits dating to the 13th century were found in the surroundings of the cathedral.[64]

Eventually, this great change in the general view of church building on the mainland also affected the study of castles. Earlier, the western gate of Turku Castle had been dated to the end of the 13th century,[65] but in the 1990s, Drake proposed dating it to the early 14th century instead.[66] Also, in Häme, the dating of the castle and the HCCH were set circa one hundred years later than before.[67] At the same time, doubt was cast upon the early dating of the brick structures found, e.g., in Hakoinen and Vanhalinna since Taavitsainen's doctoral dissertation showed that many of the hillforts were much younger than previously expected.[68] In addition, the minor castles, which were wooden or stone with brick features and previously assumed to date to the 12th and 13th centuries, were re-dated, partly with scientific dating methods, to the end of the 14th century or later.[69] Consequently, building in masonry and the use of brick seemed much younger than previously expected. In contrast, the archaeological research of the town suggested that masonry buildings and brick structures were already being constructed in Turku in the early 14th century,[70] a hundred years before the stone churches were begun. Furthermore, in the countryside, some stone cellars were built before the stone church of the parish was erected.[71]

1.7 Koroinen and At the Dawn of the Middle Ages project

The bishop's fortified site of Koroinen was excavated at the turn of the 20th century by Hjalmar Appelgren and Juhani Rinne. The excavation report was never completed, and the material was not thoroughly analysed and published. Fortunately, the excavation was well documented for its time, e.g., sieves were used, and all the finds except for the human bones were saved. A coordinate system was applied in the documentation, and notes, photographs, and drawings were made.[72] Rinne presented his interpretations in the first part on the history of Turku Cathedral and

[64] Drake 2003b; 2003c; 2005; 2006; 2009; 2013.
[65] Kronqvist 1946, pp. 7–32; Gardberg 1957, pp. 25, 48–50, 54–57; 1971, pp. 189–190.
[66] Drake 1994, pp. 49–56.
[67] Drake 2001a; Ratilainen 2001b; Drake 2003a; Hiekkanen 2003a; Ratilainen 2003.
[68] Taavitsainen 1990; 1999b.
[69] Drake 1993, p. 240; Lovén 1996, pp. 308–309; Suhonen 2002a; 2002b; 2002c.
[70] Uotila 2002, pp. 8–10; 2003a, pp. 123–125; Ratilainen 2010; Seppänen 2012b, p. 649.
[71] Uotila 1985; 1992, p. 198; 2009a, p. 307b.
[72] See e.g. Koivunen 2003; article II and III.

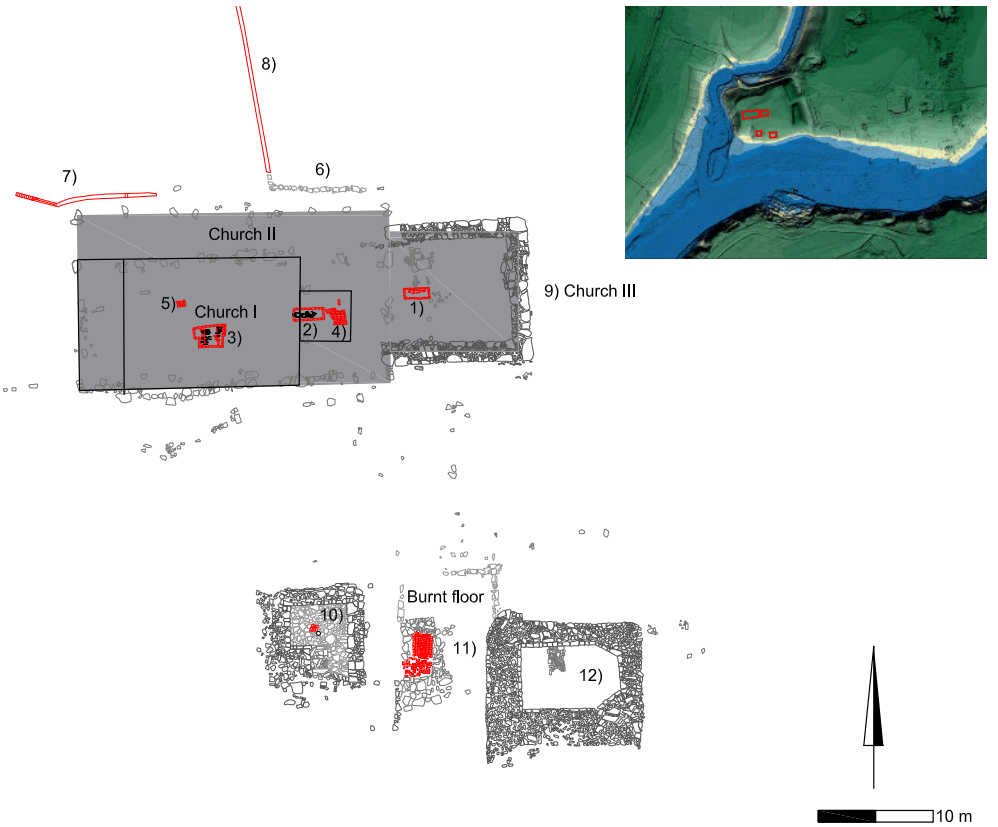

Figure 2. Structures and building remains at Koroinen. The brick structures are marked with red. Church area: two consecutive wooden churches (I–II). 1–3) Brick-walled graves; 4) brick altar in Church I; 5) font foundation in Church II; 6–8) sub terrain drain (mostly bricks) built for Church II; 9) masonry foundations of a stone church (III). Residential area: 10) stone keep with first stone and then brick floors; 11) wooden building with a heat storage hypocaust in brick and a brick floor in front of the hypocaust and a burnt floor level on the north part; 12) remains of a brick house, the bishop's residence. (Drawing: S. Hukantaival and T. Ratilainen. Digital Surface Model in the right corner: K. Uotila). Map published in article VI.

touched briefly on the subject in many of his writings.[73] Pentti Koivunen continued his work by gathering all the finds, samples and documentation material dispersed throughout the decades,[74] but other engagements took his time. Over the years, because of its importance in church history, Koroinen became an iconic archaeological site and the subject of many published overviews and separated finds

[73] Rinne 1914; 1932; 1941; 1946.
[74] Koivunen 1977; 1979; 2003.

analyses,[75] but there was no profound analysis of the documented material. Among many things, Koroinen was considered to be the first site where brick was introduced as a building material.[76]

The project *At the Dawn of the Middle Ages* (2012–2018) was begun to study the Koroinen material thoroughly as a whole. During this project, all the structures of the site were re-analysed and published. The saved building fragments, including bricks, were analysed and the results published for the first time (articles II and III). Furthermore, the full potential of the dating material was used to create a new, more solid chronology of the site (article VI). Thus, this created an opportunity to re-evaluate the early brick use.

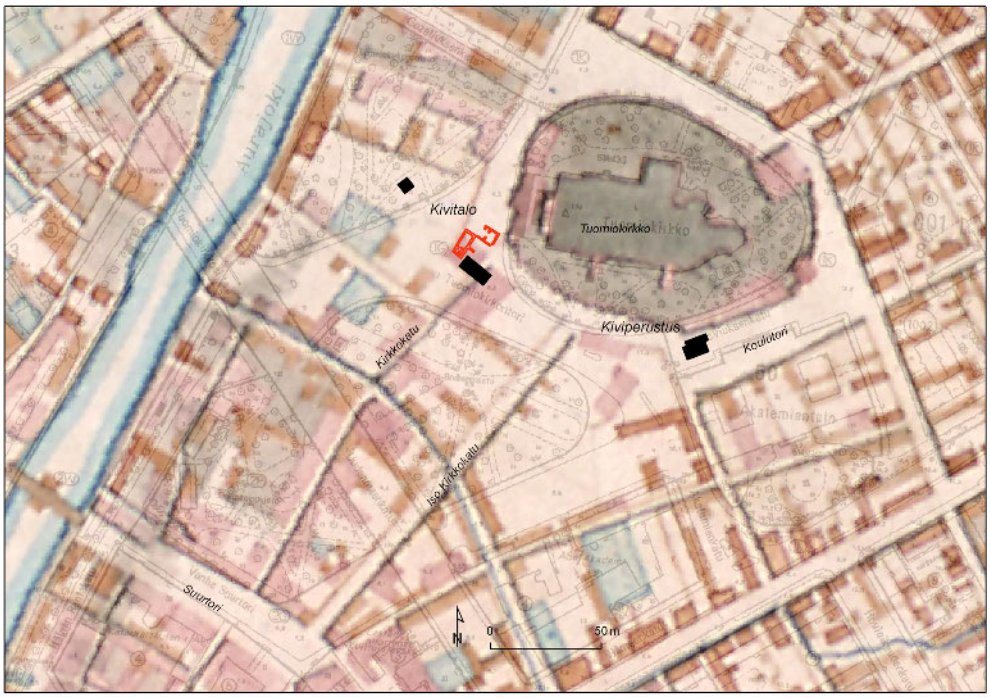

Figure 3. The excavation areas (in black) of the EPT project around the cathedral. The so-called Russian map (1743) fitted together with the present-day plan. Map by Tapani Tuovinen / MCT and modified by Tanja Ratilainen.

[75] See Harjula and Immonen 2012 and references therein.
[76] Rinne 1914, p. 201; 1932, p. 90; 1941, pp. 41, 51–52; Gardberg 1957, pp. 6–8; Koivunen 2003, p. 54.

1.8 The Early Phases of Turku (EPT) project

The excavations conducted by the EPT project (2005–2007) were the first excavations in Turku in which the archaeological research interests and not a development project defined the premises. The aim of the research was to study the oldest settlement of the town, which was expected to locate near the cathedral and to date to the end of the 13th century. Surprisingly, the earliest traces of urban settlement were dated only to the beginning of the 14th century, while plough marks and radiocarbon dating results indicated that the surroundings of the cathedral had been under cultivation in the 13th century. Later, more traces of cultivation were found, and it currently seems that the town was founded only at the beginning of the 14th century.[77] The project provided excellent brick material to investigate the early phases of brick use in town, including the unusual oven made of unfired bricks found during the excavations (article I).[78]

Figure 4. HCCH from the southwest. Photo by Tanja Ratilainen published in article IV.

[77] Pihlman 2007; 2010; See further: Seppänen 2012b; Ratilainen et al. 2016; Seppänen 2019.
[78] Excavation report: Ainasoja et al. 2007.

1.9 The Holy Cross Church of Hattula (HCCH)

The Holy Cross Church of Hattula in Häme is the only parish church in medieval Finland that was originally completely brick-built. It was previously considered to have been the mother church of Häme, built in the 13th century.[79] Over the years, the church got younger and younger,[80] but not even the dendrochronological dating method seemed to provide answers about the construction time of the church.[81] A detailed building archaeological study in 3D showed that the church was likely built as a single building project by a certain group of masons (article IV), but two different hypotheses on the dating still remained: the one claiming it was built at the end of the 14th century and an another saying a hundred years later.[82] Thus, other methods such as OSL and WM had to be implemented (article IV). Furthermore, the latest interpretations on the building phases of Häme Castle and the coin analyses raised questions about the introduction of brick building in Häme (article IV). [83]

1.10 The acquisition of bricks

After Carolus Lindberg's dissertation in 1919, it was a generally accepted idea that brick-making skills arrived with the foreign masons and bricklayers; thus, bricks would not have been imported to medieval Finland.[84] The kilns were founded nearby the construction sites, and the bricks were not usually transported for long distances. This is also supported by the archaeological evidence on medieval brick production.[85] On the other hand, Eemeli Winnari and Knut Drake have proposed that the first bricks might actually have been imported.[86] Written sources from the 16th century show that merchants of Viipuri imported bricks into the town, even if they were also produced there at the same time.[87] In general, the 17th-century yellow bricks from the current Netherlands area are considered to be the first imported

[79] Nervander 1887; Aspelin 1891, p. 11; Ailio 1913, pp. 2–9; Mäntylä 1976, p. 290.
[80] Lindberg 1934, p. 37; But cfr. Wennervirta 1937, p. 178; Kronqvist 1941, p. 50; Jaakkola 1944, pp. 137–138; Kartano 1946; 1948; Kronqvist 1948, p. 50; Rinne 1952, p. 59; Hällström 1955, p. 4; Pettersson 1955, p. 574; Mäntylä 1976, pp. 290–291.
[81] Cfr., e.g., Knapas 1997, p. 17; Hiekkanen 2000.
[82] Knapas 1997, p. 17; e.g., Ratilainen 2001b; 2003; Hiekkanen 2003a.
[83] Cfr. Drake 2001a; 2003a; Ehrnsten 2013; 2015; 2019, p. 163.
[84] Lindberg 1919, pp. 14–16; Gardberg 1957, pp. 6–7, 20, 32; Drake 2007, p. 115; Seppänen 2012a, p. 7.
[85] Knapas 1974; Kuokkanen 1981, pp. 42–46; Smith 1985, pp. 39, 60; Antell 1986, p. 9; Uotila 2000b, p. 121; Andersson and Hildebrand 2002, pp. 51–55; Hiekkanen 2003b, pp. 31–32; Svanberg 2013, pp. 31–32; article I.
[86] Winnari 1925, p. 60; Drake 1967, p. 29.
[87] Issakainen 2010, p. 26.

bricks.[88] In turn, roof tiles are assumed to have been mainly imported, but this has also been verified using the Pixe method with Kuusisto and Laukko roof tile materials.[89] This topic is dealt with in article V.

[88] Gardberg 1957, pp. 96–97; Uotila 1991, p. 167; Andersson and Hildebrand 2002, p. 52.
[89] Venhe 2000, p. 114; Wahlberg 2000; Uotila 2009b, p. 311; Seppänen 2012b, pp. 802–803.

2 Materials and methods

2.1 The Koroinen material

The structures and remains of buildings documented at Koroinen and a total of 514 bricks or their fragments collected from the site comprise the core of the church archaeological material of this study (articles II and III). Most of the brick samples are small fragments of moulded bricks. Of the 441 identified moulded brick samples, only 14 were whole. Of 54 identified wall brick samples, only 14 were whole.

Unfortunately, 16 brick samples are missing, and two fragments were not identified by type.[90] In addition, there are a couple of unnumbered brick fragments for which the context is lost. The missing bricks probably got lost in the bombing of Turku Castle or were reused there.[91] Unfortunately, this applies to all of the brick structures from the church area in Koroinen, such as the brick-walled graves 2 and 3, the foundations of the altar and the font (article II). In addition, Rinne did not save any bricks from the brick-walled grave 1 (article II). A photo of each moulded brick type from Koroinen is presented in Appendix 2.

For the pXRF analysis, 20 brick samples from Koroinen were chosen. Most of them are from the brick waste layer found above and inside the structures on the riverbank. In only a few cases, it is certain that these samples derive from an in situ structure (1417a–c, 1449d, 1450c). Eleven of the pottery fragments used as reference material were locally produced, and five were imported.[92] All of the local pottery derives from outside the embankment area, which was excavated by Pentti Koivunen in 1974 and 1977.[93] The pottery material was selected by Aki Pihlman. All the pXRF-analysed bricks were also dated with OSL (article VI, Table 1).

[90] Missing bricks: KM52100:1451, 1455, 1458, 1459, 1461, 1475, 1503, 1595. Unidentified: KM52100: 1417a, 1417b.
[91] Koivunen 2003. It is also possible that some have gone missing since arriving in Oulu; however, according to the notes found among the bricks, most seem to have been lost before they were transferred to Oulu.
[92] See the latest analysis on them: Pihlman 2018.
[93] See Koivunen 2003.

2.2 The EPT project and reference material from the town of Turku

The oven foundation made of raw bricks and a selection of the brick and tile material collected during the excavations of the EPT project constitute the core of the town archaeological material of this study. The oven is interpreted and dated in article I. From the collected materials, fifteen bricks and three roof tiles were chosen for a pXRF analysis based on their context and dating (article V).[94]

Locally produced reference material of two bricks and ten pieces of pottery was used. The reference bricks are from the oven foundation made of raw bricks. The locally produced reference pottery material derives from several excavations: Tuomiokirkonkatu (1976), Suurtori/Raatihuone (1986–1987), Linnankatu 35b (2012) and the Cathedral School (2015). The imported pottery selected for the reference material is from the following excavations sites: Suurtori/Raatihuone (1986–1987), Nunnankatu 4 (2004), Itäinen rantakatu (2010), Kaupunginkirjasto (2003–2004), the EPT project/Tuomiokirkontori (2005–2006) and Cathedral School (2015).[95] The sample ID 36 (TMM22367:KE1034:006) in Table 1 (article V) was excluded from the reference material since it was not certain whether it was imported or locally made, but it is among the IDs shown in the figures of article V, which present the elemental compositions. Two reference bricks were imported Dutch bricks from the 17th century or later. One of them was collected from the Cathedral School excavation (2015) and the other from the Porthan–Brahe park excavations (2010) (article V, Table 1). The corrections to Table 1, published in article V, are presented in red in Appendix 3.

So far, the roof tile material from Turku has not been studied thoroughly as a whole. Only three roof tiles are included in this study; therefore, they are not dealt with equally to other materials but are mainly in connection with importing ceramic building materials.

2.3 The HCCH material

The vertical stratigraphic data and the dating results from the HCCH (article III) comprises the third main church archaeological and building archaeological core of

[94] In article V, the amount of bricks and tiles analysed from the town is mistakenly reported to be 38 (which is the total amount of bricks) instead of the correct 18.
[95] I thank Aki Pihlman for selecting the reference pottery. About the mentioned excavations and pottery analyses, see: Pihlman 1995; Tulkki 2001; Pihlman 2003; Laukkanen and Sipilä 2004; Tuovinen and Team 2004; Ainasoja et al. 2007; Ainasoja 2010; Sipilä 2013; Saloranta 2018; Pihlman and Savolainen 2019.

this study. For the first time, the exterior walls of the church were studied thoroughly with stratigraphy in mind, and they were documented brick by brick with rectified photos in scale. The 3D digital techniques applied also created new possibilities for building archaeological examination.[96] The building process and the duration of the construction works is not the focus of this dissertation; however, the brick material for dating could only be selected through a thorough study of the church.

2.4 Archaeological and building archaeological methods

In this study, all structure and building remains at Koroinen were re-analysed and interpreted, first based on the documented material alone and then as a whole if possible (articles II and III). Then, the brick and mortar samples for dating and pXRF analysis were chosen (articles V and VI). In dating the structures, finds were also included, consisted mostly of pottery analysed by Aki Pihlman and coins analysed by Frida Ehrnsten.[97]

The brick material from Koroinen and from the EPT project was studied for traces of fire, mortar remains, glazing and limewash as well as for the bricks' consistency, colour, size and the marks and traces made on their surfaces (articles III and V). All the information was saved on an Access database or in an Excel table. The same kind of study, though not as detailed, was performed during the stratigraphic study of the brickwork of the HCCH. In addition, the mortar, joints and bonding technique as well as many types of irregularities in the masonry were studied and the building stages defined. The observations were documented on a 3D CAD model and in Excel tables (article IV).

2.5 Scientific methods

The scientific methods applied in this study can be divided into two groups: dating methods and a material analysis method. The dating methods applied are dendrochronology, tree-ring-wiggle-matching (WM), optically stimulated luminescence (OSL) and radiocarbon dating of organic substances and of mortar (^{14}C-AMS). Each method was chosen based on the datable materials available and the context they would date. The material analysis of bricks and tiles was performed with a portable X-ray Fluorescence spectrometer (pXRF). In the next paragraphs, the

[96] Ratilainen 2009; 2011; 2012a.
[97] Ehrnsten 2018; Pihlman 2018; Ehrnsten 2019, pp. 277–278, 303–304.

less commonly applied dating methods, such as WM, OSL, radiocarbon dating of mortar and the pXRF method, will be shortly introduced.

2.5.1 Tree-ring-wiggle-matching

In tree-ring-wiggle-matching, radiocarbon dates are acquired every 10 or 20 tree-ring intervals, thus in known calendar years with a sequence minimum of 50 years. In this way, the wide probability range of a certain calendar year period gained by radiocarbon dating can be narrowed down since the sequential radiocarbon datings are more precisely matched with the wiggling calibration curve.[98] The method is expensive since it requires several radiocarbon dates, but it is worthwhile when the tree sample is deformed in a way that makes dendrochronological dating impossible, or if it is in a difficult location so that sampling is not possible. The latter situation applied to the case of the lower bolt timber inside the west wall of the Holy Cross Church (article IV). The best results are naturally gained when the last tree rings are preserved. The method can also be used when analysing stratigraphic sequences and dating several short-lived samples in each context, after which the modelling of dates with a priori information is performed. In this way, the usability of radiocarbon dating in historical archaeology is largely improved since it yields very precise dating results.[99] However, the cost of this method is high. So far in Finnish medieval archaeology, this method has been rarely applied.[100]

2.5.2 Optically stimulated luminescence

Optically stimulated luminescence is a dating method based on measuring the radiation dose of crystalline minerals (e.g., quartz, feldspar) in the materials or layers after the last heating, i.e., zeroing event of accumulated radiation. The ceramic materials must be heated above 400 degrees to gain the zeroing event. When the traps in crystalline minerals are stimulated with external energy, by light in OSL, the radiation dose can be deduced by measuring the amount of emitted luminescence light. The time to the last zeroing event is obtained by dividing the total dose (the paleodose) by the annual dose. The annual dose rate should be measured on site.[101]

[98] Aitken 1990, pp. 103–104; Oinonen et al. 2013.
[99] Oinonen et al. 2013.
[100] See Oinonen et al. 2013; Article IV.
[101] Aitken 1985; Bailiff 2008; Blain and Hall 2017.

Particularly, the OSL method requiring smaller sample sizes than TL and with well-controlled light exposure has been successful in dating bricks.[102]

The wide error margins have partly been a limiting factor, but also, applying the Bayesian chronological tools here supports OSL dating so that it can be applied together with other methods.[103] For a more thorough discussion, see article VI.

2.5.3 Radiocarbon dating of mortar

The radiocarbon dating method of mortar is based on the principle that, as the lime mortar (calcium hydroxide) hardens, it reacts with carbon dioxide in the atmosphere and turns back into stone again (calcium carbonate). Since mortar cannot be re-used like bricks can, it is ideal for dating. In principle, the hardening of mortar equals the construction time of the building or structure.[104] In practice, there are several error sources that must be considered in the dating process, such as the re-crystallization of mortar and delayed hardening, which produce ages that are too young. In turn, not fully burnt limestone and lime sand may contaminate the sample and project the age to be too old. One must also be careful with sampling.[105] Fire-damaged and hydraulic lime mortars behave differently than non-hydraulic mortars.[106]

With the sequential dissolution method, in which 3–5 fractions per sample are dated, it is possible to recognize the contaminants from a non-hydraulic mortar sample. In addition, dating pure lime lumps, which are not fully mixed pieces of lime in the mortar, are good for dating since they do not contain contaminants. It seems that, with the procedures developed, conclusive results are gained in most cases.[107] However, the method is expensive, and because the radiocarbon dating often has wide margins, it appears to be more useful together with other dating techniques than alone.[108] Like WM, analysing stratigraphic sequences and modelling of dates with a priori information probability ranges could be narrowed down.

[102] Sanjurjo-Sánchez 2016.
[103] Oinonen et al. 2013.
[104] E.g., Perander 1985; Konow and Lindroos 1997, p. 209; Ringbom 2010, pp. 137–139; Ortega et al. 2012; Sanjurjo-Sánchez 2016, pp. 625–626.
[105] Van Strydonck et al. 1986, p. Heinemeier et al. 1997; 2010, pp. 172–173; Lindroos et al. 2012; Ringbom et al. 2014; Sanjurjo-Sánchez 2016, p. 626; Lindroos et al. 2020.
[106] E.g., Ringbom et al. 2014, p. 624.
[107] Heinemeier et al. 2010; Ringbom et al. 2014; Sanjurjo-Sánchez 2016.
[108] See, e.g., Heinemeier et al. 2010; Ringbom et al. 2014.

In Finnish medieval archaeology, the method has been applied mostly by its developers in the Åland Islands, the archipelago of Turku and to Turku Cathedral.[109] For a more thorough discussion on the method, see article VI.

2.5.4 pXRF

The pXRF (portable X-ray fluorescence) method is an analytical method where the element composition of the surface of a solid or liquid material is analysed. X-ray radiation energy is used to stimulate electron transitions in surface atoms of the sample. This also wakes up secondary fluorescent radiation, where the energy level of each quantum is characteristic of a corresponding element. Emitted secondary fluorescent radiation quanta are detected and counted by the pXRF instrument. Finally, the proportions of the counted elements are calculated, and their percentage value is an analysis result. The pXRF method is generally suitable only for heavier elements (Z>12) and also has many other restrictions which have to be accounted for (article V). [110] On the equipment and quality control, see Jussi Kinnunen's (2019) study.

In this study, the pXRF equipment was tested on brick and tile material for the first time in Finland. Some previous pXRF analyses on medieval bricks and tiles have been published in Europe.[111]

2.5.5 On the scientific methods used in this study

At Koroinen, the preservation of organic materials was not good; therefore, the starting point of the project was to use the full potential of the datable materials and to date as many samples as possible with different methods. Moreover, we had to cope with ambiguities in the documentation of the contexts. Thus, OSL on bricks and the ^{14}C-AMS of organic substances was mainly applied, but radiocarbon dating of mortar was also tested. In addition, to improve the probability ranges of the dating results, two or three different materials from the same context were dated when possible. To my knowledge, this was the first attempt to date brick pieces in the mortar, the mortar itself, and a brick from the same context. Unfortunately, the brick piece turned out to be too small for dating. From other contexts, however, a brick

[109] Ringbom 2010; Lindroos et al. 2011; Ringbom et al. 2011; Sjöberg 2011; Ringbom et al. 2014.
[110] See, e.g., Holmqvist 2017; Kinnunen 2019.
[111] Donais and George 2013; Bonizzoni et al. 2013; Lamm and Lindahl 2014; Lensen 2015. On pottery research: Jokisalo 2018; On building stone research: Kinnunen and Seppänen 2019.

and burnt bone in the brick, as well as a brick and jointing mortar attached to it, were successfully dated. Radiocarbon dating results of mortar were modelled together with OSL for age control and to get narrower margins for probability ranges. In only one case, it was applied alone (article VI). The OSL sampling report of Koroinen is attached in Appendix 4, the OSL dating report in Appendix 5, the mortar dating reports in Appendix 6a–b, and photos of mortar samples before and after sampling in Appendix 7.

In the project EPT, dendrochronology and radiocarbon dating (of seeds) were applied as routine town archaeological dating methods when the contexts and stratigraphy relating to the oven made of raw bricks were dated (article I). This applies also to the contexts in which bricks chosen for the pXRF analysis and the reference material were found (article V). The good preservation of organic materials, along with context documentation, provided time frames within 20 to 50 years, or even within a decade.[112]

To date, the construction time and phases of the HCCH, dendrochronology, OSL and WM were used (article IV). They were planned to be combined and modelled with the OxCal software, but only the OSL method provided results, likely in connection with the construction time of the church (article III). In this case, the problem with dendrochronology and with WM was the re-use and working of timbers (lack of last tree-rings) as well as deformed tree-rings. For example, the scaffolding timber was felled in 1205–1225, and the log inside the west doorway of the nave provided a dating to the early 14th century. Therefore, the OSL method, even with wide margins, finally provided conclusive results. The dendrochronological dating report of the HCCH is in Appendix 8, the WM dating report in Appendix 9 and the OSL dating report in Appendix 10 of this work.

For provenience analyses, the Olympus Delta DP-6500 portable X-ray fluorescence spectrometer with Mining Plus application was applied. The area of analysis of the device is 10 mm in diameter. With the application, the device 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. Data plots were made with the GeoChemical Data ToolKIT, i.e., GCDkit, written in R, which is a programming language and an environment for statistical computing and graphics.[113] It is an open-source freeware. More detailed information on the device, its calibration and the approximate limits of detection are presented in article V.

[112] Ainasoja et al. 2007.
[113] Janoušek et al. 2006, http://www.gcdkit.org/.

3 Results

3.1 Dating and nature of the structures and building remains at Koroinen

In article VI, the results of OSL dating of bricks from Koroinen and the ^{14}C-AMS dating of mortar, wood and burnt bone in the brick mixture are presented and interpreted based on the analysis of structures in articles II and III. The earlier radiocarbon dating of wood, bone, wax and textile, combined with the structures of the site, suggested that Koroinen was in active use in the 13th and 14th centuries, but activities ceased by the early 15th century[114] (and articles II and III).

The first bishop's wooden church was built in the 13th century, probably in the 1230s and the second after the 1340s. Based on coin finds, it is likely that the first wooden church was burnt down circa 1320.[115] (see Fig. 2)

1250–1300: The first brick structures by the riverbank were the heat storage hypocaust and the floor in front of it in a wooden building. At the same time, a stone keep was built next to the wooden house. It is possible that bricks were originally applied in the keep as well, but there is no physical evidence to support that. In the first wooden church located in the middle of the cape, at least the foundation of an altar was made of bricks, but it seems likely that the whole altar was originally brick-built. Two brick-walled graves were likely built in the first wooden church. In addition, brick was used in a burial preceding one of the brick-walled graves, too. In all the structures except for the last-mentioned burial, mortar was also applied (articles II–III and VI).

1300–1350: In the first half of the 14th century, the stone keep was likely renovated and a brick floor was built in it. Most of the brick waste found above the keep seems to originate from the eastern masonry building, i.e., the brick house built on the riverbank in the second half of the 14th century. It therefore seems likely that there were no brick vaults in the stone keep.

[114] Harjula et al. 2018.
[115] Ratilainen 2018b, p. 103; Ehrnsten 2018, pp. 261–270; Salonen 2018a, p. 126; See also: Salonen 2014, p. 16.

1350–1430: Between the 1340s and early 15th century, the second wooden church was equipped with a drain, a foundation for a font or a podium and brick-walled grave 1. The drain on the north side of the church was partly laid of stones without mortar, but mostly of bricks. The foundation of a font or a podium consisted only of a few bricks, but it may have originally been larger. The brick-walled grave 1 was mortared with lime and made completely of bricks.

The masonry building on the east side of the wooden church may date to the end of the 14th or the early 15th century and thus represents the last activity phase on the cape, probably of an interrupted stone church building project. It is likely that only foundations were erected. No signs of brick use were found in connection to it. The plan was either to build a narrow choir or a nave.

3.2 Dating of the oven made of raw bricks

Based on the stratigraphy, finds and dendrochronology, the oven made of raw bricks was likely constructed in the 1320s at the earliest, after the spring of 1317. It was likely used until the early 1340s (article I).

3.3 Dating of the HCCH

Article IV shows that, according to the OSL dating results, the HCCH was likely built during the second half of the 15th century or the early 16th century at the latest.

3.4 What kinds of bricks were used?

The brick material studied in articles I–V shows right from the start that, besides ordinary wall bricks, moulded bricks were applied in vaultings, window openings and doorways, and in the decorations of façades or gables in the Turku area. Curved nun/monk roof tiles were not used at all at Koroinen.

The analysed bricks were usually well-fired, compact and solid. In the Koroinen material, over-fired bricks had also been used in the masonry, despite the deformations. Black-headed bricks were found in all three materials. A special feature of the material found in Koroinen in connection with the heat storage hypocaust is that lots of particles of charcoal were mixed in the bricks. Furthermore, the flat upper side of these bricks was carved with fingers before firing (Fig. 5). In addition, pieces of burnt bone were detected in the mixture of KM5200:1432d/Koroinen (articles II–III and VI).

Figure 5. Finger-carved and moulded brick from Koroinen. KM52100:1450. Photo by Tanja Ratilainen.

The average size of the bricks applied in the raw brick oven found in Turku was 30 x 14 x 8 cm (article I). The average size of the bricks in Hattula was 28 x 14 x 10 cm and, according to the percentage distribution for length, the brick-maker first aimed at a brick length of 28 cm and later at 27 cm (article IV).

On the exterior walls at Hattula, including the gables, four kinds of moulded bricks were applied in the ornamentation: concave, ovolo bricks and pointed and round-moulded bricks. In the portals, at least ovolo and round-moulded bricks were applied. Pointed bricks were used to create a ridged band in the lower part of the gables (article IV). In Koroinen, the same kind of pointed bricks were used, but there were also at least two types of rib bricks and other different kinds of moulded bricks applied apparently in the mullions and in the jambs of the window. In the hypocaust oven, a moulded brick with a slanted side was also applied (article III).

The diversity of early brick use is shown also by using raw bricks in construction (article 1). The raw bricks were applied in the foundations of an oven, manufactured as normal wall bricks, which were cut sideways or length ways as necessary when constructing the oven. In addition, lime mortar was applied in the foundations.

3.5 Acquisition – bricks produced locally or imported?

The raw bricks discussed in article I suggest that local brick production was going on in Turku as early as the 1310s, but at least in the 1320s. This was also supported by the pXRF results presented in article V.

The pXRF analysis showed that, from the early stages on, bricks were likely imported to Koroinen and Turku as well as produced there. In total, at least 25% but probably as much as 37% of the analysed bricks seem to have been imported. Not only moulded bricks or roof tiles were imported, but also ordinary wall bricks. There are indications in the material that the importation continued in the 15th century, but this must be further studied based on more vast brick and clay sample material.

4 Discussion and interpretation

In order to answer the first main question about when brick came into use as a building material on the mainland of medieval Finland, we must look at an overview of the known masonry and brickwork structures there. The focus of the discussion is when *the first bricks appeared in different regions.* The regions and sites discussed are listed in Appendix 1. In the text, regions are analysed from west to east. In each region, the sites are dealt with in the following order, from first to last: the towns; the castles and the churches and associated buildings; and the village plots. In the appendix, the sites are listed accordingly, but in alphabetical order. But first, to get a wider view, I will take a look at the arrival of brick use around the Baltic Sea Region and the Åland Islands. The sites mentioned from the Åland Islands are included in Appendix 1. Finally, I will discuss the features relating to early bricks, as well as how they were acquired and, finally, by whom and why.

4.1 The Baltic Sea area

4.1.1 The invention of brick technology and its arrival to the North of the Alps

The first air-dried bricks (adobe) moulded by hand were made in the near East circa 8000 BC. The invention of using moulds and firing made the building material more regular and efficient to produce and more durable to the weather compared to adobe.[116] The first fired ceramic building materials dating to 3600–3200 BC have been found in Southern Mesopotamia. The glazing of tiles emerged in Egypt in 2600 BC.[117] The Romans were efficient in brick (and tile) production and building, and they spread those skills all over the Empire. Roman spolia were applied in buildings for a long time.[118] Byzantine Ravenna kept brick-making alive after the Empire, and

[116] Campbell 2003, pp. 13, 26, 28, 30.
[117] van Lemmen 2013, p. 13.
[118] Goll 2005; Krongaard Kristensen 2007, p. 230; for a recent study on roof tiles from the

it was probably the Longobards who introduced it to the Carolingians. Medieval brick type is believed to have been developed in Lombardy in Northern Italy by the Cistercian order. From there, brick-building skills spread over the Alps in the 12th century.[119]

4.1.2 Brick arrival to the Baltic Sea area

Roof tiles were the first ceramic building materials produced in Western Europe after the fall of the Roman Empire. They were made from the 8th century onwards; first, monk and nun tiles were developed and then the *fjäll* tile in the 11th century.[120] In Scania, i.e., Southern Sweden, the oldest roof tiles date to at least the first half of the 12th century.[121]

In the area of present-day North Poland, North Germany, Denmark and Scania in Sweden, the first brick buildings were erected, and wall bricks were introduced in the second half of the 12th century. Brick technology spread quickly, probably accelerated by direct contact and itinerant craftsmen.[122] According to Perlich, there were many separate places in Northwest Germany—such places as Ratzeburg, Jerichow, Brandenburg an der Havel, Segeberg and Lübeck—where brick buildings started being constructed after 1150. These first buildings were monastery churches and cathedrals. Around these sites, more and more brick buildings began being built and their features copied. By the mid-14th century, the amount of brick buildings had grown up dramatically, spreading all over from the Baltic coast to southern Brandenburg.[123]

In Hanseatic towns, merchants built brick halls and smaller brick houses from the 13th century onwards, but the earliest structures, like stairs of brick, were already being made in wooden townhouses in Lübeck circa 1180. The town wall and the fortress gate are also dated to the same period.[124] Early brick use in wooden secular houses in Lübeck suggests that brick was not such a limited symbol of power (only for high-ranking ecclesiastical and secular architecture) as previously assumed, but the building material was available for all those who could afford it.[125]

Eastern Mediterranean in Roman Antiquity, see Hamari 2019.
[119] Goll 2005; Krongaard Kristensen 2007, p. 230.
[120] Meissner 2010, pp. 11–12.
[121] Gardelin 2002, p. 156.
[122] Krongaard Kristensen 2007, p. 230; Biermann and Herrmann 2014.
[123] Perlich 2005, pp. 89–90.
[124] Rieger 2014; Radis 2019 and the references therein.
[125] Radis 2019, p. 75.

Between the 1160s and the 1190s, several brick buildings were constructed in Denmark and Scania. King Valdemar reinforced the Danevirke wall with a brick one. In Ringsted, Fjenneslev, Bjernede and Kalundborg, churches were erected with the contribution of noble builders. In Roskilde and Slesvik, brick cathedrals were built. In addition, abbeys in Antvorskov, Vitsköl and Sörö were constructed at the same time. In Scania, the first brick church, in Gumlösä was inaugurated in 1192.[126] So far, the oldest brick house, probably belonging to the archbishop of Lund, dates to the 12th century.[127] Private secular brick houses were built in towns in medieval Denmark from the 14th century onwards.[128]

The convent church at Sigtuna, built circa 1237–1247, and the monastery church at Sko, built between 1250 and the end of the 13th century, are traditionally considered the first brick buildings in the Lake Mälaren area, located in the southern part of Uppland and Västmanland and in the northern part of Södermanland, with Stockholm on the east coast.[129] According to Malm, a stone masonry structure with brick buttresses preceding Uppsala Cathedral could also be dated between the 1230s and the 1280s.[130] In Östergötland, located south of Södermanland and between Lake Vättern and the Baltic Sea, the brick tower of Stegeborg was likely built by 1250.[131] The only brick parish church in Östergötland, Järstad Church, belongs to the same period, too.[132] However, in recent excavations of the Skänninge Dominican Convent, the remains of a brick building preceding the convent were discovered and dated to the first half of the 13th century.[133]

In the second half of the 13th century, several imposing brick buildings were constructed in the area of Mälaren. In Uppland, the construction of the brick-built Uppsala Cathedral began probably in the 1270s.[134] Next to it, the manor of the archbishop was built, as was the brick wall around the cathedral and other brick buildings related to it. Malm sees the building of the brick cathedral and its surroundings in Uppsala as some sort of trigger for building more brick

[126] Sundnér 1982, p. 115; Nørregård-Nielsen 2006; Konsmar 2013, p. 260.
[127] Gardelin 2002, p. 156.
[128] Konsmar 2013, p. 261 and references therein.
[129] Tesch 1997, pp. 9–10; Bonnier et al. 2008, pp. 312, 314; Malm 2014, p. 71. Redelius 2006. Redelius (2006) dates the Sigtuna church to the 1220s–1237 and Sko to 1215–1220.
[130] Malm 2014. Cfr. Lovén 2010, pp. 288–289.
[131] Malm 2014 and references therein. However, Lovén considered the grounds for dating not too solid and safe and maintains it was built probably at the end of the century (Lovén 1996, p. 82).
[132] Bonnier et al. 2008, pp. 195–196.
[133] Konsmar 2013, p. 262; Stibeus 2013, pp. 231–232.
[134] Lovén 2010, p. 300.

monuments.[135] Strängnäs Cathedral in Södermanland and Västerås Cathedral in Västmanland were constructed too.[136]

Not only cathedrals but also parish churches were erected, like the ones in Tensta and Vendel, where the builder was not likely the parish but a noble family.[137] At Alsnö, a brick residence or palace was built by the royal family in 1270.[138] In Skänninge, the Church of Our Lady, the buildings of the Dominican Convent of St Olav, including the church and the bishop's brick tower (in 1270) near the convent, were built in the second half of the 13th century.[139]

Brick town churches were built, like the one in Uppsala and St Nicolai in Stockholm.[140] King Valdermar built the stone and brick buildings of his Vadstena estate in 1250–1275, including the brick palace, which was later donated to the Bridgettine Convent. In Söderköping, a town church of St Lawrence was possibly built in the second half of the 13th century, too. The bishop of Linköping built several brick buildings in the town and its vicinity. One of the earliest was a brick tower and hall with a stone cellar in Linköpings gård, i.e., Linköping Castle, in the second half of the 13th century. Another brick tower was probably at Bro. The builders behind these grand brick building projects were the bishops and archbishops as well as private persons from the high nobility, including the royal family. The Dominicans and Cistercians played a leading role as well.[141]

According to Biermann and Herrmann, the brick building tradition in present-day Northeast Germany and Northern Poland emerged along with the Danish rule and monastic orders, especially with the Cistercians' commissioning of Danish masons. In the 13th century, besides ecclesiastical buildings, round brick towers were also built, although the Danish influence is no longer considered certain.[142] In the northeasternmost area of Poland and Southern Lithuania, in the region of Prussia, brick technology arrived only in 1240 by the Order and German colonists from the West. According to Herrmann, among the innovations developed in the region were the ornaments created with black-headed bricks.[143] In present-day Lithuania, the Castle of Vilnius was brick-built in the second half of the 13th century.[144]

[135] Malm 2014.
[136] Bonnier et al. 2008, pp. 253–256; Malm 2014.
[137] Bonnier 1987, p. Katalog, 193–206. For Alsike, Tuna and Danmarks churches, see: Bonnier et al. 2008, pp. 319–320, 328.
[138] Konsmar 2013, p. 267 and references therein.
[139] Konsmar 2013, p. 263; Menander and Arcini 2013; Stibeus 2013, pp. 235–236.
[140] Bonnier 1987, pp. 29–30.
[141] Konsmar 2013.
[142] Biermann and Herrmann 2014.
[143] Herrmann 2005.
[144] Kitkauskas and Sliogieris 1993.

In the area of present-day Latvia and Southern Estonia, i.e., Livonia, and in Northern Estonia, i.e., the Dutchy of Estonia, building in masonry arrived with the German and Danish conquest in the late 12th and early 13th centuries.[145] Brick castles of the Teutonic Order were erected, churches were built and towns were founded in central commercial places in the Livonian area. The hindering element in this development was the demographic and economic effects of the plague in the mid-14th century. As a result, the German expansion to the eastern part of the Baltic ceased. The growing towns gained more power as independent actors as part of the network of towns and the Hanseatic League in the Baltic area. In this network, merchants and artisans were mobile and actively interacted with each other.[146]

In Riga, the first bricks appeared before 1211, but bricks were not widely adopted into use until after the building regulations of 1293, which ordered builders to use fireproof materials. In the course of 13th century, the town wall and churches were built in brick, and later, public buildings and private houses were also brick-built. According to Ose, this was mainly due to a lack of proper building stone in the area.[147] In Tartu and Viljandi, brick-making started only in the 14th century in connection with the building boom of the towns. In Tartu, the first brick buildings were erected in the early 14th century onwards after the re-planning of the town and building of the brick town wall. St John's Church, with elaborate terracottas, was built after 1321.[148]

In Northern Estonia, including Tallinn, the principal building material was limestone. Bricks were mainly applied in the details of masonry but were otherwise impossible to implement with limestone. In Tallinn, brick was applied from the late 13th century onwards, and at least by 1365, the town's brick kiln was functioning outside the urban area. The local need for roof tiles, however, was so large that the demand had to be satisfied with imports. Tiles were imported to Tallinn from both Sweden and the Southern Baltic, mainly from Lübeck. Bricks were mostly applied in heat storage hypocausts, but not often in open hearths. Roof tiles were commonly used in the stone buildings.[149]

[145] Ose 2015, p. 61; Bernotas 2017, pp. 10–14.
[146] Bernotas 2017, pp. 10–14 and references therein.
[147] Ose 2015, pp. 61–68. See also: Sparitis 2007.
[148] Bernotas 2017, pp. 27, 40 and references therein. In ancient Russia, the first stone church was erected in Kiev by the Greek masons with Byzantine technology and traditions in the 10th century. Bricks of the Western tradition were applied very rarely in the 1220s and 1230s. The brick technology of the Western tradition arrived near Novgorod for the first time in the 1290s. Masons and brick-makers from the Baltic area built St Nicholas Church on Lipno with the local master builder. This new Western brick-building technique prevailed in Novgorod until 1478 (Antipov et Gervais 2015).
[149] Russow 2017 and references therein.

In sum, the first brick buildings south of the Baltic were erected after 1150. The rapid sprawl of brick technology was probably due to itinerant craftsmen. On the east side of the Baltic, brick technology was introduced by German and Danish colonists in the 13th century. On the west side, in the Lake Mälaren area, the first brick buildings were erected by the orders and the church in the first half of the 13th century.

4.2 Åland

4.2.1 The castle province of Kastelholm

Kastelholm Castle is widely studied using archaeology, building archaeology and a wide variety of dating methods such as dendrochronology, radiocarbon dating of mortar and TL dating of bricks.[150] However, interpretations of the building phases and their dating have been contradictory and complex among scholars.[151] Nevertheless, it is currently more or less accepted that the castle was founded in the 1380s, and soon after, the building works of a stone castle began. The principal building material was stone, and brick was mostly used in the details of the castle. The main castle with the tower and buildings inside as well as the northern and eastern outer baileys were probably built between the 1380s and 1500.[152]

The churches of Åland have been widely studied as well, but the conclusions based on building archaeological research, art history and scientific dating results by Hiekkanen and Åsa Ringbom in most cases differ profoundly from each other. Even when only the dendrochronological results are available, the conclusions on building phases seem not to agree. Here, both views will be presented when discussing the stone churches. Most of the methods on which the interpretations are based are presented in Appendix 1.

According to Hiekkanen, the stone church in Jomala is the oldest standing stone church as well as the oldest masonry building in present-day Finland. The remaining tower and the west part of the nave were built circa 1275–1285. In addition, a choir belonged to the original plan.[153] According to Ringbom, the nave and the choir were built first and should date to the period before the 1280s, and the tower was built

[150] See Carlsson 1993.
[151] See on the problems: Uotila 1998, pp. 129–133.
[152] Gardberg 1993, pp. 92–96; Lovén 1996, pp. 149–152; Uotila 1998, pp. 132–134; Palamarz 2004, pp. 20–32.
[153] Hiekkanen 2014, p. 389.

second in the 1280s.[154] The special feature in Jomala are the details built in limestone. The original vaults of the nave were also built in stone. No brick was applied.[155]

In 1909, Björn Cederhvarf excavated several ***remains of wooden houses*** east of the Jomala church. Based on the roof tiles and bricks found, he concluded that houses built in the late 14th or early 15th century were roofed with tiles, and bricks were applied in the hearths.[156] However, according to Haggrén, the finds date rather to the Late Middle Ages and the 16th century.[157] ***A stone cellar*** found south of the church was re-excavated in the 1980s. According to Olle Hörfors, the first phase of the building dates to the second half of the 13th century. The second phase was dated to the early 14th century. In the third and youngest phase, dating to the late 14th century, brick waste was mentioned. The building was out of use by the end of the 15th century. Hörfors regarded the stone cellar as the oldest example in Finland.[158] According to Haggrén, the roof tiles found east of the church probably derived from this house with a stone cellar.[159] Liisa Seppänen suggested that they were from the church of Jomala, but this seems unlikely.[160] Nevertheless, it appears that bricks and tiles were used in the buildings, probably in the vicarage, near Jomala church at the end of the 14th century at the earliest.[161]

Based on a compound of certain architectural features, Hiekkanen maintains that the **nave at *Sund Church*** was built at the end of the 13th century, or 1310 at the latest. The tower and the porch were built at the end of the 14th century and the sacristy in the mid-15th century.[162] Based on the radiocarbon dating of mortar, Ringbom dates the nave slightly earlier, to 1250–1275. The sacristy and the tower were built at the beginning of the 14th century and the porch as well as vaults of the tower were added in the 15th century.[163] No brick was applied in the details of the church.[164] Moreover, the ***remains of a stone*** *house*, probably of a vicarage, was found at ***Sund***. The renaissance bond in the upper part of the walls showed that it

[154] Ringbom 2010, p. 91.
[155] Ringbom 2010, pp. 86–91.
[156] Cederhvarf 1910.
[157] Haggrén 2015, p. 445.
[158] Hörfors 1992.
[159] Haggrén 2015, p. 445.
[160] Seppänen 2012b, p. 797. Medieval stone churches were usually covered with shingles (Hiekkanen 2003b, p. 40; Pihkala 2009, 15, 52).
[161] Ringbom and Remmer 2000, p. 52. On the vicarages, see Pellinen 2011.
[162] Hiekkanen 2014, p. 415.
[163] Ringbom 2010, pp. 124–125.
[164] Ringbom and Remmer 2005, pp. 43–91; Ringbom 2010, pp. 123–125; Hiekkanen 2014, p. 416.

was likely renovated in the post-medieval times; thus, no evidence on medieval brick use exists.[165]

According to Ringbom, **Lemböte Chapel** was built at the end of the 13th century or circa 1370.[166] Hiekkanen disagrees with this interpretation and dates the stone chapel rather to the Late Middle Ages, although the wooden chapel was built there probably at the end of the 12th or the beginning of the 13th century.[167] No bricks were applied in the structures.[168]

At Lemland Church, dendrochronological results showed that *the nave* was built at the end of the 13th century. The tower was built in the early 14th century**.** The sacristy and the porch are from the period after the 1450s or later.[169] However, based on dendrochronological results, Ringbom maintained that they were also built in the early 14th century.[170] Most of the details of the church were built in limestone, and brick was used only in the portal of the sacristy.[171]

In Eckerö Church, according to Hiekkanen, the nave and the sacristy were built at the end of the 14th or early 15th century.[172] In turn, Ringbom dates them to the end of the 13th century. There were no brick vaults in the nave, but rather a wooden straight ceiling, although some special details of the nave were built in brick.[173]

The nave of ***Hammarland Church*** was erected in the early 14th century and the tower/porch after the mid-14th or early 15th century, according to Hiekkanen. The choir and the sacristy were built in the 15th century.[174] Ringbom dated the nave somewhat older than Hiekkanen, to the second half of the 13th century and the tower to the beginning of the 14th. The nave was enlarged, and a choir was added at the beginning of the 15th century. Nevertheless, bricks were applied only in the western portal of the nave and in the attic portal. Also, imitation paintings were made.[175] North of the church of ***Hammarland, a stone house foundation*** with a stone floor and a secondary brick wall were discovered. The only hint of the dating is a coin minted in 1450–1470.[176]

[165] Remmer 1986, pp. 24–29; Ringbom and Remmer 2005, pp. 21–26.
[166] Ringbom 2010, p. 103.
[167] Hiekkanen 2014, p. 407.
[168] Ringbom 2010, p. 103; Hiekkanen 2014, p. 407.
[169] Hiekkanen 2014, pp. 401–402.
[170] Ringbom 2010, p. 107.
[171] Ringbom 2010, p. 106.
[172] Hiekkanen 2014, pp. 363–364.
[173] Ringbom and Remmer 1995, pp. 183–188; Ringbom 2010, pp. 64–65.
[174] Hiekkanen 2014, pp. 382–383.
[175] Ringbom and Remmer 1995, pp. 35–38; Ringbom 2010, p. 85.
[176] Remmer 1986, p. 30; See on the vicarages: Pellinen 2011; Coin analysis: Ehrnsten 2019, pp. 159, Fyndkatalog p. 319.

The nave of ***Saltvik* Church** was built in the early 1370s based on dendrochronology, TL results and the radiocarbon results on wood. The building works were continued with the tower and the porch around 1380. The sacristy was probably added in the mid-15th century.[177] Ringbom sees the phases as much more varied than Hiekkanen; based on radiocarbon dating results of the mortar, he maintains that, at first, the nave with stone vaults and brick wedges in the joints of the western façade as well as the sacristy with a brick-decorated portal were built in 1270–1296. Secondly, brick vaults were added into the nave, while the porch and the tower were also built at the end of the 14th century.[178] Thus, at Saltvik, brick was applied in the details of the church, either already in 1270–1296 or only in the 1370s.

Regarding ***Finström Church***, based on the coin finds and written sources, Ringbom stated that the nave and sacristy were built at the end of the 13th century. The *church* was renovated in the mid-15th century based on dendrochronological analysis supported by the radiocarbon dating of mortar. Then the sacristy was heightened, the nave was vaulted and the porch and the tower built.[179] In turn, Hiekkanen maintains that the church was first built between the end of the 1440s and the 1470s.[180] Nevertheless, some bricks were used only among the rib stones of the nave vaulting.[181] *Near* ***Finström*** Church, the remains of a ***brick-vaulted stone building*** were found. According to Remmer, the oldest coin from the site is from the 14th century, and she suggests that an older settlement phase is also possible,[182] but according to recent coin analysis, only coins from the 15th century or later have been recognised in the material.[183] Thus, there do not seem to be grounds for the dating proposed by Remmer.

According to Hiekkanen, the stone churches at **Föglö, Kumlinge** and **Kökar** date to the late medieval period (1500–1520).[184] Based mostly on the radiocarbon dating results of the mortar, Ringbom et al. maintain that the tower at Föglö would date to the 15th century. At Kökar, the choir was built already in the 14th century and the tower in the first half of the 15th century.[185] If so, the roof tile fragments in the masonry of the choir would be among the oldest on the Åland Islands.[186] According

[177] Hiekkanen 2014, p. 411.
[178] Ringbom and Remmer 1995, pp. 35–38; Ringbom 2010, pp. 85, 114–115.
[179] Ringbom 2010, pp. 70–71.
[180] Hiekkanen 2014, p. 369.
[181] Ringbom 2010, p. 68.
[182] Remmer 1986, p. 30.
[183] Ehrnsten 2019, pp. 159, Fyndkatalog 319.
[184] Hiekkanen 2014, pp. 372–375, 392–393, 397–399. The porch at Föglö is post-medieval according to Hiekkanen.
[185] Ringbom et al. 2011.
[186] Roof tiles mentioned by Hiekkanen 2014, pp. 397–399; Cfr. Cederhvarf 1910; Seppänen

to Ringbom et al., Kumlinge church was already built in the 14th century, and the west gable was repaired in the early 15th century.[187]

4.2.2 Summary

In Åland, masonry buildings had already begun being erected at the end of the 13th century; however, brick was not yet applied in the churches of Jomala, Sund and Lemland, or in the stone cellar of Jomala. Brick was not applied in the chapel of Lemböte either, which was built in the late medieval period or much earlier. The first bricks appeared in Eckerö (special details in the nave wall), Hammarland (western portal and attic portal of the nave), Saltvik (wedges in the nave, brick portal of the sacristy) possibly at the same time at the end of the 13th century,[188] but at least in the early 14th century onwards (Hammarland). A special feature of the region is the medieval stone cellars, apparently of vicarages, of which the oldest at Jomala is dated to the second half of the 13th century. Roof tiles were applied in the Jomala vicarage at the end of the 14th century and in the nave of Kökar in either the 14th century or in the Late Middle Ages.

Thus, based on current research, it seems that in the Åland Islands, brick was applied only a little if *not at all* in the 13th century. Hiekkanen's interpretation of the building of the Finström, Eckerö and Saltvik churches would rather suggest that, as a building material, brick became more common in the Åland Islands towards the end of the 14th century, perhaps along with the building works of Kastelholm Castle. The oldest examples of roof tiles are possibly from the 14th century, but no entire medieval brick buildings are known from there so far.

4.3 Mainland of medieval Finland

4.3.1 The castle province of Turku

In this section, I will discuss when the brick **Turku Cathedral** was built. Previously, it was taken for granted that the building works of the brick cathedral were started at the end of the 13th century and finished by 1300.[189] However, according to Drake,

2012b, p. 796, note 674; Haggrén 2015, p. 445.
[187] Ringbom et al. 2011.
[188] The early dating of Finström Church is based mainly on coins; therefore, it is not very plausible that it belonged to this group but rather was built in the 15th century.
[189] Kronqvist 1948, p. 34; Gardberg 1987a, p. 53; Hiekkanen 1994, pp. 225–227; Gardberg 2000, pp. 38–40.

the first stone cathedral was begun in the first half of the 14th century, but only a stone sacristy was finished. Then stone sacristy II, the five-sided choir and part of the north wall were built until the building works at the end of the 14th century were interrupted again. In the first phase, brick was applied only in the details, but in the second construction phase, a brick cathedral was already planned; however, plans were altered once more, and the brick cathedral was finished only in the early 15th century, or 1425 at the latest.[190] Radiocarbon dating results of the mortar suggest that sacristy I was built in 1270–1300 with a probability of 84.4%, but with a probability of 95.2%, the range is 1270–1380. The sacristy II was given a range of 1315–1430 and the pentagonal choir of 1316–1417 with a probability of 95%.[191] All of these dating results are in concordance also with Drake's hypothesis and with the interpretation that the town was founded circa 1300.[192]

The first secular masonry building in the town of Turku, the **town hall**, was built in the early 14th century. However, brick seems to have been applied only in the second phase between 1350 and 1430.[193] The oldest **private masonry house** with brick vaults, possibly also with brick walls, is from the area of Aboa Vetus & Ars Nova Museum and is dendrochronologically dated to the 1390s. In the 1450s, the house was enlarged, and at least after that, its exterior walls were brick-built. **Two other stone houses** in the area, likely also with exterior brick walls, are dated to the early 15th century.[194] According to Kari Uotila, this special feature, i.e., interior walls made of stone and exterior walls of brick, would indicate the owner's desire to show off and raise the value of the house.[195] The remains of another **masonry building** with clear traces of some brick use were found near the hillside of Vartiovuori in 2001. It possibly dates to the second half of the 14th century.[196] Furthermore, in the Mätäjärvi area, **a two-story house without a cellar** and likely with brick walls on the ground floor was built in the mid-1420s or after the fire of 1429.[197] Moreover, the first phase of **a stone house** complex found near the Old Great Market at the corner of the medieval Luostarin Jokikatu Street and a narrow alley between Jokikatu and Luostarin Välikatu Street seems to have been built in the early 15th century as

[190] Drake 2013.
[191] Lindroos et al. 2011.
[192] E.g., Pihlman 2007; 2010; Ratilainen et al. 2016; Seppänen 2019.
[193] Uotila 1991, pp. 118–131; Pihlman 1995; Uotila 2002; 2003b.
[194] Uotila 2003b; 2006; 2009a.
[195] Uotila 2003b, p. 130.
[196] Ratilainen 2010.
[197] Seppänen 2012b, pp. 200–209. Exterior and interior surfaces were brick-built, see Seppänen 2012b, 187. The first floor was probably wooden.

well. It is possible, but not certain, that its original vaults were brick-built.[198] Near the cathedral, **a gate house** or some other large brick structure or building nearby was likely in use between the mid-14th and mid-15th centuries.[199] So far, the oldest roof tiles of Turku are from the late 14th and early 15th centuries.[200] At the moment, it seems that the first stone house building period in Turku was at the end of 14th century and early 15th century, but the first certain brick walls in them were built only in the 15th century. However, there are several stone cellars and other masonry building remains in the surroundings of the Old Great Market and the cathedral that need to be studied and dated more thoroughly.[201] This might change the overall picture in the future.

In Turku, the first **minor structures** in which bricks were applied mostly among other building materials date to the first half of the 14th century, too. At least three hearths, two open ones and an oven as well as two floor structures, have been found. From the second half of the 14th century, there are five more known hearth foundations. In addition, several pieces of bricks or loose bricks have been discovered in town layers dating to the first half of the 14th century.[202]

With regard to the building phases of **Turku Castle**, it was interpreted by Kronqvist and Gardberg that brick was applied in the **details of the west tower** in the 1280s.[203] Later, Drake presented that the first masonry phase, including the west tower, the curtain wall and two buildings in its corners, actually date to the first half of the 14th century. The west tower with brick details was built right after circa 1300 AD. In Drake's view, the builder of the first masonry castle was Nils Andersson, who is mentioned in written sources in 1303.[204] This interpretation is supported by the dendrochronological dating result, indicating that the curtain wall at the location of the north gate was built in the 14th century.[205] During the second half of the 14th century and by the early 15th century, the west tower was added with four storeys, and buildings in the corners were renovated and the east tower gate was built. The main castle was divided with a wall. This reconstruction of the building phases is supported by the fact that the eastern outer bailey with three towers was

[198] Saloranta 2018; 2019, p. 111. The dating is based on only 1 dendrochronological dating result.
[199] Ratilainen 2010.
[200] Seppänen 2012b, pp. 802–803.
[201] Uotila 2003b.
[202] Ratilainen 2010.
[203] Kronqvist 1946; 1947; Gardberg 1967; 1987b, p. 43.
[204] Drake 1994, pp. 52–53. Drake questioned the existence of the first 'prefectus finlandiae', Karolus Gustavi, in the 1280s. However, it was later proven to be a historical person. See also Drake 1993; 1996; 2000.
[205] Uotila 1998, pp. 60–71.

dendrochronologically dated to the 1380s–1410s.[206] In these phases, brick seems to have been used mainly in the details of the castle, such as the vaults.

The alignment of the curtain wall was altered during the oldest building phase. Drake explained it with a change in the building plans.[207] According to Uotila, a change in the alignment would have been done to gain a better view into the town, which had begun being built at the end of the 13th century; thus, the earliest phases of the castle would date somewhat prior to that.[208] However, currently, it is more likely that the town was founded only in the early 14th century,[209] and therefore, Drake's dating seems more likely.

At **Kuusisto,** the building works of a **stone castle** probably started in the early 14th century, during which time a three-room stone house on the west side of the main castle, a gate-tower, another large stone house on the east side and the curtain walls were built . It is possible that, already in the 14th century, the lower parts of two outer baileys on the north and northeast sides and a tower in between them were built. The main building material was stone, and brick was applied in the details, such as in floors or vaults.[210] However, the roof tiles found in a deposit dating to the 14th century show that they were applied in the castle very early.[211] In the first half of the 15th century, the upper parts of the above-mentioned outer baileys were built using relieving brick arches. The south wing of the main castle and two new towers were constructed and a tower between the baileys renovated. The main building material of the upper parts of the baileys was brick. Later in the 15th century, the southern outer bailey and its southwest and eastern towers were mainly built in brick.[212]

The brick structures that Juhani Rinne found in the slope of the **hillfort of Vanhalinna** (remains of a brick wall) and on the top (a large foundation of a building with traces of brick use) were first dated to the end of the 12th century or the early 13th.[213] Later, based on Koroinen, Gardberg suggested that they were built after 1229.[214] According to Luoto, the third and last active phase in the history of the hillfort started in the 11th century and continued until the early 14th century, possibly

[206] Uotila 1998, pp. 60–71, 84.
[207] Drake 1996, p. 31.
[208] Uotila 2003c.
[209] E.g., Ratilainen et al. 2016; Seppänen 2019.
[210] Uotila 1998, pp. 107–111; See also Suna and Lounatvuori 2009, pp. 10–37.
[211] Suna 1994, p. 19.
[212] Uotila 1998, pp. 107–109; Suna and Lounatvuori 2009, pp. 12, 18, 20–21, 30, 35.
[213] Rinne 1914, pp. 209–210, 220–221.
[214] Gardberg 1993, p. 22.

until 1360s.[215] The dating of the only late coin (1360–1370) was apparently suspected by Taavitsainen since he set the end of the active use of the site to the 1320s and 1330s.[216] According to a recent dissertation by Ehrnsten, there are no coin finds younger than 1320–1340.[217] Considering the fact that TL dating results from the middle of the brick wall gave a probable range between 1350 and 1450[218] and that there are some other finds probably dating to the 14th century or later,[219] the early dating of the brick structures as well as duration of the last phase of the hillfort can be questioned. It might be that they were built much later, in the 14th and 15th centuries.

The remains of **Stenberga Castle** in Masku were revealed by Rinne in the early 20th century. On a rocky hilltop, he discovered a square stone masonry foundation with three-meter–thick walls. The second building phase constituted of brick walls dividing the building into three rooms. Furthermore, in the contours of the door opening and on the steps of the stairs, bricks were also applied. In addition, rib bricks and a limestone console indicated that the upper floors had been vaulted. There was even evidence of brick relief or ornamentation of the façade. Besides the main castle, the remains of another masonry building (tower gate) were also found.[220] Rinne deduced that the first building phase dated to the end of the 12th century and the second to the end of the 14th. The dating was based on the idea that the castle was built for the protection of the first bishop's base in Nousiainen and, thus, was the oldest masonry building in medieval Finland.[221] As Drake stated, Rinne's dating was purely speculation. Based on written sources, Drake suggested that the first phase of the castle was built in the 1380s and the second in 1438, when it was owned by the Bridgettine Convent.[222] In turn, Hiekkanen proposed that the second phase may have been built even as late as the early 16th century since the first convent was wooden.[223] Uotila considers the 14th and 15th centuries to be a more accurate dating based on land-up-lift models.[224]

[215] Luoto 1984, pp. 151–153; Gardberg 1993, p. 21.
[216] Taavitsainen 1990, p. 141.
[217] Ehrnsten 2019, pp. 321–322.
[218] Hiekkanen 2002c.
[219] Luoto 1984, p. 152. It has not been possible to re-analyse these finds, but at least the Spanish horseshoe dates to the 14th century or younger.
[220] Rinne 1932, pp. 85–88. The decorative element made of rib bricks shows that how moulded bricks are used in the gables in Holy Cross Church and Häme Castle is not all that unique.
[221] Rinne 1932, pp. 90–91.
[222] Drake 1993, p. 240; Lovén 1996, pp. 308–309; Suhonen 2002b.
[223] Hiekkanen 2002c.
[224] Uotila 2003a, pp. 372–374.

The excavated material of Stenberga needs a thorough re-analysis, including the use of scientific dating methods, before anything certain about the site can be said.[225] Nevertheless, even if the current dating of the site is not very firm, it is more likely than Rinne's 12th-century dating. The brick phase of the castle may be from the 1380s, but perhaps rather from the 15th century, based on the magnitude of brick use.[226]

According to Hiekkanen, **Nousiainen parish church** was built in the 1420s or 1430s at the latest. The nave, the sacristy and the porch were of stone, but the narrow, five-sided choir was of brick. The vaulting plan was altered during the construction works, and a two-aisled church became three-aisled.[227] The rest of the parish churches were built in stone with brick details around the Turku Castle province between the 1430s and 1480s.[228]

Contrarily, stone churches in the archipelago of Turku may have been built earlier than described above. According to Pia Sjöberg, the **sacristy of Nagu** may be from the first half of the 14th century or from around the turn of the 15th century. However, the nave, porch and vaulting seem to have been built in the first half of the 15th century, in the 1430s. This interpretation is based on seven dendrochronological dating results, two of which derive from the porch roof and the rest from the nave roof. Several radiocarbon dating results from organic matter and from mortar are in concordance with the results.[229] These dating results mostly agree with Hiekkanen's timeframe for Nagu Church (1430–1450), excluding the porch.[230] Furthermore, according to Sjöberg, the first **stone church** building project in **Pargas** (including the nave, first sacristy, narrow choir, porch and possibly the vaulting) was started already at the end of the 14th century, likely in the 1380s. The second building project, including a new sacristy, was executed in the 1480s. So far, there is only one dendrochronological dating result suggesting the 1380s, but in total, eight radiocarbon dating results of wood and two of mortar are in concordance with the

[225] For example, a quick look on the finds catalogue showed there are hardly datable finds to the medieval period, but a couple of post-medieval finds suggest, at least, that there may have been some later activity on the site, too. See finds catalogue by Rinne (KM 5216). I also have doubts about the two different building phases. In addition, interestingly, according to Rinne, the foundations of the tower gate were later used as a brick kiln.
[226] In addition, in the archipelago near Turku, a small wooden castle at Hitis, Högholmen was built at the end of the 14th century and the early 15th century, too. Bricks were likely used there in the hearths of the fortification (Edgren 1999).
[227] Hiekkanen 2014, p. 121.
[228] Hiekkanen 2014, pp. 24–25; 2014, pp. 24–25, 70–73.
[229] Sjöberg 2011; Sjöberg et al. 2011.
[230] Hiekkanen 2014, pp. 116-117. Porch is dated by Hiekkanen to 1500.

result.[231] Moreover, according to Sjöberg, the third building phase of the **Korpo stone church** (including the upper part of the tower, gables and the porch) was done in the first half of the 15th century. The sacristy, nave, choir and lower part of the tower would date to the period before that.[232] In addition, in the parish of Kalanti, on the coast of Finland Proper, a stone cellar of the vicarage is known to have already existed in 1411.[233] Nevertheless, in these ecclesiastical sites, bricks were applied mostly in the details.

In sum, in the castle province of Turku, with the exception of Koroinen, it seems that buildings and structures in masonry were begun from the early 14th century onwards, both in the town of Turku, in the Kuusisto bishop castle and possibly in Nagu as well. It is possible that the oldest masonry with brick details in Turku Castle are from the end of the 13th century, but in light of the current research, it is more likely that they too were built in the early 14th century. Apparently, no brick buildings were constructed yet. The oldest entire brick structure in town is the oven made of raw bricks dating to the early 14th century (article I). Towards the end of the century, building in masonry seems to increase notably as Stenberga Castle and the structures at Vanhalinna as well as the first phases of stone church projects in Pargas and Korpo were probably built, and other major projects, such as the castles of Turku and Kuusisto and the cathedral were continued or re-started. In Kuusisto, roof tiles were already being applied in the 14th century, apparently somewhat before Turku. The first stone houses were erected in Turku at the end of the 14th century, but the first certain brick houses date to the early 15th century. In the countryside, the oldest stone cellar of Kalanti vicarage is at least from the 1410s.

4.3.2 The Kokemäki area

The first known town rights of **Ulvila** are from 1365, but Ulvila and St Gertrude's guild were already mentioned in 1344. The town was deserted in the early 1550s when the inhabitants were forced to move to Helsinki.[234] In the archaeological excavations conducted in the 1970s, four building remains including a wooden building with a hearth, a wooden cellar, cooking hut and a smithy were found. These oldest contexts were dated by means of pottery finds between 1350 and 1500 AD.[235]

[231] Sjöberg 2011; Sjöberg et al. 2011. Hiekkanen 2014, pp. 126–129 dates the first project to 1440s–1450s and the second, according to a date marked on the paintings, to 1480s.
[232] Sjöberg 2011, p. 182; Sjöberg et al. 2011.
[233] Uotila 2009b, p. 307. See also: Uotila 2003a, p. 369.
[234] Haggrén 2015, p. 460.
[235] Pihlman 1982; 1984.

Later research has supported the chronological frame.[236] In the excavations, brick waste was found in the wooden building with the hearth and under the stone floor of the cellar. Furthermore, bricks were applied in the hearth of the cooking hut. In addition, bricks were found in the bottom of two ditches.[237] These contexts are the oldest examples of brick use in Ulvila. However, few finds and the wide margins of the context dating do not allow a more precise dating for them than 1350–1500.

Liinmaa Castle was likely a wooden fortress with a moat and two embankments on an island by the sea between two river mouths in present-day Eurajoki. According to Luoto, the building remains found inside were constructed of bricks with so-called *fachwerk* technique. Another possibility is that the bricks found derived from the hearths of the castle. Based on finds and written sources, Luoto and Pihlman dated the fortress to the second half of the 14th century. Its use was finished by 1400.[238] Later, Uotila conducted excavations on the site. Based on the radiocarbon and dendrochronological dating results, the site had been in use since the second half of the 13th century until early 15th century.[239] However, two dating results from bone suggest that the stratigraphy of the site may be somehow mixed since the bone found in the lower layer gave younger results than the bone in the upper layer.[240] Nevertheless, documentation done by Luoto and Pihlman shows that most of the bricks were found in the uppermost layers and almost none in the lowest one.[241] Therefore, it seems reasonable to assume that brick was not yet applied in Liinmaa in the 13th century, but rather in the 14th.

Linnaluoto wooden fortress was located on an island on the river of Kokemäki near the Kokemäki manor. Only 1.5 km upstream from Linnaluoto was another island, **Isoluoto**, which has been considered a suitable place for a medieval fortification as well. At Linnaluoto, excavations in the 1880s revealed Late Iron Age and medieval finds, but the only Iron Age finds were pieces of local pottery, which, according to the current research, was still in use in the 14th century.[242] In the 1970s, Luoto and Pihlman dug some test pits and found traces of a brick building. Unfortunately, there is no documentation on the test pits.[243] At Isoluoto, there have

[236] See Haggrén 2000; Jäkärä 2000.
[237] Pihlman 1981, pp. 9–10, 14–15.
[238] Luoto and Pihlman 1980, pp. 42–44; Luoto 1987, p. 67.
[239] Uotila 2011, pp. 14–15.
[240] Uotila and Lehtonen 2004, Appendix 7 and 8; Uotila 2011, pp. 156, Appendix 1.
[241] Luoto and Pihlman 1979.
[242] Luoto and Pihlman 1980, p. 45. Pihlman had already doubted the dating of the Iron Age–type pottery and considered it more likely that it had been in use for a long time. See also: Taavitsainen 1990, pp. 222–223.
[243] Luoto and Pihlman 1980, p. 46.

been no excavations, but two arrowheads, probably dating to the end of the 14th century, and a brick were collected from there.[244] According to Lovén, there was a stone foundation still visible in the 19th century.[245] Currently, Linnaluoto fortress is considered to be the one mentioned in the written sources in 1367 and one of Albrekt Mecklenburgs' castles.[246] Based mainly on pottery finds, the castle was used in the 14th century,[247] and thus, the brick building could be from that time. However, further archaeological excavations at Linnaluoto are needed before the brick building and its dating can be confirmed. The same applies to studying Isoluoto and the possible brick structures there.

Currently, it seems that in the Kokemäki area, north of the castle province of Turku, brick use started only in the 14th century, rather than in the second half of the century. Evidence of the brick-walled buildings at Liinmaa and Linnaluoto in the 14th century is rather weak;[248] they should be more thoroughly studied and dated with scientific dating methods before further conclusions.

4.3.3 The castle province of Häme

The oldest building phase of the Crown's Häme Castle, with details in brick, was previously dated by Drake to the second half of the 13th century. He also dated Cock Tower in the first half of the 14th century and the monumental brickwork castle between 1350 and 1450. The dating scheme was based on comparisons between Stockholm Castle, Turku Cathedral and the possible reference to the builders in written sources.[249] In the early 21st century, Drake presented a new interpretation of the building phases. This, too, was based on the idea that chiefs of the castle could afford to pay for the building works, but the conception about how long the building works took changed considerably. The first stone phase with brick details was set to

[244] Luoto and Pihlman 1980, p. 48; Luoto 1987, p. 76; Lovén 1996, p. 154; Suhonen 2002a.
[245] Lovén 1996, p. 154.
[246] Luoto 1987, p. 63; Lovén 1996, pp. 154–155; Suhonen 2002a, p. 30. On a small island next to the site, a stone tower was dismantled in 1834. According to Suhonen, however, the tower was not medieval (Suhonen 2002b; see also Lovén 1996, p. 154).
[247] Luoto and Pihlman 1980, p. 47; Luoto 1987, p. 63; Suhonen 2002a.
[248] I think a post and brick waste from a narrow trial trench at Liinmaa are not enough evidence for Fachwerk, which would be a very exceptional technique in medieval Finland. In timber-framed structures, the vertical beams were set upon the lowest horizontal logs, not directly on stone foundations (see, e.g., Roesdahl and Sholkmann 2007, pp. 166–169). The brick remains may as well relate to the hearth, and the post suggests a building with open walls. At Linnaluoto, the interpretation of a brick building is based on undocumented test pits with brick waste.
[249] Drake 1968; 2001a; 2003a.

the end of the 14th century, circa 1372–1390, Cock Tower to 1410–1443, the brickwork castle to 1472–1490 and the corner tower castle to 1503–1520.[250] Later, an extensive effort to date the castle with scientific dating methods was made by the "Vallan asuinsijat" project. Unfortunately, all the dendrochronological dating results were post-medieval.[251] However, recent numismatic research by Ehrnsten, in which 24 coins found on the first floor of the brickwork castle were dated in the second half of the 14th century, has questioned Drake's dating frame. Even if the contexts are not well documented, most coins seem to have been found in the floor fillings.[252] Therefore, it seems quite possible that the brickwork castle had already been built at the end of the 14th century or early 15th century, which increases the age of Cock Tower and the first stone phase with brick details by a few years.

According to Päivi Luppi, the lower parts of the curtain wall of Häme Castle were built in stone and the upper parts in brick. The works were started in the southern part and proceeded towards the north via the west. Then, the works proceeded towards the SE part of the curtain wall. The building material of the south tower outside the curtain wall is not known, but the so-called Dansker Tower and Fatabur Tower were built in brick. The chronological relationship between the curtain wall and the main castle is not clear. Drake suggested the building works of the curtain wall may have started when the main castle was still wooden, i.e., before the 1370s.[253] In turn, Uotila finds it unlikely that the upper class would have settled for wooden buildings at that time. A radiocarbon dating of mortar taken from the masonry of the northwest part of the curtain wall suggests that it was built at the end of the 14th century or early 15th.[254] Dansker and Fatabur Towers probably date to the 15th century.[255]

Approximately 17 km southeast of Häme Castle, on top of Hakoinen hill, Rinne found the remains of a curtain wall, a two-room stone house and perhaps a tower. On the lower level, there was also a curtain wall of an outer bailey and a dry moat, and the inside contained the remains of a wooden building and a water reservoir. Indications of brick use were found in connection with almost all the structures, but possibly the stone house, its hearth and the tower were mostly brick-built.[256] At the foot of the hill was the manor of Hakoinen, inhabited since the medieval times.[257]

[250] Drake 2001a; 2003a.
[251] Uotila and Vilkuna 2009; Zetterberg 2009.
[252] Ehrnsten 2013; 2015; 2019, pp. 162–163.
[253] Drake 2003a, p. 13.
[254] Uotila 2009a, p. 86.
[255] Luppi 1992; Uotila 1998, p. 119; Luppi 2003, p. 146.
[256] Rinne 1914, pp. 145–168.
[257] Gardberg 1993, p. 23.

Traditionally, Hakoinen has been seen as the predecessor of Häme Castle and as a hillfort, even if no finds from the prehistoric period have been found there.[258] Rinne connected the site with the crusade led by Birger Jarl and set the dating to the mid-13th century. Furthermore, he suggested that it was still in use when the Novgorodians attacked in 1311.[259] In Drake's view, they attacked Häme Castle, but based on the remains of a chimney, he pointed out that Hakoinen may have still been in use in the 14th or even the 15th century.[260] Lovén argues that both castles, Häme and Hakoinen, may have been used at the same time and that Hakoinen was perhaps abandoned during the 14th century.[261]

In general, the finds at Hakoinen have been described as medieval.[262] The only medieval coin struck in 1290–1318 suggests that the site was in use at the end of the 13th century or the early 14th.[263] However, there were some post-medieval finds, a TL dating of a brick to the late 18th or 19th centuries, and Rinne's mention of drilling marks on the stones around the water reservoir, all indicating that the hilltop was actively used for a long time.[264] If the interpretation of the chimney is correct, that could indicate that the brick house was built in the 15th century at the earliest.[265] Nevertheless, there is no clear evidence on brick use in the 13th century.

The HCCH, the only parish church originally built completely in brick, was previously considered to be the main church of Häme and built in the 13th century. One of the dating grounds were, for example, the terracotta masks visible in the exterior of the church.[266] Over the years, the church has gotten younger and

[258] Gardberg 1993, pp. 23–24 and references therein; Lovén 1996, p. 63.
[259] Rinne 1914, pp. 267, 280.
[260] Drake 1967, p. 33; Taavitsainen 1990, pp. 236–237.
[261] Lovén 1996, p. 64.
[262] Taavitsainen 1990, pp. 236–237.
[263] Rinne 1914, p. 157; Drake 1967; Taavitsainen 1990, pp. 236–237. The coin was found at the location of the brick building (Rinne 1914, p. 168), but from the surface layers when no indication of building was discovered. Thus, it also indicates that the deposits were mixed. The coin is not re-analysed in Ehrnsten's dissertation.
[264] On drilling marks and post medieval finds: Rinne 1914, pp. 157, 181. In addition, a quick look at the finds catalogue revealed a Russian coin from 1840 (KM5455). On TL dating: Hiekkanen 2002c. According to Hiekkanen, the dated sample KM5455:14 is from the brick house, but according to the finds catalogue, the sample is from the area of the outer bailey.
[265] On the chimneys, see, e.g., Seppänen 2012b, p. 724. A modern analysis on the land use of the site and its surroundings as well as scientific dating analysis should be made before anything new on firmer ground than before can be presented. In a current research situation, it is difficult to understand the purpose and the relationship of the castle with Häme Castle. It seems to be similar to the Vanhalinna hillfort in Lieto, which was still used even when Turku Castle existed, but the possibility of a private castle relating to the events of the end of the 14th century should also be considered together with the manor nearby.
[266] Nervander 1887; Aspelin 1891, p. 11; Ailio 1913, pp. 2–9; Mäntylä 1976, p. 290.

younger.[267] In the 1990s, the first dendrochronological results did not provide a definite answer, but it seemed that the church could not have been built before 1388.[268] Based on Hiekkanen's studies and the new interpretation of the building phases of Häme Castle presented by Drake,[269] I suggested that the church was built at the same time as the brickwork castle in 1472–1490.[270] However, the OSL results showed (article IV) that the church was likely built in the second half of the 15th century, or the early 16th century at the latest. The second wall paintings in the church were likely made sometime between 1513 and 1520, giving a *terminus ante quem* for the church.[271]

Holy Cross Church is not necessarily the oldest church in the region, but it may have been built at the same time as the churches of Hollola (1495–1510), Pälkäne (1495–1505), Vanaja (1490–1510) and Sääksmäki (1490–1500).[272] However, on the north side of the church are the remains of a sacristy, in which vaults and walls were brick built. Based on the window glass fragments and wall paintings, the building was probably completed, but the plans were altered, and a brick church was eventually built on its south side.[273] Thus, a brick building project seems to have been begun somewhat earlier than the current Holy Cross Church. In addition, since the dating of the brickwork castle (1472–1490) is questionable, because of the 14th century coins found there,[274] it seems that it is actually older than the HCCH (article IV).

The dating of the earliest phases of Häme Castle and its curtain wall are not firm until more scientific dating results can be acquired. It seems that the building works of a grey stone castle with brick details started at the end of the 14th century; based on coin finds, however, it may be somewhat earlier. The curtain wall construction may have begun at the end of the 14th century. If the upper parts of the curtain wall were brick-laid straight away, then brick was already applied in abundance at the end of the 14th century or early 15th century. However, based on the coin analysis by Ehrnsten, the brickwork phase of the main castle may have already started at the end of the 14th century or early 15th (see above). Hakoinen fortress was probably already

[267] Lindberg 1934, p. 37; Kronqvist 1941, p. 50; Jaakkola 1944, pp. 137–138; Kartano 1946; 1948; Kronqvist 1948, p. 50; Rinne 1952, p. 59; Hällström 1955, p. 4; Pettersson 1955, p. 574; Mäntylä 1976, pp. 290–291; Knapas 1997, p. 18. But cfr. Wennervirta 1937, p. 178.
[268] Knapas 1997, p. 18.
269 Hiekkanen 1994; 1996; 2000; Drake 2001a, p. 217; 2001b, pp. 126–127; 2003b, pp. 11–14.
[270] Ratilainen 2001a; 2001b; See also: Hiekkanen 2003a; Ratilainen 2003; 2006.
[271] Pettersson 1981, pp. 215–216; Edgrén 1997, p. 42.
[272] Hiekkanen 2014, pp. 278–358.
[273] Hiekkanen 1996, pp. 63–69.
[274] Ehrnsten 2013; 2015; 2019, pp. 162–163.

in use at the end of the 13th century and during the 14th century, but based on archaeological evidence, the site was actively used for a long time, which severely questions the early brick use there. It is possible that a brick house was built there in the 15th century. No clear evidence on 13th-century brick use exists. The HCCH was constructed some time between the second half of the 15th century and the early 16th century, and it was likely preceded by a brick sacristy. In Häme, brick use likely started in the 14th century, perhaps around the mid-14th century. If the curtain wall and the brickwork castle were built at the end of the 14th or early 15th century, brick was applied on a much larger scale and sooner than Drake suggested.

4.3.4 The castle province of Raseborg

Raseborg Castle, nowadays a heavily restored ruin located in western Uusimaa, was in use from the 1370s until the 1550s.[275] According to Drake, the curtain wall and three towers were built in the 1370s–1400s.[276] The eastern outer bailey of the castle was possibly built before 1427.[277] The rest of the building phases are probably from the later 15th and 16th centuries.[278] The oldest coins found in the castle and its surroundings were struck between 1340 and 1380.[279] The current look of the castle gives an impression that the building material was mostly stone and only the details built in brick. However, according to Drake, there is so much brick waste in the deposits of the castle that, even if it is difficult to indicate which parts were originally built in brick, it was applied there more than just in details.[280]

Junkarsborg Fortress located on a cape on the Mustionjoki River was previously considered the predecessor of Raseborg Castle. There was an outer bailey built on the south side of the wooden main castle surrounded by an earthen rampart and a moat. There was a stone well and the remains of nine wooden buildings found in the excavations inside. Based on several coins, minted between 1320 and 1420, and the analysis of historical events, Suhonen concluded that the castle was built in the 1320s at the earliest, but it probably belongs among the small castles built at the end of the 14th century, and thus, it was used at the same time as Raseborg.[281] A TL dating from a brick resulted in 1510±70, thus also suggesting late medieval or post-

[275] Drake 1991; Lovén 1996, pp. 156–157; Haggrén 2009.
[276] Drake 1991, pp. 128–132.
[277] Lovén 1996, p. 159; Uotila 1998, p. 128.
[278] See Drake 1991, p. 132. Lovén 1996, pp. 159–160.
[279] Lovén 1996, p. 159; Ehrnsten 2019, pp. 165, 320, 325.
[280] Drake 1991, p. 94; See also Uotila and Vilkuna 2009, p. 82.
[281] Suhonen 2001; 2002c.

medieval building activity on the site.[282] The current timeframe of the coins is 1340–1398.[283]

The **fortified hill of Vartiokylä** is located by the sea, at the bottom of the bay of Vartiokylänlahti in Helsinki. In excavations, no remains of masonry buildings or curtain walls were found, only brick waste, likely from the hearths of wooden houses. The observations on bricks suggested two building phases. Radiocarbon results, e.g., from charcoal under the stone ramparts, gave ranges between the second half of the 13th century and 1410. The few finds date to the end of the 13th century or the 14th century. Heikkinen suggests that the fortification may belong to the group of small castles built at the end of the 14th century during Albrekt Mecklenburgs' time, but it could also be earlier.[284] At Vartiokylä, brick use was already possible in the 13th century, but it seems more likely that it dates to the 14th century, if not later.[285]

The first stone church in the area was probably **Inkoo stone church**, for which building works were completed in the 1430s,[286] but most of the stone churches in the region were built in the second half of the 15th or even the early 16th century.[287]

According to the latest research on medieval village plots in Uusimaa, brick was applied in the ovens at least from the end of the 15th century onwards.[288] However, in the excavations of Vantaa vicarage, bricks were discovered in the foundations of an oven, interpreted as a stove tile oven in a building used in the 14th and 15th centuries. A TL analysis dated the stones of the oven to the 13th and 14th centuries. However, the TL dating from the bricks resulted in a much younger age, to the 16th and 17th centuries.[289] Together with the piece of faience found in the middle of the

[282] Hiekkanen 2002c. However, the KM37138 indicated in the article refers to a Stone Age site. The correct number is maybe KM2860:3 or :4.
[283] Ehrnsten 2019, pp. 320, 324.
[284] Heikkinen 2003; Haggrén 2015, p. 428.
[285] The dating of the fortification mostly depends on one radiocarbon dating result of wood and only on a few finds, while the brick material suggests two building phases. More dating results from short-lived seeds and animal bones should be made to get a better idea about the history of the fortification.
[286] Hiekkanen 2014, p. 433.
[287] Hiekkanen 2014, pp. 429, 437, 443, 445, 477, 481, 489.
[288] Mikkanen 2017, p. 16.
[289] The piece of charcoal found in the oven gave a range from the 14th century to the early 15th, and a dating from burnt bone found in the remains of another oven of the building gave a range from the end of the 13th century to the entire 14th century (Väisänen 2016, p. 243). However, no stove tiles were found in connection with the building (Väisänen 2016, pp. 225–226).

oven,[290] the TL results of bricks suggest the structure was perhaps repaired and still in use in the early modern period.

In the castle province of Raseborg, the use of brick seems to have begun at the end of the 14th century. In Raseborg Castle, bricks were likely applied much more than just in the details.

4.3.5 Porvoo County

Linnamäki fortress is located on the north side of the town of Porvoo. The square-shaped plateau area in the middle of the hill is surrounded by a double dry moat and embankment system. In the 1880s, the remains of several hearths and two cellars were discovered on the west part of the hill. Bricks were apparently found at the east part of the hill.[291] Excavations in the 1970s provided a sample from a piece of charcoal under the edge of the inner moat, radiocarbon dated to the Viking Age. Finds mostly date from the late 13th to the early 15th centuries, but among them, there are also post-medieval finds, such as clay pipes and 18th-century coins. No Iron Age finds have been found.[292] According to written sources, the fortress was out of use by the mid-16th century. Later land use of the site has been severe, since sand is known to have been taken from there in the late 18th century and in the 19th century until it was ceased in 1842.[293] The bricks found on the site were assumed to be from an early date by J. R. Aspelin.[294]

The dating of Linnamäki has been under discussion for a long time.[295] Gardberg concluded that the evidence roughly suggested the 14th century rather than the 13th century.[296] According to Päivi Hakanpää, there could be two phases, one dating to the Iron Age or early medieval period and the other to the end of the 14th century and early 15th century.[297] The town and the fortress may even belong to the same plan.[298] It seems reasonable to assume that the remains of the possible Iron Age or early medieval fortification were mostly destroyed in the building works of the ramparts and moats at the end of the 14th century, if they ever existed. It seems more likely

[290] Väisänen 2016, pp. 126, 224–227, 243.
[291] Aspelin's excavation map published in: Gardberg 1996, p. 162.
[292] Edgren 1996, pp. 44–54; Gardberg 1996, pp. 156–171; Hakanpää 2008, p. 64.
[293] Gardberg 1996, pp. 157–161.
[294] Edgren 1985; Lovén 1996, p. 395.
[295] On the research history: Gardberg 1996, pp. 163–164.
[296] Gardberg 1996, p. 162.
[297] Hakanpää 2008, pp. 64–65.
[298] Edgren 1996; Gardberg 1996, pp. 152–156; See also: Hiekkanen 2014, p. 458; Hakanpää 2008, pp. 64–65.

that the bricks derive from the end of the 14th century and early 15th century at the earliest.

Husholmen Fortress is located on an island circa 10 km from Porvoo. Not much is known about it. According to Suhonen, there may have been a bailey, and on top of the hill, in the main castle, there were three or four buildings, one of which may have been a stone tower. In addition, a stone wall probably formed a defence corridor with the steep bedrock wall.[299] Brick and mortar waste has been detected, too.[300] According to dendrochronological results, an underwater wooden defence system was built around the island at the end of the 14th century. The finds from the site date to the 14th century. Suhonen suggests that the castle was not used for a long period of time.[301] Therefore, the bricks probably applied in the hearths and details of the masonry structures date to the end of the 14th century at the earliest.

Sibbesborg Fortress is located 20 km from Porvoo on an island at the mouth of the Sipoonjoki River. Isolated by two moats and an underwater wooden defence system, a large masonry house with brick walls was built there. There was probably a tower in the corner of the house. Two finds suggest that the fortress was used at the end of the 14th century, but a TL analysis from the brick house, dating to 1590–1690, indicates a much younger building activity on the site.[302]

According to Hiekkanen, the stone churches of Porvoo County belong to the group of the oldest stone churches of mainland Finland.[303] The sacristy of Pernaja was already built in the 1410s, and its nave and porch were finished in the 1440s.[304] The stone church in Porvoo was first built in the 1410s or 1420s and was enlarged in the 1440s.[305] Bricks were applied in the details, such as in the pillars and vaults.

In the county of Porvoo, brick use was begun in the wooden fortresses at the end of the 14th century at the earliest. There is no clear evidence on brick use before that.

4.3.6 The castle province of Viipuri

The inhabitants of **Viipuri** near the castle are first mentioned in 1316. It seems feasible that the harbour next to the castle grew up as a town during the 14th century, even if the town rights are known only since 1403.[306] In Aleksandr Saksa's view,

[299] Suhonen 1999.
[300] Edgren 1996, p. 111, note 1.
[301] Suhonen 1999.
[302] Lovén 1996, pp. 183–185; Hiekkanen 2002c; Suhonen 2002b.
[303] Hiekkanen 2014, p. 26.
[304] Hiekkanen 2014, p. 451.
[305] Hiekkanen 1994, p. 218; 2014, pp. 459–460.
[306] Korpela 2004, pp. 240–246; Niukkanen et al. 2014, p. 38; Haggrén 2015, p. 458.

the settlement prior to 1400 was composed of three separate village-like units in the middle of the cape, which only grew up to cover the whole area in the 15th century.[307] It was earlier assumed that there had been many stone houses built in the medieval period, but in the excavations, no such stone house foundations have been found. Furthermore, the small stone houses still standing have been interpreted to be from the early modern period.[308] In addition, in town archaeological excavations, mostly 15th- and 16th-century deposits or younger have been found so far.[309] Among the few indications of older activity,[310] no traces of brick use seem to have been found.[311] According to Saksa, even the hearths were simple stone stoves built without lime mortar before the masonry building boom in the second half of the 15th century started.[312] However, it would be very surprising if ovens and open hearths were not built at all and if brick was not applied in them already in the 14th century, but this must be left open for future research. Likewise, circa 30 cellars or stone buildings aligned with the plan of the pre-17th century need more thorough building archaeological studies.[313]

The town church of Viipuri was built in stone in the 1430s–1440s,[314] but most of the monumental masonry architecture, the town wall and two convents with churches were built in the second half of the 15th century or early 16th century.[315] From the written sources, it is known that Karl Knutsson donated a farm with a brick

[307] Saksa 2009.
[308] Korpela 2004, p. 248 and references therein. Taavitsainen 2007, pp. 220–223; Saksa and Taavitsainen 2008; Katajala 2010, pp. 31–33; Saksa 2010, pp. 34–35; Haggrén 2015, p. 459; Saksa 2018, p. 74.
[309] Suhonen 2004; Taavitsainen 2007, p. 222; Saksa 2009; 2018.
[310] The only hints of an earlier settlement are a floor plank, some seeds and a wooden structure found in the lowest deposits. The floor plank from Possenkatu and Vahtitorninkatu corner is from the 1270s, and the seeds were radiocarbon dated to the turn of 14th century and the 14th century. The wooden structure was dated to the 1410s (Saarnisto and Saksa 2004, p. 261; Saksa and Taavitsainen 2008, p. 395–396; Saksa 2009). However, in 2019, OxCal gave a dating range to 1190–1294, with a probability of 95.4% for the plank. A seed found from the corner of Uusiportinkatu and Etelävalli gave a date range of 1290–1398, with a probability of 95.4%, and the range for the wooden structure was 1310–1432 CalAD.
[311] In his articles, Saksa describes the oldest layers consisting of organic matter, wood chips, bark, fishing equipment, etc., but no brick waste or pieces of brick are mentioned (see, e.g., Saarnisto and Saksa 2004, p. 259; Saksa 2018). Brick waste is marked, e.g., on the maps with wooden structures from the 15th and 16th centuries (see, e.g., Saksa 2009).
[312] Saksa 2018, pp. 70–71.
[313] Niukkanen et al. 2014, p. 38.
[314] Hiekkanen 2014, p. 549.
[315] Hiekkanen 2014, pp. 544, 546–547.

kiln to the Dominicans in 1448.[316] So far in Viipuri, no clear signs of brick use date prior to the 1430s–1440s.

The **castle of Viipuri** was likely founded in the 1293.[317] St Olav's tower and the curtain wall of the main castle were built before 1322 according to Tjulenev. In contrast, Drake claims that the first structure in masonry was the round curtain wall of stone in the northwest side of the main castle, built after 1293. The rectangular walls of the main castle were built in the 14th century. The tower of St Olav was constructed circa 1400, but it was re-built in brick in the 1560s.[318] The outer baileys were probably built in the 1440s or in the second half of the 15th century.[319] Thus, it currently seems that, in the castle of Viipuri, brick was not used in the 1290s, but rather from the 14th century onwards. In contrast, in the town area, brick does not seem to have appeared before the early 15th century.

4.3.7 Summary

From Porvoo County and in Häme, there is no clear evidence on brick use dating to the end of the 13th century. On the contrary, it appears that, in both regions, bricks and building in masonry emerged at the end of the 14th century.[320] This probably also applies to the Raseborg area as well as to Kokemäki. However, at Häme Castle, the main building material may already have been brick at the end of the 14th century or early 15th century. Furthermore, in Raseborg Castle, bricks were likely applied not only in the details but probably in building the walls, too. The same possibly also applies to the wooden fortresses of Liinmaa and Linnaluoto in the Kokemäki region. In Viipuri Castle, building works of a round curtain wall of stone were already started after 1293, but brick was probably only applied there in the 14th century onwards. In turn, in the town area, brick does not seem to have appeared before the early 15th century (see above).

4.4 Interpretation

Consequently, it seems that the oldest stone building on the mainland of medieval Finland is the keep of Koroinen, built in the second half of the 13th century (1250–1300). It is possible that bricks were applied in the details of the keep since, at the

[316] Kuokkanen 1981, p. 29.
[317] Gardberg 1993, pp. 65–66.
[318] Drake 2001c and references therein; See also Lovén 1996, pp. 97–99 and references therein.
[319] Uotila 1998, p. 122; see also Lovén 1996, pp. 97–99.
[320] In Häme Castle, perhaps already closer to the mid-14th century.

same time, bricks were applied in other constructions of the cape. However, there is no physical evidence of that (article VI). It is possible that the oldest parts of the castles of Turku (1280s, with brick details) and of Viipuri (after 1293, only stone) date to the end of the 13th century as well, but so far, there are no scientific dating results in support of that. For Turku Castle, it is more likely that the building works started only in the early 14th century. The stone keep of Koroinen was probably built at the same time as the earliest stone churches in Åland (Jomala, Sund, Lemland, Lemböte (?)). Also, the stone cellar at Jomala may date to the same period.

Among the oldest brick structures on the mainland are likely the heat storage hypocaust and the brick floor in the wooden building on the riverbank, and the brick altar or at least its foundation built in the first wooden church at Koroinen. Two brick-walled graves (2 and 3) probably belong to the 13th-century constructions too, but it is also possible that they were built in the early 14th century before the first church was destroyed circa 1320. Nevertheless, besides the altar, the oldest example of brick use, which probably dates to *at least* the second half of the century, is a brick from the church area found under brick-walled grave 3 and two earlier layers of burials (article VI). Based on the stratigraphy, radiocarbon dating result and the bishop's arrival to the cape, it is even possible that the brick dates to a period in the 1230s–1270s (Fig. 6). However, considering the emergence of brick around the

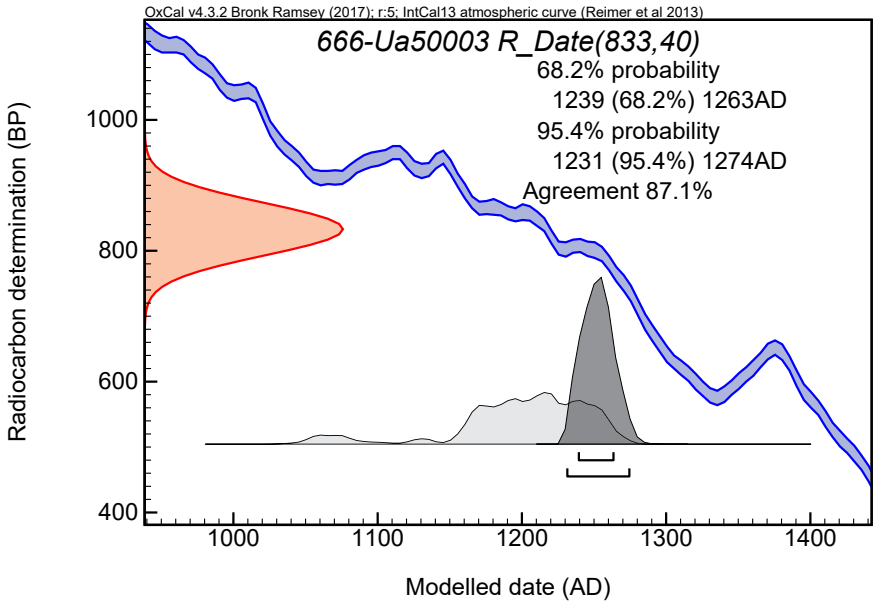

Figure 6. Wood sample KM52100:666 provided a probability range of 1239–1274 CalAD when terminus post quem was set to 1229 and terminus ante quem to 1652 in OxCal. Graphic by Tanja Ratilainen.

Baltic Sea region, especially in the Lake Mälaren area, the first bricks at Koroinen should be dated to a period between the 1250s and the 1270s. Moreover, looking at the dating of Koroinen as a whole, it must be noted here that the only direct scientific dating result from the structures of the church is from brick-walled grave 3, and all the other features have been dated indirectly, based mainly on the stratigraphy or the contemporaneity of the structures. The grounds for dating the structures by the riverbank are more solid since a total of 17 OSL and 11 radiocarbon dating results have been obtained from there. Another point worth noting is that the contexts of Koroinen were not documented according to the modern standards. Furthermore, the deposits by the riverbank were likely disturbed by later human activity on the cape, which makes the interpretation of the material complicated. On the other hand, a large number of dated samples and the use of Bayesian modelling have compensated the above-mentioned weaknesses (articles II, III and VI). Thus, the evidence of brick use at Koroinen already in the second half of the 13th century is strong. Nevertheless, the remains of the stone house outside the moat in the area of the Koroinen estate, not to mention the rest of the estate, have not yet been thoroughly studied and dated.[321]

It seems that, in the 14th century, Koroinen follows the general tendency of increasing brick use as a brick floor was built in the renovated keep. In the second half of the century, the second wooden church was equipped with a brick drain, font foundation and brick-walled grave 1. On the riverbank, a brick house, probably the residence of the bishop, was constructed (1350–1400). It is one of the oldest brick houses,[322] if not the oldest, in medieval Finland so far. It is interesting that the bishop did not built a tiled roof for the residence at Koroinen, as that seems to have happened at Kuusisto. The lack of roof tiles cannot be due to Rinne, since he also collected the post-medieval roof tiles found on the site. It is also interesting that, according to written sources, the bishop bought land on the north side of Turku Cathedral to establish a temporary residence in the 1340s and, thus, had a town house built there (discussion in article III). If the residence or base near the cathedral was temporary, it would be reasonable to assume that it was not yet built in masonry; many have agreed that it was built only after the fire of 1429.[323] Consequently, the brick house on the cape of Koroinen was likely his steady base when not residing at Kuusisto.

[321] See, e.g., Koivunen 2003.
[322] Other possible ones built before the 15th century are the Liinmaa (fachwerk?) building, the Linnaluoto brick building (?), and the stone house with brick walls (?) in the area of the Aboa Vetus & Ars Nova Museum from the 1390s.
[323] Palola 2003, p. 111; Seppänen 2012b, pp. 660–662; Paarma 2015.

As for the construction of stone churches, the building works at Koroinen probably started at the end of the 14th century or early 15th at the latest, which, following Hiekkanen's chronology on the stone church building in Finland, would make it the oldest stone building project in Finland Proper (article VI). However, it is possible that, at the same time in Pargas and perhaps in Nagu and Korpo, stone church building projects were launched too (see above).

4.5 Discussion on early brick use and brick-building

4.5.1 Some technical features

One aspect of introducing brick technology is the use of moulded bricks. The only certain moulded brick dating likely to the second half of the 13th century is the one found in connection with the heat storage hypocaust at Koroinen (Fig. 5 and articles III, VI). It is a simple brick with one slanted side. It may have been applied in shaping the firebox.[324] The rest of the 13th-century brick structures at Koroinen were of the type that moulded bricks were not needed, and their amount increased expectedly as the brick house was constructed on the cape.

The technique of using moulded bricks in the façades of Hattula Church and Häme Castle has been seen as exceptional since bricks, partly the same kinds of bricks meant for doorways and portals, were applied sideways in creating decorative elements (article IV). However, the same phenomenon was detected by Rinne in Stenberga Castle in Masku when he found a fragment of a façade decoration made of rib bricks.[325] This phenomenon should be further investigated in the future, but it nevertheless gives a reason to doubt whether the technique was anything unique or simply another way of using moulded bricks as decorative elements.

In Finnish material, there are also indications of unique technical solutions not applied outside the northernmost areas of Europe. In the early 14th century, an oven made of raw bricks was built near the Turku Cathedral (article I). Raw bricks have also been found in the walls of a brick kiln in Tartu, Estonia.[326] Another place is Skänninge Dominican Convent, where two rows of raw bricks were used in the edge of a foundation of a hearth, though without mortar.[327] The distinguishing feature compared to building timber-framed houses with clay lumps struck in moulds is that

[324] Cfr. Bingenheimer 1998, pp. 312, Figure K48.
[325] Rinne 1932, p. 86.
[326] Bernotas 2013.
[327] Konsmar 2013.

lime mortar was applied in between the bricks.[328] Thus, the oven made of raw bricks seems to be something unique in medieval Europe. Since no slag or any kind of production waste was found in connection with the oven, it seems that it was applied for cooking and heating. Raw bricks were used just because building materials were needed, and some dried bricks were left over from a large brick production project (article I). In addition, the measurements of the bricks (30 x 14 x 8 cm) suggest that shrinking was acknowledged by the brick-maker. This implies, not surprisingly, that a professional craftsman was likely involved in the production.

4.5.2 The early actors and the acquirement and meanings of brick

A great deal of brick buildings were already being constructed at the end of the 13th century in the Lake Mälaren area, not to mention the rest of the Baltic Sea area, which provides a perspective in evaluating the premises presented in previous research on the introduction of brick use in Finland. Why would brick buildings not be erected in Österland, i.e., medieval Finland, after the establishment of the Swedish Crown, the Church and the Dominicans in Turku, and the founding of the town of Turku? All the same actors had convents, keeps, residences, churches and castles constructed elsewhere, but why would they not have the same in Finland, with plenty of suitable clay for brick-making?

The founding town of Turku and the castle were probably part of the economic boom between 1250 and 1320 when 24 towns and 13 crown castles were established in medieval Sweden.[329] According to Hiekkanen, Turku was founded by three actors: the Swedish Crown, the Dominicans and the Church at the end of the 13th century,[330] although it presently seems that the founding happened somewhat later, right at the beginning of the 14th century.[331] In addition to these actors, Gardberg already underlined the high number of merchants of German origin who would have strongly influenced the town by having material and cultural connections with Tallinn, Lübeck, Stockholm and other towns around the Baltic Sea region. Moreover, along with the merchants came masons and other craftsmen.[332] According to Seppänen, German burghers launched and promoted private masonry house building in Turku.[333]

[328] Cfr. Schofield and Vince 2003.
[329] Drake 1996.
[330] Hiekkanen 2002a; 2003c.
[331] Pihlman 2007; 2010; Seppänen 2012b; Ratilainen et al. 2016; Seppänen 2019.
[332] Gardberg 1971, pp. 282–291, 308–312; See also: Kallioinen 2000.
[333] Seppänen 2012a; 2012b, p. 948.

According to Drake, all the masonry buildings in medieval Finland belong to the North European Gothic brick-building tradition, which arrived in Turku from the area of Lake Mälaren after the 1290s. The Swedish Gothic building style would have acted as an example for the poor Österland, which was forced to build mainly in stone and use brick only in the details. Turku Cathedral, with its first construction phases of stone and then of brick, acted as an example for the parishes.[334]

The oven built of raw bricks and the deposits with brick waste, as well as the lesser structures such as floors and hearths built in Turku during the first half of the 14th century, suggest that there must have been a large brick building project going on in the town. Why go through the trouble of acquiring some bricks for just a few structures (article I)? Given also that only a small portion of masonry building remains in the town have been studied and dated so far, in my view, it is quite possible that the building works of a brick cathedral had already started in Turku at the beginning of the 14th century, perhaps after the attack of the Novgorodians in 1318. This seems possible since, during the 13th century, the Church had established the parish system, developed an administration and organized the collection of taxes in the diocese.[335] Early bishops were in close contact with the Dominican Order, and it is likely that brothers resided at Koroinen before the foundation of the town and a proper convent, although their presence cannot be seen in the archaeological material of Koroinen in any way.[336] Nevertheless, the Dominicans and the bishops were likely familiar with the brick technology used in the Mälaren area, and the first steps in building masonry and using brick had likely already been adopted by the church at Koroinen during the second half of the 13th century, before Turku was founded.

Hence, it could be that in the 13th century, the above-mentioned actors were not yet established and organised well enough in medieval Finland, but from the 14th century onwards they probably implemented the same kind of building projects as in other parts of the Baltic area but on a somewhat more minor scale. The building works of Turku Cathedral as a brick cathedral may have started already in the early 14th century, but especially from the second half of the 14th century onwards, more masonry buildings and structures were erected in Finland, and the use of brick as building material increased.

Besides the raw bricks, the results of the pXRF analyses support the idea that bricks used both in Koroinen and in the town were locally produced. A little bit surprisingly, they seemed to have also imported bricks to both sites, and this was not detected in the Finnish wall brick material earlier. The PIXE-analysed bricks from

[334] Drake 2007.
[335] Salonen 2018.
[336] Hiekkanen 2003d; Jakobsen and Räsänen 2018.

Kuusisto (3 bricks) indicated local production.[337] However, it should be noted that the total number of pXRF-analysed bricks in the study is relatively low (there were 40, 4 of which were used as a reference).

In future research, to further confirm this result and to estimate the magnitude of brick importation in the Turku area, pXRF analyses should be done on a larger number of brick material and clay samples (article V). Furthermore, if we take a closer look at the Koroinen material, there were only two bricks imported in the 13th century material. On the other hand, most of the bricks dating to the 13th century are probably missing or were not saved. At least to improve the statistical credibility of the results, more bricks from the heat storage hypocaust and the floor in front of it should be analysed with the pXRF. On the other hand, the rest of the results from the younger structures in Koroinen and the town support the idea that the importation of bricks continued later in the 14th century. This seems to apply equally to all sorts of moulded bricks. Of the three analysed roof tiles (curved) from Turku, two were likely imported and one locally made (article V). In the Kuusisto material, one of the analysed roof tiles was locally made, while the other one was imported.[338] Consequently, on the basis of the scientific analyses, bricks and roof tiles were acquired the same way.

At Hattula, it seems that bricks were produced in a kiln found nearby (article IV). However, in further investigations, in addition to building phases, it would be interesting to study with the pXRF if bricks were also imported there. All in all, the importation and exportation of bricks and tiles should be investigated with a large sample of archaeological material in the future.

Based on Tamm, Bernotas suggests that the brick trade may have been active between Hanseatic towns and other towns involved in the trade network around the Baltic Sea region, but the scale of brick importation could not have been large due to the size of the ships and high costs.[339] In the case of Koroinen and Turku, the bricks needed were not necessarily imported far away, since one brick production site, active since the mid-13th century, was located in the archipelago of Stockholm.[340] Another place close to Turku was the brick kiln of Tallinn, which was active at least from the mid-14th century onwards.[341] In the future, it would be very

[337] Wahlberg 2000.
[338] Wahlberg 2000.
[339] Bernotas 2017, p. 23 and references therein. According to Bernotas citing Rieger, bricks would have been brought to Lübeck as ballast, but this is a misunderstanding, as Rieger states in his article that limestone was brought from Gotland. Cfr. Rieger 2014, 46.
[340] Lamm and Lindahl 2014, p. 88.
[341] Russow, 2017.

interesting to study brick material from both of these kiln sites as well as bricks found as cargo in shipwrecks.

About 75% of the analysed bricks from Koroinen and Turku were locally produced, probably near the construction sites. It is clear that, in the early phases, masons and brick-makers must have been foreign. Based solely on the analysed bricks and structures of Koroinen and the town of Turku, it is impossible to say where the experts came from. Even with written sources, it is not easy to identify their origins. The earliest known craftsman related to building construction was Conradus Pictor, who was active in Turku in the first half of the 14th century, while Thomas was the first known mason active in the area in the 1380s. The first mason of Finnish origin was probably Petrus de Kymitto, who renovated the cathedral in the 1460s. Foreign brick-makers and masons were still invited in later centuries, even though locals had adopted the masonry technology.[342]

The only concrete hint of a possible connection between the Turku area and the German and Baltic areas are the bricks with finger carvings on the flat side found in connection with the heat storage hypocaust at Koroinen. It is not known how common the technique was. It should be investigated whether it was more practical—as Ose interpreted—than related to the certain tradition of brick-building,[343] but these kinds of bricks have been used at least in present-day Northeast Germany, Northern Poland and Latvia.[344] At Turaida Castle, these finger-carved bricks have been dated to the 15th and 16th centuries and in Germany to the 13th century.[345] In the Finnish archaeological material, finger carvings have been found on imported roof tiles from Laukko Manor.[346] Based on the pXRF analyses, at least one of the finger-carved bricks from Koroinen was imported (article V).

In the case of Hattula, I have previously suggested that the masons could have been of Hinrich Brunsberg's school, that is, of German origin from modern North Poland.[347] The interpretation was based on the common features between Turku Cathedral, Häme Castle and Hattula,[348] but since the castle and HCCH do not seem to have been built at the same time, and because the uniqueness of the technique of

[342] Ruuth 1916, p. 122; Rinne 1935, pp. 259–267; Gardberg 1957, pp. 22–27, 41, 47–49, 53–54, 59; 1959, pp. 227–232, 331–325, 329, 358, 433, 550; Kuokkanen 1981, pp. 50–55; Kuujo 1981, pp. 153–155; REA 86, 94, 127, 576.
[343] Ose 2015. It was used to attach the mortar better between the bricks.
[344] Trummer 2005 and my own observations in the area of Malborg.
[345] Trummer 2005; Ose 2015, p. 109.
[346] Venhe 2000; Wahlberg 2000.
[347] Ratilainen 2006.
[348] Drake 2001a; 2003a.

using the moulded bricks sideways is questioned in the present work, the suggestion no longer has grounds.

The fact that bricks were imported into Koroinen and that they were used in an ecclesiastical site in such special structures as the heat storage hypocaust system, the altar and the brick-walled graves suggests that, in the early phases, bricks were highly appreciated and exclusive, and they were meant to impress. This is also supported by the brick imitation paintings in the Åland Islands. However, in Turku, bricks were used in lesser structures in wooden buildings shortly after the foundation of the town, just like in Lübeck. This shows that bricks were available for all that could afford them and were not limited to certain institutions. Compared with the whole Baltic Sea region, brick-building was launched somewhat modestly in medieval Finland, but as the analysis on the known traces and remains in Finland show, it was richer and more varied earlier than thought before.

5 Conclusions

The oldest masonry building on the mainland of medieval Finland is the stone keep built in the second half of the 13th century in Koroinen (1250–1300). It is possible that bricks were used in the details of the keep since, at the same time, bricks were applied in other constructions on the cape. However, there is no physical evidence of that. It is possible that the oldest parts of the castles of Turku (the 1280s, with brick details) and of Viipuri (after 1293, only stone) date to the end of the 13th century, but so far, there are no scientific dating results in support of that. At least for the Castle of Turku, it is more likely that the building works in masonry started only in the early 14th century.

The oldest brick structures on the mainland, dating to the second half of the 13th century, are likely the heat storage hypocaust and the brick floor in the wooden building on the riverbank of Koroinen as well as the brick altar of the first wooden church in Koroinen. Two brick-walled graves probably belong to the 13th century constructions too. Besides the altar, the oldest example of brick use in the church area is a brick found under brick-walled grave 3, likely dating to the second half of the 13th century, but possibly even between the 1250s and the 1270s. Elsewhere on the mainland, no certain traces of brick use dating to the 13th century are known. It is even possible that, on the Åland Islands, brick emerged as a building material only in the early 14th century.

Building in masonry started in the early 14th century both in the town of Turku and in Kuusisto Castle and possibly in Nagu Church, too. No brick buildings are known from the first half of the 14th century unless the building works of the brick cathedral were started after 1318, which seems quite possible based on the earliest traces of brick use in Turku. The oldest entire brick structure outside Koroinen dated with scientific methods is the oven made of raw bricks, which was in use between the 1320s and the 1340s. Presently, the structure is unique in medieval Europe. However, to broaden the picture of brick use, the numerous masonry building remains in Turku should be further investigated and dated. This also applies to the brick structures of nearby parishes.

In the 14th century, Koroinen follows the general tendency of increasing brick use in medieval Finland, as a brick floor was built in the renovated keep. The second

wooden church was equipped with a brick drain, font foundation and brick-walled grave 1. On the riverbank, a brick house, probably the residence of the bishop, was constructed (1350–1400); it is one of the oldest brick houses, if not the oldest, in medieval Finland. Building works of a stone church started probably at the end of the 14th century or the early 15th at the latest at Koroinen, which, following Hiekkanen's framework for stone church building, would make it the oldest stone church building project in Finland Proper.

In Häme, no clear evidence on 13th-century brick use exists. Brick use likely started in the 14th century, perhaps around the mid-14th century when the first stone phase of Häme Castle was begun. It seems probable that the curtain wall and the brickwork castle were built at the end of the 14th or early 15th century. If so, brick was used on a much larger scale and sooner in Häme than previously thought. These interpretations of the dating of the building phases are mostly based on the coin analysis by Ehrnsten. Nonetheless, it should be remembered that the dating of the castle is not firm until more scientific dating results are acquired. The same applies to Hakoinen Fortress. Based on OSL dating results, Holy Cross Church was built in the second half of the 15th century, but by the early 16th century at the latest. Therefore, Holy Cross Church is not necessarily the oldest church in Häme, but it may have been built at the same time as other stone churches of the region. However, a brick building project at Hattula seems to have begun somewhat earlier than the present-day church. Nevertheless, the Crown seems to have launched brick-building in Häme.

Normal wall bricks as well as moulded bricks were used right from the early phases of Koroinen and the town. No roof tiles were used in Koroinen, but they were already present at Kuusisto Castle in the 14th century, apparently before Turku. A unique feature in the early brick use is the oven built of raw bricks in Turku. Another special feature in the material were finger-carved bricks found in connection with the heat storage hypocaust at Koroinen. The commonality of this technique and whether it can be connected with bricks of German or Baltic origin must be further investigated in the future. In addition, the uniqueness of using moulded bricks sideways in Hattula was questioned in this study. In the early phases, normal wall bricks and moulded bricks were imported and locally produced in Koroinen and in the town of Turku. This also applies to roof tiles in Turku, but they should be studied more thoroughly in the future.

Since the first bricks were imported and used in special structures at an ecclesiastical site, this suggests that, in the earliest phase, bricks were highly appreciated and exclusive, and they were meant to impress. Early bishops and the Dominicans had contacts with the Mälaren area, where brick technology was known at the time. Shortly after Turku was founded, the use of brick also emerged there. Brick use in lesser structures in wooden buildings suggests that bricks were not

limited to certain institutions but were available for all that could afford them. In addition, raw bricks and other traces of brick use from the first half of the 14th century strongly suggest that a large brick building project, probably a cathedral, was going on in Turku.

On the mainland of medieval Finland, the first steps in building masonry and using brick were already bring taken by the Church in Koroinen during the second half of the 13th century. From the 14th century onwards, the Crown, the Dominicans and the burghers of Turku probably also implemented the same kinds of building projects, although somewhat more modestly, than elsewhere in the Baltic Sea region. Especially from the second half of the 14th century onwards, constructing in masonry and using brick as building material increased and was spread also elsewhere in medieval Finland. As the analysis on the known traces and remains showed, brick use on the mainland of medieval Finland began sooner and was richer and more varied than previously thought.

Abbreviations

EPT	Early Phases of Turku project
HCCH	Holy Cross Church of Hattula
KK2003	Kaupunginkirjasto excavation site 2003
OSL	Optically stimulated luminescence
PIXE	Particle-induced X-ray emission
pXRF	Portable X-ray fluorescence spectrometer
RR00/01	Rettiginrinne excavation site 2000–2001
SEM	Scanning electron microscope
^{14}C-AMS	Radiocarbon dating with accelerator mass spectrometry
WM	Wiggle matching, dating method based on radiocarbon dating and dendrochronology
ÅA98	Åbo Akademi main building site 1998

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Appendices

Appendix 1. The sites indicating brick use before 1430 on the mainland and in Åland. Table by author.

Castle province / other area according to Haggrén et al. 2015, p. 436	Site	Structure / Building	Only stone	Some bricks besides other materials	Stone and brick (vaults or other details of brick) / tiled roofs	Mostly / only brick, (stone foundations, brick walls/otherwise brick or only brick)	Current dating / Time of construction	Out of use	Dating method	Source
Castle province of Turku / Finland Proper	**Cape of Koroinen**	Time of use					c. 1000/1230s	1430		Harjula et al. 2018; Ratilainen et al. 2020
		Stone keep	?				1250–1300	By 1430	OSL+finds	Ratilainen et al. 2017; Ratilainen et al. 2020
		Brick floor in the stone keep (phase II)				x	1300–1350	By 1430	OSL	Ratilainen et al. 2017; Ratilainen et al. 2020
		Heat storage hypocaust and brick floor in front of it				x	1250–1300	1350?/1430	OSL+finds+14C	Ratilainen et al. 2017; Ratilainen et al. 2020
		Brick house / palace				x	1350–1400	By 1430	OSL, 14C of bone	Ratilainen et al. 2017; Ratilainen et al. 2020
		Altar in Church I				x	1250–1300?	1320s	Contemporaneity, coins	Ratilainen 2016; Ratilainen et al. 2020
		Brick-walled grave 2 in Church I				x	1250–1300?	By 1430	Contemporaneity	Ratilainen 2016; Ratilainen et al. 2020
		Brick-walled grave 3 in Church I and bricks under the lowest scheletons				x	1250–1300?	By 1430	14C wood, stratigraphy	Ratilainen 2016; Ratilainen et al. 2020
		Burial under brick-walled grave 3 in Church I		1			1250–1300	1300	14C wood, stratigraphy	Ratilainen 2016; Ratilainen et al. 2020
		Drain in Church II			x		After 1340s	By 1430	Contemporaneity	Ratilainen 2016; Ratilainen et al. 2020
		Foundation for a font in Church II				x	After 1340s	By 1430	Contemporaneity	Ratilainen 2016; Ratilainen et al. 2020
		Brick-walled grave 1 in Church II				x	After 1340s	By 1430	Contemporaneity	Ratilainen 2016; Ratilainen et al. 2020
		Choir/east end of the nave, Church III	x				After 1340s, End of 14th–early 15th?	Interrupted, by 1430	Interpretation of building phases, C14 of mortar not conclusive	Ratilainen 2016; Ratilainen et al. 2020
	Turku town / Turku Cathedral	Stone sacristy I			x		1300–1350?	After sacristy II was built	Building archaeology, town archaeology	Drake 2013
		Stone sacristy I			x		1280–1295/1270–1380 (1270–1300 84,4%)	After sacristy II was built	14C mortar, TKK09, TKK010 combined	Lindroos et al. 2011
		Stone cathedral (sacristy II+ five-sided choir + part of the north wall)			x		End of 14th century	1440s? at least by 1466	Building archaeology, town archaeology	Drake 2003, 2013
		Stone cathedral (sacristy II)			x		1326–1420/1315–1430 (56% 1388–1430)	1440s? at least by 1466	14Cmortar, TKK017	Lindroos et al. 2011, re-calibrated 2018. Out of use: Drake 2003
		Pentagonal choir				x	1326–1410/1316–1417	After the polygonal choir was built	14Cmortar, TKK023, highly contaminated.	Lindroos et al. 2011, re-calibrated 2018
		Brick cathedral				x	Early 15th, by 1425	Standing	Town archaeology, building archaeology	Drake 2013

Castle province / other area according to Haggrén et al. 2015, p. 436	Site	Structure / Building	Only stone	Some bricks besides other materials	Stone and brick (vaults or other details of brick) / tiled roofs	Mostly / only brick, (stone foundations, brick walls/otherwise brick or only brick)	Current dating / Time of construction	Out of use	Dating method	Source
	Turku town	Town hall I	x				1300–1350	After 1350	Finds	Uotila 2003; Ratilainen 2010
		Town hall II			x		1350–1430	Until 1730–40	Finds	Uotila 2003; Ratilainen 2010
		Aboa vetus / Stone house 2/A			x	Brick walls?	1390s	After 17th century	Dendrochronology	Uotila 2003; 2006; 2009
		Aboa vetus / Stone house 2/A+				x	1450s	After 17th century	Dendrochronology	Uotila 2003; 2006; 2009
		Aboa vetus / Stone house 1/B				x	1404–1420s/1401–1404	Second half of 17th century	Dendrochonology	Uotila 2003; 2006; 2009
		Aboa vetus / Stone house 1/B+				x	1410	Second half of 17th century	Dendrochonology	Uotila 2009
		Aboa vetus / Stone house F			?		1390s	Second half of 17th century	?	Uotila 2009, indicated only in the map
		Tuomiokirkontori 2005–2006, Gate Building?				x	1350	1429?/1450	Stratigraphy, dendrochronology, finds	Ratilainen 2010
		RR00/01, foundation of a stone house			x		1350	After Middle Ages?	Dendro, but not direct	Ratilainen 2010
		Katedralskolan 2014–2015, stone house			?		1409/1410		Dendrochronology, but only one result	Saloranta 2019
		Tuomiokirkontori 2005–2006, oven made of unfired bricks				x	1320s	1340s	Stratigraphy, dendrochronology, finds	Ratilainen 2014
		ÅA1998, house: street level brick, first floor wooden, 1st phase				x	1425s/after 1429?	16th century	Stratigraphy, dendrochronology, finds	Seppänen 2012, pp. 200–209
		ÅA1998, house: street floor brick, first floor wooden, 2nd phase				x	After 1446	16th century	Stratigraphy, dendrochronology, finds	Seppänen 2012, pp. 200–209
		Vanha Suurtori 1987, hearth		x			1300	1330s	Stratigraphy, dendrochronology, finds	Ratilainen 2010
		Vanha Suurtori 1987, hearth		3			1325	1350	Stratigraphy, dendrochronology, finds	Ratilainen 2010
		Vanha Suurtori 1987, wooden floor		2–3			1325	1350	Stratigraphy, dendrochronology, finds	Ratilainen 2010
		Tuomiokirkontori 2005–2006, oven?		x			1300–1350	1400	Stratigraphy, dendrochronology, finds	Ratilainen 2010
		Tuomiokirkontori 2005–2006, floor?		some			1300–1350		Stratigraphy, dendrochronology, finds	Ratilainen 2010
		ÅA1998, oven		x			End of 14th century	1450	Stratigraphy, dendrochronology, finds	Ratilainen 2010
		ÅA1998, oven		Some			End of 14th century	1450	Stratigraphy, dendrochronology, finds	Ratilainen 2010

Castle province / other area according to Haggrén et al. 2015, p. 436	Site	Structure / Building	Only stone	Some bricks besides other materials	Stone and brick (vaults or other details of brick) / tiled roofs	Mostly / only brick, (stone foundations, brick walls/otherwise brick or only brick)	Current dating / Time of construction	Out of use	Dating method	Source
		ÅA1998, hearth		x			1360s	1400	Stratigraphy, dendrochronology, finds	Ratilainen 2010
		RR00/01, oven?		2			1360s	Before early modern	Stratigraphy, dendrochronology, finds	Ratilainen 2010
		KK2003, hearth		some			1350–1400	15th century	Dendro: after 1249, but shore displacement and finds	Ratilainen 2010
		Bricks under wooden building (D) / Valonen		2			1310s	?	Dendrochronology	Valonen 1957, p. 78; Ratilainen 2010
		Hjelt 1989, lowest deposit		1			End of 13th–early 14th century	Deposit	Dendrochronology, finds	Ratilainen 2010
		Old Great Market 1987, deposit of gravel, brick waste and wood chips		x			1300–1325	Deposit	Stratigraphy, dendrochronology, finds	Ratilainen 2010
		Hjelt/1989, pile of stones		1			1300–1350	Deposit	Stratigraphy, dendrochronology, finds	Ratilainen 2010
		Aboa Vetus & Ars Nova, deposit of brick waste				x	1300–1350	Deposit	Stratigraphy, dendrochronology, finds	Ratilainen 2010
		Tuomiokirkonkori 2005–2006, R1676; rooftile		x			First half of the 15th century	In secondary use	Stratigraphy, dendrochronology, finds	Seppänen 2012, p. 797
		ÅA1998, deformed roof tiles		x			End of 14th century and early 15th century	Deposit	Stratigraphy, dendrochronology, finds	Seppänen 2012, pp. 802–803
	Turku Castle	West tower of the main castle and northern part of curtain wall			x		after circa 1300	Standing	Building archaeology, written sources but not direct	Drake 1994; Lovén 1996, p. 91
		West tower of the main castle + west part of northern curtain wall			x		1280s	Standing	Building archaeology, 3D reconstruction	Uotila 2003
		Rest of curtain wall of the main castle			x		First half of the 14th century	Standing	Building archaeology, written sources but not direct	Drake 1994; Lovén 1996, p. 91
		Palace in NW corner of the main castle			Likely, but not mentioned		First half of the 14th century	Destoyed in the second phase	Building archaeology, written sources but not direct	Drake 1994
		First storey of a stone building (chapel?) in NE corner	Brick not mentioned				First half of the 14th century	Destoyed in the second phase?	Building archaeology, written sources but not direct	Drake 1994
		North gate of the main castle (belongs to the first curtainwall)			Likely, but not mentioned		14th century	Not known	Dendrochonology	Uotila 1998, pp. 60–71
		Four more storeys to west tower			Likely, but not mentioned		Second half of the 14th century?	Standing	Does not mention	Drake 1994
		Palace II in the NW corner			Likely, but not mentioned		Second half of the 14th century?	Standing	Does not mention	Drake 1994
		Wall dividing the main castle in two	Brick not mentioned				Early 15th century	Standing	Building archaeology	Drake 1994
		NE corner, chapel of the castle			x		Early 15th century	Standing	Building archaeology	Drake 1994

Castle province / other area according to Haggrén et al. 2015, p. 436	Site	Structure / Building	Only stone	Some bricks besides other materials	Stone and brick (vaults or other details of brick) / tiled roofs	Mostly / only brick, (stone foundations, brick walls/otherwise brick or only brick)	Current dating / Time of construction	Out of use	Dating method	Source
		East tower+gate			Likely, but not mentioned		Early 15th century	Standing	Building archaeology	Drake 1994
		Eastern outer bailey			Likely, but not mentioned		1380s–1410s	1505	Dendrochronology	Uotila 1998, pp. 60–71
		Three towers in Eastern outer Bailey			x	?	1380s–1410s	1505	Dendrochronology	Uotila 1998, p. 84
	Hitis, Högholmen (wooden fortress)	Hearths			x		End of 14th century, early 15th century			Edgren 1999,
	Kaarina, Kuusisto Castle	Three-room Stone house, I, K, L			Likely, but not mentioned		Early 14th century	1520s	Finds, history, dendros but not direct	Uotila 1998, p. 107
		Gate G			Likely, but not mentioned		14th century	1520s	Building archaeology	Uotila 1998, pp. 92, 108
		Wall of the main castle	x				14th century	1520s	Building archaeology	Uotila 1998, pp. 92, 108
		Parts of tower D	x				14th century	1520s	Building archaeology	Uotila 1998, p. 107
		Outer Bailey 2 lower parts	x				14th century	1520s	Building archaeology	Uotila 1998, p. 107
		Outer Bailey 3, parts of it	x				14th century	1520s	Building archaeology	Uotila 1998, p. 107
		Itäosan iso kivitalo, XY			Likely, but not mentioned		14th century	1520s	Building archaeology	Uotila 1994
		Palace + outer bailey 1			x		1410s/1430s/1440s	1520s	Finds, history, dendrochronology	Uotila 1998, pp. 107–109
		Outer Bailey 2 upper parts				x	1410s/1430s/1440s	1520s	Finds, history, dendrochronology	Uotila 1998, pp. 107–109
		Outer Bailey 3, upper parts				x	1410s/1430s/1440s	1520s	Finds, history, dendrochronology	Uotila 1998, pp. 107–109
		Cellar-house H			Likely, but not mentioned		1480–1520	1520s	Finds, history, dendros but not direct	Uotila 1998, p. 107
		Roof tiles			x		14th-century layer	Deposit	Finds, stratigraphy	Suna 1994, pp. 19–20
	Lieto, Vanhalinna	Hillfort III phase of use					1000	1360s/1320s–1330s		Drake 1967, p. 33; Luoto 1984, pp. 128–129., 152–153; Taavitsainen 1990, pp. 140–141, 236–237.
		Eturinne H, defensive? Structure			x	?	?	1360s/1320s–1330s	Finds	Rinne 1914; Luoto 1984, p. 152; Gardberg 1993, pp. 21–22
		Defensive? Structure on top?				?	?	1360s/1320s–1330s	Finds	Rinne 1914; Luoto 1984, p. 152; Gardberg 1993, pp. 21–22
		Brick from Vanhalinna, KM5452:39					1350–1450	1360s/1320s–1330s	TL	Hiekkanen 2002

Castle province / other area according to Haggrén et al. 2015, p. 436	Site	Structure / Building	Only stone	Some bricks besides other materials	Stone and brick (vaults or other details of brick) / tiled roofs	Mostly / only brick, (stone foundations, brick walls/otherwise brick or only brick)	Current dating / Time of construction	Out of use	Dating method	Source
	Masku, Stenberga	Keep	x				End of 14th century	Soon after (Christina)	Written (1398)	Drake 1993, p. 240; Lovén 1996, pp. 308–309; Suhonen 2002
		Keep II			x		1430s–1440s?	Soon after (no convent)	Written	Drake 1993, p. 240; Lovén 1996, pp. 308–309; Suhonen 2002
		Tower	x				1430s–1440s?	Soon after (no convent)	Written	Drake 1993, p. 240; Lovén 1996, pp. 308–309; Suhonen 2002
	Korpo stone church	Nave, sacristy, porch, tower (no choir)			x		1430s or 1440s	Standing	Comparative building archaeology	Hiekkanen 2014, pp. 70–73
		Complex church, 1st: Sacristy			x		Does not give dating	Standing	–	Sjöberg 2011, p. 182; Bilaga pp. 1–3
		Complex church, 2nd: Nave, choir, lower part of tower first			x		Does not give dating	Standing	–	Sjöberg 2011, p. 182; Bilaga pp. 1–3
		3rd: Upper part of tower, gables and porch			x		First half of the 15th century	Standing	Radiocarbon dating of organic matter (x 5) and 4 conclusive 14C datings of mortar, no deadwood	Sjöberg 2011, p. 182; Bilaga pp. 1–3
	Nagu Stone Church	Nave, sacristy			x		1430–1450	Standing	Comparative buidling archaeology	Hiekkanen 2014, pp. 116–117
		Porch	?		?		1500	Standing	Comparative buidling archaeology	Hiekkanen 2014, pp. 116–117
		Sacristy			x		First half of the 14th century / circa turn of the 15th century	Standing	Radiocarbon dating of plant remains and organic inclusions x 3, mortar dating x 1	Sjöberg 2011, p. 182; Sjöberg et al. 2011
		Nave 2nd, porch and vaulting 3rd			x		First half of the 15th century/ 1430s	Standing	Dendrochronology (nave roof: 1434/35, 1433+10, 1434/35, 1435/36, 1435/36, porch: 1433+8, 1431+10), radiocarbon datings of organic matter x 15 (e.g., shingles, roofboards, plant remains, organic inclusions), mortar dating x 2	Sjöberg 2011, p. 182; Sjöberg et al. 2011: Results in Sjöberg 2011, in Bilaga 1 marked slightly ambigously
	Nousiainen Stone Church	Nave, sacristy, porch			x		1420s/1430s	Standing		Hiekkanen 2014, p. 121
		Choir				x	1420s/1430s	Standing		Hiekkanen 2014, p. 121
	Pargas Stone Church	Nave, sacristy I, choir			x		1440–1450s	Standing	Comparative building archaeology	Hiekkanen 2014, pp. 126–129
		Sacristy II			x		1480s	Standing	Comparative building archaeology, date 1486 on wall painting	Hiekkanen 2014, pp. 126–129
		Porch			?		Maybe end of 15th century	Standing	Comparative building archaeology, date 1486 on wall painting	Hiekkanen 2014, pp. 126–129
		Nave, sacristy I, narrow choir, porch, possibly vaulting			x		End of the 14th century, likely 1380s	Standing	Dendrochronology (1380+3), 14C organic (wood) samples x 8+2 x 14C mortars	Sjöberg 2011a; Sjöberg et al. 2011
		Sacristy II			x		1480s	Standing	1486 on wall painting	Sjöberg 2011a; Sjöberg et al. 2011

Castle province / other area according to Haggrén et al. 2015, p. 436	Site	Structure / Building	Only stone	Some bricks besides other materials	Stone and brick (vaults or other details of brick) / tiled roofs	Mostly / only brick, (stone foundations, brick walls/otherwise brick or only brick)	Current dating / Time of construction	Out of use	Dating method	Source
	Uusikaupunki, Kalanti vicarage	Stone cellar			Brick not mentioned		At least 1411	?	Written sources	Uotila 2009b, p. 307
Kokemäki area	**Ulvila town**	Time of use					1344	1550s/by 1600	Written	Haggrén et al. 2015, p. 460
		Wooden building with a hearth		x			1350–1500		Finds	Pihlman 1982; 1984
		Wooden cellar with stone wall, brick waste under it		x			1350–1500		Finds	Pihlman 1982; 1984
		Brick waste in 2 ditches		x			1350–1500		Finds	Pihlman 1982; 1984
		Cooking hut, hearth		x			1350–1500		Finds	Pihlman 1982; 1984
	Eurajoki, Liinmaa	Wooden fortress					1250–1300	Early 15th century	14C, dendro, finds	Luoto & Pihlman 1980; Luoto 1987, pp. 66–77; Suhonen 2002; Uotila 2011, p. 14
		Hearth in a wooden building		?	?		End of 14th century	Early 15th century	Finds	Luoto & Pihlman 1980, pp. 42–44; Suhonen 2002; Uotila 2011, p. 14
		Building				Fachwerk?	End of 14th century	Early 15th century	Finds	Luoto 1987, p. 67; Suhonen 2002; Uotila 2011, p. 14
	Kokemäki, Isoluoto	Wooden fortress? / Kokemäki manor?		x			End of 14th century	?	Finds	Luoto & Pihlman 1980, p. 48; Luoto 1987, p. 67; Suhonen 2002b
	Kokemäki, Linnaluoto / Forsby	Wooden fortress: Brick building?				x	At least end of the 14th century / 14th century?	?	Finds	Luoto & Pihlman 1980, p. 46; Luoto 1987, p. 63; Suhonen 2002b
Castle province of Häme	**Häme Castle**	Grey stone main castle			x	Residential storey of brick intended but interrupted?	1370s–1390s		Comparative building archaelogy, written sources on chiefs	Drake 2001, pp. 215–217; 2003, p. 13, but see on the coin finds: Ehrnsten 2013
		First part of curtain wall (SW–N+S)				x	before 1370s? / or 1370s–1390s? or later?		Comparative building archaelogy, written sources	Drake 2003, p. 13; Luppi 1992
		NW curtain wall				x	End of 14th century–early 15th century		14C, mortar	Uotila 2009
		South tower outside curtain wall I	?				before 1370s? / or 1370s–1390s?		Comparative building archaelogy, written sources	Uotila 1998, p. 119
		Curtain wall N ja NE (from N corner to rondel) + SE wall				x	before 1370s? / or 1370s–1390s? or later?		Comparative building archaelogy, written sources	Uotila 1998, p. 119
		Dansker (N), not contemporary with curtainwall				x	14th century or 1420s–1450s? Or second half of the 15th century?		Comparative building archaeology, written sources	Uotila 1998, pp. 116–119; Luppi 1992; 2003
		Fatabur Tower (W)				x	Early 15th or second half of 15th century?		Comparative building archaeology, written sources	Uotila 1998, p. 119; Luppi 1992; 2003, p. 146
		Cock Tower			x		1400–1450		Comparative building archaeology, written sources on chiefs	Drake 2001, pp. 215–217; 2003
		Brickwork castle				x	1472–1490? / End of the 14th century, early 15th century?		Comparative building archaeology, written sources on chiefs / 14th-century coins analysed by Ehrnsten	Drake 2001, pp. 215–217; 2003 / Ehrnsten 2013, 2015, 2019

Castle province / other area according to Haggrén et al. 2015, p. 436	Site	Structure / Building	Only stone	Some bricks besides other materials	Stone and brick (vaults or other details of brick) / tiled roofs	Mostly / only brick, (stone foundations, brick walls/otherwise brick or only brick)	Current dating / Time of construction	Out of use	Dating method	Source
	Hakoinen Fortress	Time of use					Medieval?	?	Coin 1290–1318, chimney	Drake 1967, p. 33; Gardberg 1993, pp. 23–24; Taavitsainen 1990, pp. 140–141, 236–237; Lovén 1996, p. 63
		Curtain wall			x		?	?	Finds	Drake 1967, p. 33; Gardberg 1993, pp. 23–24; Taavitsainen 1990, pp. 140–141, 236–237; Lovén 1996, p. 63
		Lower curtain wall			x		14th–15th centuries	?	Finds	Drake 1967, p. 33; Gardberg 1993, pp. 23–24; Taavitsainen 1990, pp. 140–141, 236–237; Lovén 1996, p. 63
		Two-room brick building inside the curtain wall				?	14th–15th centuries	?	Finds, chimney	Drake 1967, p. 33; Gardberg 1993, pp. 23–24; Taavitsainen 1990, pp. 140–141, 236–237; Lovén 1996, p. 63
		Hearth				x	14th–15th centuries	?	Finds, chimney	Drake 1967, p. 33; Gardberg 1993, pp. 23–24; Taavitsainen 1990, pp. 140–141, 236–237; Lovén 1996, p. 63
		Hearth?				?	14th–15th centuries	?	Finds, chimney	Drake 1967, p. 33; Gardberg 1993, pp. 23–24; Taavitsainen 1990, pp. 140–141, 236–237; Lovén 1996, p. 63
		Foundations of a tower				?	?	?	Finds, chimney	Drake 1967, p. 33; Gardberg 1993, pp. 23–24; Taavitsainen 1990, pp. 140–141, 236–237; Lovén 1996, p. 63
		Brick from Hakoinen, KM5455:14					1790–1890	?	TL	Hiekkanen 2002
Castle province of Raseborg	**Raseborg Castle**	Time of use					1370s	1550s		Haggrén et al. 2009; Drake 1991, pp. 128, 138
		Curtain (main castle) walls (horse shoe) + east and west, three towers, at least two			x	?	1370s–early 1400s	1550	Building archaeology, written sources	Drake 1991, pp. 128–132
		Eastern outer bailey			?		possibly before 1427	1550	Dendrochonology, but not direct	Lovén 1996, p. 159; Uotila 1998, p. 128
	Helsinki, Vartiokylä	Hillfort/wooden fortress; time of use					1260–1410	By early 15th century	14C, 10 samples, but charcoal, finds from end of 13th-14th century	Heikkinen 2003
		Brick waste from a hearth				x	1260–1410	?		Heikkinen 2003
	Karjaa, Junkarsborg	Wooden fortress?		?			1320s at the earliest, likely 1360s	1420s	Finds, written sources	Suhonen 2001, 2002
		Brick, KM37128:91					1460–1580		TL	Hiekkanen 2002
	Inkoo Stone Church	Whole church			x		1430s		Standing	Hiiekkanen 2014, p. 433
Porvoo / County	**Porvoo town/stone church**	Stone nave + sacristy I			x		1410s	1440s	Comparative building archaeology, no direct dating results	Hiekkanen 1994, p. 218; Hiekkanen 2014, p. 459

Castle province / other area according to Haggrén et al. 2015, p. 436	Site	Structure / Building	Only stone	Some bricks besides other materials	Stone and brick (vaults or other details of brick) / tiled roofs	Mostly / only brick, (stone foundations, brick walls/otherwise brick or only brick)	Current dating / Time of construction	Out of use	Dating method	Source
	Porvoo, Linnamäki	Hillfort / wooden fortress, time of use					From Viking Age? 1380s?	1555? In secondary use, at least 1752 onwards	14C, finds, written sources	Edgrén 1985; Lovén 1996; Gardberg 1996, p. 167; Hakanpää et al. 2008, p. 64
		Several hearths		x			End of 13th century–14th century / 1380s	1555? In secondary use at least 1752 onwards	14C, finds, written sources	Edgrén 1985; Lovén 1996; Gardberg 1996, p. 167
	Porvoo, Husholmen	Wooden fortress? time of use					1380s	In ruins but when?	Dendrochonology, but not direct	Suhonen 1999, p. 20
		Greystone wall			?		1380s	In ruins but when?	Dendrochonology, but not direct	Suhonen 1999, p. 20
		Tower foundations?			?		1380s	In ruins but when?	Dendrochonology, but not direct	Suhonen 1999, p. 20
	Sipoo, Sibbesborg	Wooden fortress, time of use					Second half of 14th century?	In ruins but when?	2 finds	Lovén 1996, pp. 183–185; Suhonen 2002
		Masonry building				x	Second half of 14th century?	In ruins but when?	2 finds	Lovén 1996, pp. 183–185; Suhonen 2002
		KM5454:14, two pieces of bricks					1590–1690	In ruins but when?	TL	Hiekkanen 2002
	Pernaja stone church	Sacristy			x		1410s	Standing	Dendrochronology	Hiekkanen 2014
	Vantaa, Kirkonkylä, vicarage	Excavated area in use at least					14th–16th centuries	By 16th century	14C, TL, finds	Väisänen 2016, pp. 126, 224–227, 243
		Wooden building with two rooms and two hearths dated					14th–15th centuries	By 16th century	14C, TL, finds	Väisänen 2016, pp. 126, 224–227, 243
		Hearth, tiled stove?	Interpretation				14th century–early 15th		See under	Väisänen 2016, pp. 126, 224–227, 243
		Wooden floor					1421–1497		14C	Väisänen 2016, pp. 126, 224–227, 243
		Hearth, stovetile?		x			1309–1427		14C, charcoal	Väisänen 2016, pp. 126, 224–227, 243
		Stones from the oven					13th–14th centuries		TL	Väisänen 2016, pp. 126, 224–227, 243
		Bricks from the oven					16th–17th centuries		TL	Väisänen 2016, pp. 126, 224–227, 243
		Dating of the other oven					1285–1397		14C, burnt bone	Väisänen 2016, pp. 126, 224–227, 243
Castle province of Viipuri	**Viipuri town**		No bricks mentioned				1293 / 14th century onwards, but mostly 15th- and 16th-century structures found		So far, no bricks mentioned	Saksa 2009
	Castle of Viipuri	Time of use					after 1293	Standing		Lovén 1996, p. 98; Drake 2001
		Round curtain wall	x				after 1293	Standing	Written sources, building archaeology	Lovén 1996, p. 98; Drake 2001

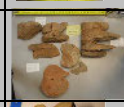
Castle province / other area according to Haggrén et al. 2015, p. 436	Site	Structure / Building	Only stone	Some bricks besides other materials	Stone and brick (vaults or other details of brick) / tiled roofs	Mostly / only brick, (stone foundations, brick walls/otherwise brick or only brick)	Current dating / Time of construction	Out of use	Dating method	Source
		Curtain wall of main castle			x		during 14th century	Standing	Written sources, building archaeology	Lovén 1996, p. 98; Drake 2001
		St Olav's tower			x		1400	1560s standing	Written sources, building archaeology	Lovén 1996, p. 99; Drake 2001
Castle province of Kastelholm, Åland	**Kastelholm Castle**	Time of use					1380	Standing		
		Northern outer bailey			x		Early 15th century	Standing		Lovén 1996, p. 151; Uotila 1998, p. 133; Palamarz 2004
		SE outer bailey			x		14th century or early 15th	Standing	Land up lift	Uotila 1998, p. 133
		Main castle: ring wall, tower and buildings inside			x		early 15th	Standing	Written sources	Lovén 1996, p. 151; Palamarz 2004
		Lifting of the wall of the main castle			x		Early 15th	Standing		Palamarz 2004, p. 25
	Finström Stone Church	Whole church		x			1440s–1470s	Standing	Dendro	Hiekkanen 2014, p. 369
		Unvaulted nave + sacristy	x				End of the 13th century	Standing	Mainly coins	Ringbom 2010, pp. 70–71
		Renovation: sacristy highetened,	x				1440s	Standing	Dendro	Ringbom 2010, p. 71
		Renovation: nave vaulted		x			1450s	Standing	Dendro	Ringbom 2010, p. 71
		Renovation: porch	x				1450s	Standing	Dendro	Ringbom 2010, p. 71
		Renovation: tower	x				1467	Standing	Dendro, mortar dating in concordance x 1	Ringbom 2010, p. 71; Heinemeier et al. 2010, p. 182
	Finström Stone Cellar				x		14th century? / older?	?	Coin finds	Remmer 1986, p. 30, however, cfr. Ehrnsten 2019
	Föglö Stone Church	1st: Nave?			Not mentioned		After 1450,maybe 1500–1520	standing	Building archaeology, common features	Hiekkanen 2014, pp. 372–375
		2nd: Sacristy, narrow choir, tower			Not mentioned		After 1520	Standing	Building archaeology, common features	Hiekkanen 2014, pp. 372–375
		Porch			Not mentioned		Post-medieval	Standing	Building archaeology, common features	Hiekkanen 2014, pp. 372–375
		Nave			x		1300–1400, 1290–1410/ 1405–1430, 1390–1440 (90.5%)	Standing	Mortar dating from west gable and altar, not conclusive	Ringbom et al. 2011
		Tower			Not mentioned		1490–1640, 1470–1640 (fire?) OR 1420–1440, 1415–1445	Standing	Mortar dating x 4	Ringbom et al. 2011
	Eckerö Stone Church	Nave + sacristy			x		End of 14th century / early 15th century	Standing	Building archaeological comparison	Hiekkanen 1994, p. 244; Hiekkanen 2014, Ahvenanmaa, note 16.
		Nave + sacristy			x		End of 13th century	Standing	Mortar 14C, 14C wood (pre many fractions)	Ringbom & Remmer 1995, pp. 204–208; Ringbom 2010, pp. 64–65

Castle province / other area according to Haggrén et al. 2015, p. 436	Site	Structure / Building	Only stone	Some bricks besides other materials	Stone and brick (vaults or other details of brick) / tiled roofs	Mostly / only brick, (stone foundations, brick walls/otherwise brick or only brick)	Current dating / Time of construction	Out of use	Dating method	Source
		Tower			Not mentioned		1465–1470	Standing	Dendrochrnology	Hiekkanen 1994, p. 244
	Hammarland Stone Church	Nave			x		Early 14th century	Standing	?	Hiekkanen 2014, 383, note 137
		Nave			x		Second half of the 13th century	Standing	C14 mortar AMS + conventional, only 2 fractions	Ringbom 2010, p. 84
		Tower	x				End of 14th century, early 15th at the latest	Standing	?	Hiekkanen 2014, 383, note 138
		Tower	x				Beginning of the 14th century	Standing	C14 mortar AMS + conventional, only 2 fractions	Ringbom 2010, p. 84
		Choir	x				1460s	Standing	Dendrochronology	Hiekkanen 2014, p. 383
		Sacristy	x				1450s or later	Standing	Building archaeological comparison	Hiekkanen 2014, p. 383
		Nave enlarged + narrow choir added	x				Beginning of the 15th century + mid 15th	Standing	Dendros from the new roof trusses, mortar dating in concordance x 1	Ringbom 2010, p. 84; Heinemeier 2010, p. 182
	Hammarland Stone House	Masonry house	x				1450s?	?	Coin	Remmer 1986, p. 30
		Secondary brick wall				x	1450s?	?	Coin	Remmer 1986, p. 30
	Jomala Stone Church	Tower + nave, choir	x				Around 1280, 1275–1285	Partly standing	Dendrochronology, tower	Hiekkanen 2014, p. 389
		1st nave and choir	x				Before 1280s	Partly standing	Style of the sculptures	Ringbom 2010, p. 90
		2nd tower	x				1280s	Standing	Dendrochronology, mortar dating in concordance x 5, tower	Ringbom 2010, p. 90; Heinemeier et al. 2010, p. 182
	Jomala vicarage?	House with a stone cellar, time of use					Second half of the 13th century	Beginning of 16th century	Finds	Hörfors 1992
		House with a cellar, phase I	Not mentioned				Second half of the 13th century	Early 14th century	Finds	Hörfors 1992
		House with a cellar, phase II	Not mentioned				Early 14th century	End of 14th century	Finds	Hörfors 1992
		House with a cellar, phase III			x		Late 14th century	Circa 1450 / by the end of the 15th century	Finds	Hörfors 1992
	Jomala, east to the church, wooden buildings, priest's estate?	Roof tiles in wooden buildings?			x		Late 14th century–early 15th century / Late Middle Ages	? At least already in 1659?	Finds	Cederhvarf 1910; Haggrén 2015, p. 445
		Hearths		x			Late 14th century–early 15th century / Late Middle Ages	? At least already in 1659?	Finds	Cederhvarf 1910; Haggrén 2015
	Kumlinge Stone Church	Nave, porch, (sacristy)			x		1500–1510	Standing	Building archaelogy, common features	Hiekkanen 2014, pp. 392–393

Castle province / other area according to Haggrén et al. 2015, p. 436	Site	Structure / Building	Only stone	Some bricks besides other materials	Stone and brick (vaults or other details of brick) / tiled roofs	Mostly / only brick, (stone foundations, brick walls/otherwise brick or only brick)	Current dating / Time of construction	Out of use	Dating method	Source
		Church			x		During 14th century	Standing	Mortar dating	Ringbom et al. 2011
		East nave gable	x				1320–1360	Standing	Mortar dating x 3	Ringbom et al. 2011
		West nave gable	x				1410–1430, 1405–1435	Standing	Mortar dating x 3	Ringbom et al. 2011
		Tower			Not mentioned		1358–1359	Standing	Dendrochronologyx 1	Ringbom et al. 2011
	Kökar Stone Church	Nave 1st			Likely, but in ruins		1500–1520	1640s	Building archaeology, common features	Hiekkanen 2014, pp. 397–399
		Narrow choir 2nd?			Vaults+roof tiles in masonry		1500–1520	1640s	Building archaeology, common features	Hiekkanen 2014, pp. 397–399
		Tower after nave			Likely, but in ruins		1500–1520	1640s	Building archaeology, common features	Hiekkanen 2014, pp. 397–399
		sacristy after choir			Likely, but in ruins		1500-1520	1640s	Building archaeology, common features	Hiekkanen 2014, pp. 397–399
		Tower			Likely, but in ruins		First half of 15th century (1430–1455, 1415–1470)	1640s	Mortar datingx 1	Ringbom et al. 2011
		Choir			Likely, but in ruins		14th century (1305–1405, 1290–1420)	1640s	Mortar datingx 2	Ringbom et al. 2011
	Lemböte Chapel	Chapel nave	?		?		1500–1530	1550	Building archaeology, common features	Hiekkanen 2014, p. 407
		Chapel nave	?		?		End of 13th century–1370	1550	Coins, 14C mortar	Ringbom 2010, p. 103. Out of use: Hiekkanen 2014, p. 407
	Lemland Stone Church	Nave	x				End of 13th	Standing	Dendrochronology	Hiekkanen 2014, p. 402; Ringbom 2010, p. 106
		Tower	x				Early 14th century	Standing	Dendrochronology + mortar dating	Hiekkanen 2014, p. 402; Ringbom 2010, p. 106; Heinemeier et al. 2010, p. 182
		Sacristy + porch			x		1450 or after	Standing	Building archaeological comparison	Hiekkanen 2014, p. 402
		Sacristy + porch			x		Early 14th century	Standing	Dendrochronology	Ringbom 2010, p. 107
	Saltvik Stone Church	Nave			x		Early 1370s	Standing	Dendrochronology, TL, 14C of wood	Hiekkanen 2014, pp. 411, note 345, 346
		Tower			x		Around 1380	Standing	Dendrochronology	Hiekkanen 2014, pp. 411, note 345, 346
		Porch	?		?		End of 14th century?	Standing	Comparative	Hiekkanen 2014, pp. 411, note 345, 346
		Sacristy			x		Mid-15th century?	Standing	Comparative	Hiekkanen 2014, pp. 411, note 345, 346
		Nave with stone vaults + sacristy stone vault			x		1270–1296	Standing	14C mortar	Ringbom 2010, p. 114

Castle province / other area according to Haggrén et al. 2015, p. 436	Site	Structure / Building	Only stone	Some bricks besides other materials	Stone and brick (vaults or other details of brick) / tiled roofs	Mostly / only brick, (stone foundations, brick walls/otherwise brick or only brick)	Current dating / Time of construction	Out of use	Dating method	Source
		Nave			x		1371/14th century	Standing	Dendrochronology x 1, Mortar dating in concordance x 12	Heinemeier et al. 2010, p. 182
		Brick vault in the nave			x		End of 14th century	Standing	Dendrochronology	Ringbom 2010, p. 114
		Porch	?		?		1370s	Standing	Dendrochronology	Ringbom 2010, p. 114
		Tower	x				1381	Standing	Dendrochronology (mortar dating in concordance x 4)	Ringbom 2010, p. 114; Heinemeier et al. 2010, p. 182
	Sund Stone Church	Nave	x				End of 13th century, 1310 at the latest	Standing	Building archaeology, common features	Hiekkanen 2014, pp. 416, note 378 ja 379
		Tower and porch	x				End of 14th century	Standing	Building archaeology, common features	Hiekkanen 2014, pp. 416, note 378 ja 379
		Sacristy	x				Mid-15th century?	Standing	Building archaeology, common features	Hiekkanen 2014, p. 416
		Nave	x				1250–1275	Standing	C14 mortar	Ringbom 2010, p. 124
		Sacristy and tower	x				Beginning of the 14th century	Standing	?	Ringbom 2010, p. 124
		Tower got vaults + porch	x				15th century	Standing	?	Ringbom 2010, p. 125
	Sund Stone Cellar	Two-roomed stone cellar	x				Medieval	?	Finds	Remmer 1986
		Upper walls + vaults				x	Post-medieval	?	Renaissance bond	Remmer 1986

Appendix 2. Table 2, published in article III, but with a photo of each analysed brick. Table by author.

KM52100:	Brick type	Moulded type	Photo	Context
1343	moulded	?		Western masonry building
1418	moulded	mullion		
1419	moulded	window jamb?		
1420a	moulded	window jamb?		
1420b	moulded	window jamb?		
1421a	moulded	?		
1421b	moulded	window jamb?		
1431		Floor?		Eastern masonry building
1432a-f	moulded	ridge band / pillar?		
1433a-q	moulded	1/4 circle, pillar? jambs		
1434a-g	moulded	mullion?		
1435a-c	moulded	jambs?		
1436a-g	moulded	ribs		
1437b	moulded	window jamb?		
1437c	moulded	window jamb?		
1438b	moulded	concave forms		
1439a	moulded	ribs		
1440a	moulded	carved with fingers		
1441a-c	moulded	mullion		
1450a	moulded	carved with fingers		Heat storage hypocaust and the wooden building
1450b	moulded	carved with fingers		
1469	moulded	same as 1437c		Eastern masonry building
1471a	wall brick or moulded?			
1471b	moulded			
1471c	moulded			
1475	missing			

Appendix 3. Corrected Table 1 published in article V. Corrections marked in red. Table by author.

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, oven	RF 378, tiili73	Raw brick	Mortar on the flat surfaces, but unmortared spot was measureable	1320s
59	Early Phases of Turku Project, R2182, oven	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, M2204	RF399	Piece of Brick	Compact; mortar all over; normal colour	1250–1320
64	Early Phases of Turku Project, M2214	RF398	Piece of Brick	Small piece among many pieces; normal colour; no mortar	1250–1320
65	Early Phases of Turku Project, R1097, stone floor? Inside a wooden building	RF92	Piece of Brick	Compact; no mortar; no original surfaces; normal colour	1300–1350
66	Early Phases of Turku Project, R1662b, stepping stones on the market	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, pavement	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, pavement	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, pavement	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, pavement	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, R1096, hearth?	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,stepping stones on the market	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, M3006	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 and from the interphase of the organic deposit under	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	M	Deposit		
		R	Structure		

Appendix 4. Original OSL sampling report by author.

Keskiajan sarastaessa -projekti

Ajoitusnäytteiden ottaminen rakennefragmenteista 16.-18.2.2016.

Raportin laati Tanja Ratilainen

Koroinen KM52100:

Kaikki rakennefragmentit, joista otettiin näyte, valokuvattiin ennen näytteenottoa. Näytteenoton suoritti konservaattori Maarit Hirvilammi. Valokuvauksen ja kirjanpidon hoiti Tanja Ratilainen. Kaikista ko. alanumeroista jäi vielä tiiltä tai laastia jäljelle.

OSL-näytteet

Näytteen tavoitekoko oli 4x4x4cm, betanäytettä (2x2x2cm) ei otettu. Pala jäi usein tavoitekokoa pienemmäksi. Näytteet otettiin jo valmiiksi rikkonaisista tiilistä ja pyrittiin valitsemaan sellaisia kohtia, joista tiili oli jo valmiiksi halkeillut ja siten, että tiilen ominaispiirteet (esim. alkup. muoto tai mitat) eivät vahingoittuneet. Yhdestäkään ehjästä tiilestä ei otettu näytettä.

Näytteet sahattiin letkuporalaitteella, jossa oli halkaisijaltaan 30 mm timanttilaikka. Sahatessa laikkaa jäähdytettiin vedessä. Lopuksi näyte irrotettiin taltalla ja vasaralla hakkaamalla. Käsittelyalustat puhdistettiin näytteiden välillä, samoin altaan vesi.

C14-näytteet

Laastin C14-näytteet otettiin kuivana, joko skalpellillä nyrhimällä, ei koskettu käsin tai laikalla sahaamalla, laitettiin folioon, muutoin samat periaatteet kuin edellä.

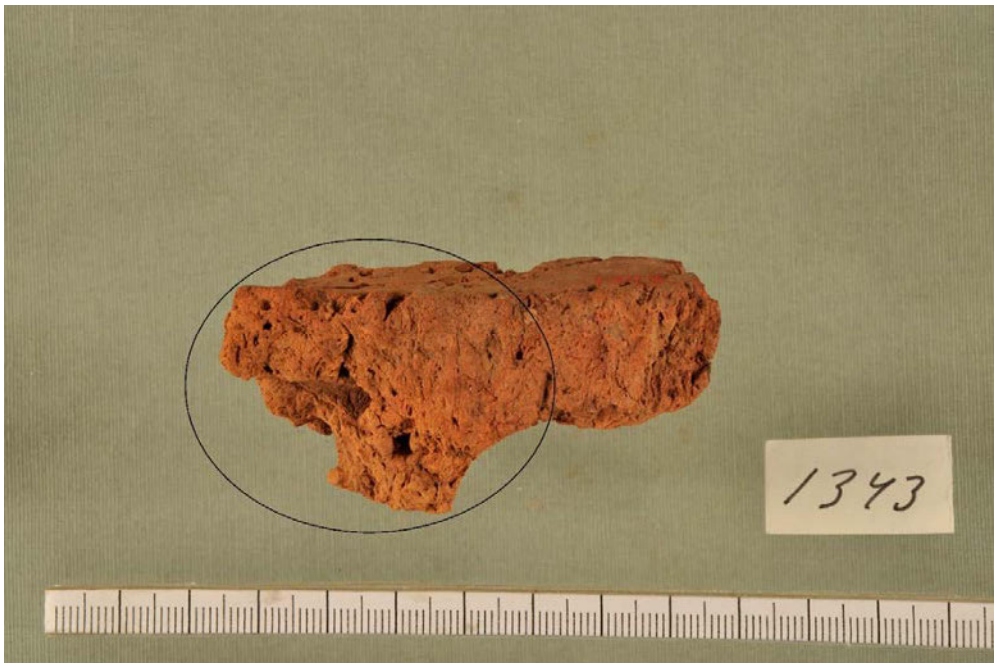
Tiilessä ollut palanut luu nyrhittiin skalpellilla irti ja laitettiin folioon.

Näytteet otettiin seuraavista alanumeroista:

Alanumero	
1343	muototiilen kappale, pieni fragmentti jo itsessään.
1417c	kaksi yhteen liimattua palasta, liuotettiin asetonilla liima pois, ettei tarvitse hajottaa tiiltä, irrotettu pala hajosi itsestään kahtia, nämä palat näytteeksi.
1417b	kaksi yhteen liimattua palaa, jotka liuotettiin asetonilla irti toisistaan. Pienempi palanen sahattiin kahtia.
1417a	oli jo paloina ja murusina, ei tarvinnut sahata sopivankokoista palasta.
1430d	näyte otettiin jo valmiiksi rakoilleesta kohdasta, rikkonaisesta tiilestä.
1441b	lohjenneesta ruodetiilen varren juuresta
1436	rikkonaisen ruodetiilen kolmionmuotoisen osan kulmasta siten, että laastit säilyivät mahd. paljon kiinni. tästä mahdollisesti laastin C14 ajoitusta saumauslaastista, otetaan myöhemmin?

1432d	kaksi yhteensopivaa tiilen kappaletta liimattu yhteen, liuotettiin pienempi pala irti ja sahattiin sisäosasta pala näytteeksi. Toisesta palasta otettiin luun C-14 näyte (luuta oli sekoitteena).
1450a	lohjenneen päädyn alapinnasta siten, että yläpinnan uurrokset säilyivät.
1450c	lohjenneen muuritiilen päädystä, uurrokset säilyivät.
1449d	Muuritiilen kaksi yhteensopivaa palasta oli liimattu yhteen. Sauma liotettiin asetonilla auki, ja pienemmästä palasesta, joka oli ko. tiilen lohjenneesta päädystä, otettiin puolet näytteeksi tiilen pituusmitta säilyttäen.
1448	Laastin palanen, josta sahattiin näyte C14-ajoitukseen. Laastin sekoitteena oli tiilenmuruja, joita irrotettiin skalpellilla nyrhien OSL-näytteeksi.
1418	ikkunanpuitetiilen rikkonaisesta päädystä, alapinnasta laastinäyte C14.
1434	valmis pala, ei jouduttu lohkomaan, alkujaan jo säpäleinä näitä paljon.
1420a	sahattiin pala rikkonaisesta pinnasta.
1421	sama kuin ed.
1437c	valmis pala, ei jouduttu sahaamaan, jätettiin edustavimmat talteen.
1419b	sahattiin sellaisesta kohdasta, että muoto ja alkup. mitat säilyvät.
1431	sahattiin sellaisesti kohdasta, että maksimimitat säilyivät.
1433C	laastinäyte lappeesta, saumauslaastia sahattiin, irtosi lopulta itsessään. Tiilinäyte jo valmiiksi lohjenneesta paikasta, siten ettei ehjää mennyt rikki.

Kuvaliitteessä näytteenottokohta on ympyröity.


1343


KM 52100:
1417 (C)


KM 52100:
1417 (B)


KM 52100: 1417
(A)


1430 D1
KM 52100
1430 d


KM52100:
1441 (b)


KM 52100:
1436


KM 52100:
1432(d)

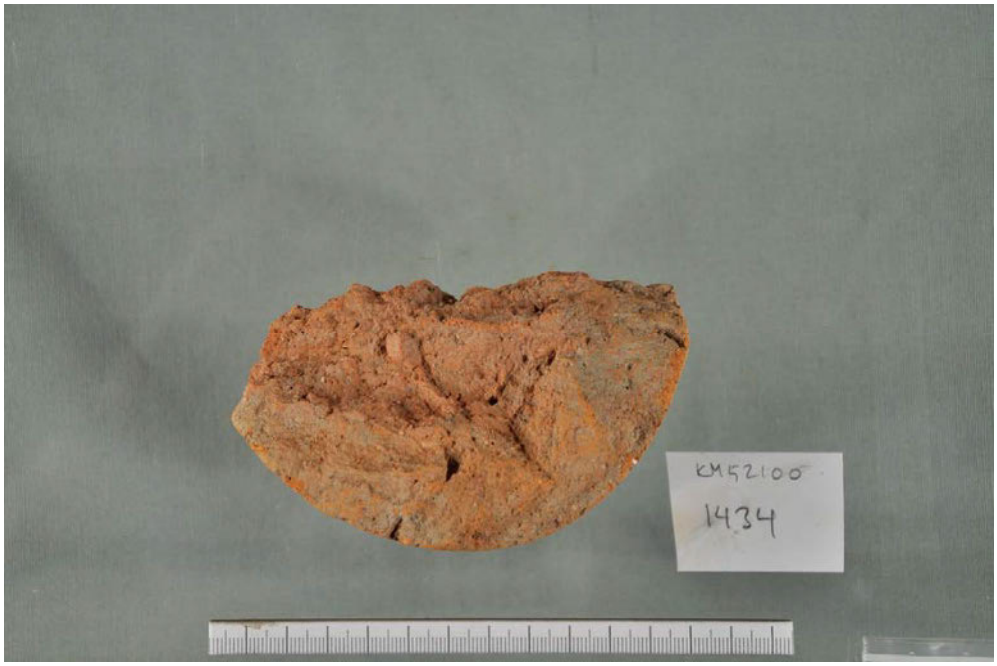

1450
KM 52100:
1450 (a)


1450
KM 52100:
1450 (c)


KM52100
1449:2


KM 52100:
1448


KM 52100
1418


KM52100
1434


KM52100
1420 (a)


KM52100:
1421


KM 52100
1437(c


KM 52100
1419 b


KM 92 100:
1431


KM 92 100:
1433 (c)

Appendix 5. Original OSL dating report of Koroinen by Oinonen and Eskola.

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Tanja Ratilainen
Turun yliopisto

Turku, Koroinen 2015-2018

AJOITUSTULOKSIA / LUMINESENSSI

Lab.nro.	Näyte	Palaeodose (Gy)	Ikä (a)
Hel-TL04323	Koroinen 1343	3,46 ± 0,34	700 ± 90
Hel-TL04324	Koroinen 1417a	3,50 ± 0,23	700 ± 80
Hel-TL04325	Koroinen 1417b	3,18 ± 0,22	680 ± 80
Hel-TL04326	Koroinen 1417c	3,74 ± 0,22	770 ± 80
Hel-TL04327	Koroinen 1421	3,65 ± 0,27	670 ± 80
Hel-TL04328	Koroinen 1433c	3,92 ± 0,33	720 ± 80
Hel-TL04329	Koroinen 1449d	4,24 ± 0,22	760 ± 80
Hel-TL04330	Koroinen 1450c	2,96 ± 0,20	740 ± 90
Hel-TL04331	Koroinen 1450a	2,64 ± 0,20	650 ± 80
Hel-TL04332	Koroinen 1434	3,47 ± 0,11	680 ± 60
Hel-TL04333	Koroinen 1430d	3,83 ± 0,32	650 ± 70
Hel-TL04334	Koroinen 1419b	3,89 ± 0,23	670 ± 70
Hel-TL04335	Koroinen 1436	3,52 ± 0,24	640 ± 70
Hel-TL04336	Koroinen 1437c	3,87 ± 0,14	680 ± 60
Hel-TL04337	Koroinen 1418	3,26 ± 0,32	660 ± 90
Hel-TL04338	Koroinen 1420a	3,89 ± 0,27	670 ± 70

LUONNONTIETEELLINEN KESKUSMUSEO
NATURHISTORISKA CENTRALMUSEET
FINNISH MUSEUM OF NATURAL HISTORY

Ajoituslaboratorio, PL 64 (Gustaf Hällströmin katu 2), 00014 Helsingin yliopisto,
Puh. 09 1911, www.luomus.fi, Y-tunnus 0313471-7

Dateringslaboratoriet, PB 64 (Gustaf Hällströms gata 2), FI-00014 Helsingfors universitet
Tel. +358 9 1911, www.luomus.fi, FO-nummer 0313471-7

Laboratory of Chronology, P.O. Box 64 (Gustaf Hällströmin katu 2), FI-00014 University of Helsinki
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Hel-TL04339	Koroinen 1432d	3,81 ± 0,32	640 ± 70

Taulukko 1. Tulokset

Taulukossa 1. esitettyjen ajoitustulosten lisäksi pyrittiin ajoittamaan seuraavat näytteet, joista ei saatu ajoitustulosta:

1431: Näyte antoi huonon OSL-signaalin. Tiili ilmeisesti ylikuumennettu valmistusprosessin aikana niin, että se oli mennyt lasimaiseksi. Tämä saattaa tuhota tiilen luminesenssiominaisuudet.

1441: Laajalla hajonnalla tuloksia, jotka menivät vanhemmiksi kuin odotettu ikä. Tässä mahdollisesti joku kontaminaatio (laastin seassa ollutta kvartsia ajautunut mahdollisesti preparointiprosessin läpi OSL-näytteeseen?) tai sitten tiili on ollut heikosti lämmitetty ja sen nollautuminen on jäänyt vajavaiseksi.

1448: Laastin seasta raavitut tiilenrippeet olivat niin pieniä ja niiden kokonaismäärä niin vähäinen, että siitä ei saada tehtyä ajoitusta.

Helsingissä 16.02.2018

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MITTAUSRAPORTTI / Koroinen

1.1 Näytteenkäsittely

Näytesarja koostui kahdestakymmenestä tiilinäytteestä. Näytteistä pyrittiin poistamaan pintakerros mahdollisimman huolellisesti, jonka jälkeen ne murskattiin ja liotettiin toistuvilla HF ja HCl käsittelyillä niin, että jäljelle jäi vain puhdasta kvartsia. Tämän jälkeen seulottiin raekoot 150-300 µm, jotka etsattiin vielä happoseoksilla HF 40% /1 h ja HCl 10% / 30 min.

1.2 Luminesenssimittaukset

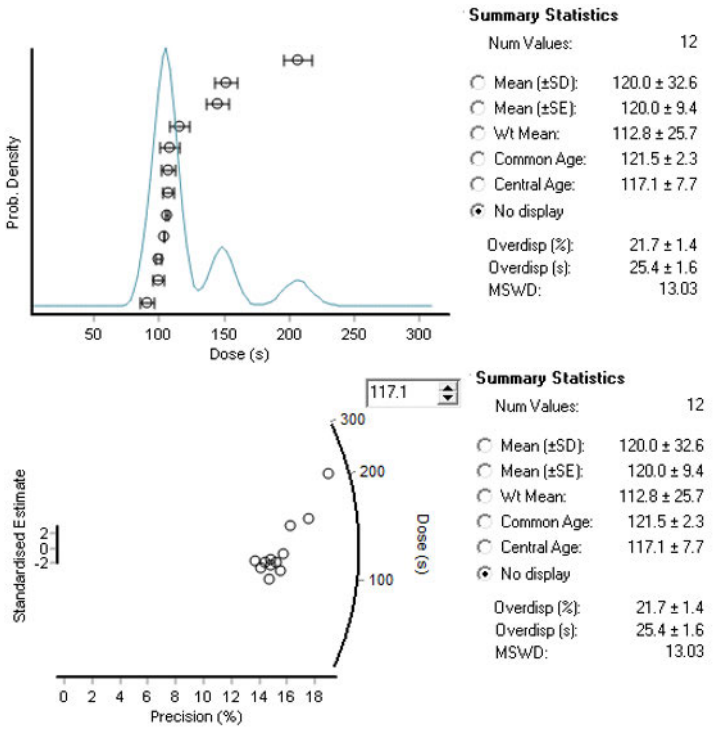
Luminesenssimittaukset suoritettiin tästä jäljelle jääneestä kvartsista OSL (optically stimulated luminescence) -menetelmällä käyttäen SAR-protokollaa (Murray & Wintle 2000). Mittaukset suoritettiin automatisoidulla Risø TL-DA-12 mittarilla (Bøtter-Jensen & Duller 1992), johon on vaihdettu halogeenilamppujen tilalle siniset LED-valot (Bøtter-Jensen et al 2000).

Saadut luminesenssimittausten tulosjakaumat olivat laadullisesti suhteellisen hyviä, mutta joitakin hajatuloksia esiintyi. Syinä näihin saattoi olla pintakontaminaatio vaikeasti pois työstettävästä pintaosasta tai toisaalta tiilien sisällä olleista taustasäteilyn paikallisista tasovaihteluista. Saadut ekvivalenssiannokset on esitetty taulukossa 1. (Palaedose (Gy)).

Tehdyissä mittauksissa käytettiin yksittäisille aliquoteille SAR-protokollaan liittyviä stabiilisuus-kriteereitä, esimerkiksi: Recycling ratio limit < 10 %, Max test dose error < 10 %, max palaeodose error < 20 %. Näillä pyritään siihen, että mittaustulosten koostamiseen hyväksytyt aliquotit sopivat laadullisilta tekijöiltään esim. tulosten toistettavuuden ja OSL-signaalin vakauden puolesta käytettäviksi OSL-ajoituksissa.

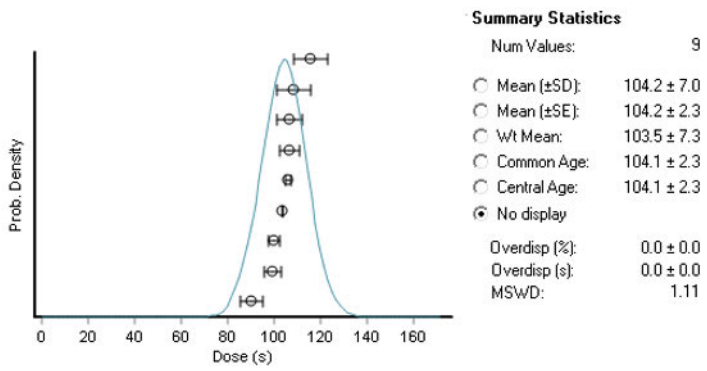
Tämän lisäksi lopullisissa tuloksissa huomioitiin se, että jos yksittäisten aliquottien antama tulos poikkesi huomattavasti muista tuloksista. Tällöin voitiin epäillä sen antaman tuloksen olevan mahdollisesti kontaminoitunut esimerkiksi tiilen valoa saaneella pintamateriaalilla tai nollautumattomalla laastiaineksella. Lisäksi yksittäisissä näytteissä saattaa löytyä hajontaa, joka johtuu satunnaisista vaihteluista näytemateriaalissa sekä siihen vaikuttaneessa taustasäteilyssä. Tässä pyrittiin käyttämään määritystä, että samaan ikäpopulaatioon kuuluakseen aliquotit piti saada mahdutettua 2-sigma rajojen sisälle.

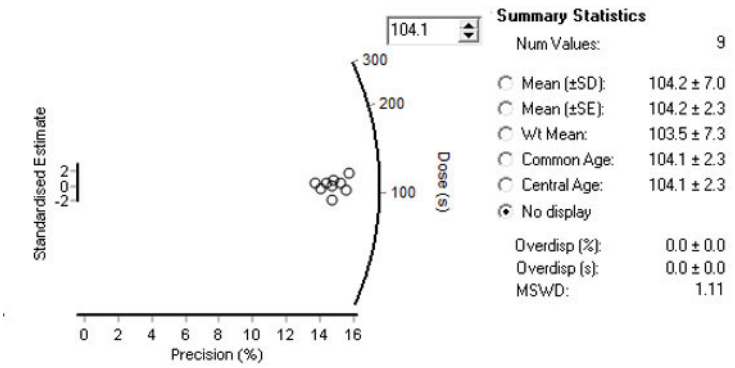
Tästä esimerkkinä näytteen 1450 C tulokset, jossa kaikki aliquotit muodostivat jakauman:



Tässä määrityksessä kolme vanhimpaan ikään viittaavaa aliquottia poikkeavat selkeästi muista ja voidaan olettaa, että niissä on jotain kontaminaatioon viittaavaa ja niiden ottaminen mukaan pelkästään heikentäisi saatavaa ikämääritystä.

Kun nämä aliquotit jätetään tarkastelusta, saadaan jakaumat:





Nämä vastaavat paljon paremmin yhtenäiseksi katsottavan ikäpopulaation arvoa.

Koska alkuperäiset näytteet olivat suhteellisen pieniä, saattoi pintamateriaalin poistamiseen liittyvien vaikeuksien vuoksi jäädä vastaavia, poikkeavaan ikään viittaavia yksittäistuloksia. Nämä olivat kuitenkin melko helposti havaittavissa ja poistettavissa verrattaessa muista aliquoteista saataviin tuloksiin. Kaikille mitatuille näytteille oli löydettävissä selvä päämaksimi, jonka perusteella ekvivalenssiannos saatiin määritetyksi.

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1.3 Taustasäteilyn mittaaminen

Betasäteilyn mittaus suoritettiin käyttämällä Risø GM-25-5 beta multicounter – laskuria (Botter-Jensen & Mejdahl 1988). Laskurilta saadut pulssimäärät muunnettiin annosnopeuksiksi lineaarisella sovituksella, joka pohjautuu pulssimittauksiin näytesarjasta, jonka radioaktiivisten alkuaineiden pitoisuudet ja siten myös β-aktiivisuus oli selvitetty neutroniaktivoinnilla.

Gammasäteilyn mittaus suoritettiin icx-Identifinder -kannettavalla gammaspektrometrilla, jolla gammakvantteja havainnoidaan ∅ 1.4" × 2" kokoisella NaI(Ti) ilmaisimella. Mittauskohteiksi valittiin paikat, joissa oli vielä tiilirakenteita jäljellä ja joiden arveltiin olevan mahdollisimman lähellä näytteiden varsinaista keräyspaikkaa. Gammamittaus ei siis vastaa täysin alkuperäisiä olosuhteita, mutta haarukoimalla aluetta ja liittämällä saatuihin tuloksiin riittävät virherajat, saatiin sille paras mahdollinen arvio, joka on nykyisillä asetelmilla saavutettavissa. Käytetty gamma-annosnopeus oli suuruudeltaan 0,20 ± 0,02 µSv/h. Gammaspektrometrillä saadaan suoraan myös paikalla vallitsevan kosmisen säteilyn säteily-annosnopeus.

Erityisesti beta-mittauksissa kriittinen tekijä on näytemateriaalin kosteus. Vesi jarruttaa säteilykantamaa ilmaa tehokkaammin ja alentaa näin taustasäteilyn voimakkuutta. Tiilien kohdalla tehtiin oletus, että saturaatiovesipitoisuus olisi luokkaa 5% ja todellinen vesipitoisuus olisi ollut luokkaa 5% tästä saturaatiopitoisuudesta eli oletuksena oli alhainen vesipitoisuus.

1.4 Iän määritys

Näytteen ikä määritettiin jakamalla luminesenssimittauksen perusteella saatu näytteen saama säteilyannos (paleodose) mitatulla taustasäteilyn annosnopeudella. Tulosten epätarkkuuden arvioinnissa huomioitiin sekä säteilymittauksen epätarkkuus että säteilyn annosnopeuden arvioinnista tuleva epätarkkuus.

$$Age = \frac{Paleodose}{Dose\ rate}$$

Määritysten perusteella saatiin ikä-arviot, jotka on esitetty talukossa 1.

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1.5 Viitteet:

Aitken M J 1985. Thermoluminescence dating, Studies on Archaeological Science, Academic Press Inc. (London) Ltd.

Bøtter-Jensen L & Mejdahl V 1988: Assessment of beta dose-rate using a GM multicounter system. *Nuclear Tracks and Radiation Measures 14*, 187–191.

Bøtter-Jensen L & Duller G A T 1992: A new system for measuring OSL from quartz samples. *Nuclear Tracks and Radiation Measurement 20*, 549–553.

Bøtter-Jensen L, Bulur E, Duller G A T & Murray A S 2000: Advances in luminescence instrument systems. *Radiation Measurements 32*, 523–528.

Murray A & Wintle A 2000. Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol, *Radiation Measurements* 32, pp. 57-73.

Appendix 6ab. Original radiocarbon dating reports of Koroinen by Lindroos.

Turku 14. 12. 2017

Radiohiilimäärityksiä, Koroinen Turku

Kolme laastinäytettä Koroisista, Varsinais Suomen Maakuntamuseon kokoelmista analysoitiin radiohiilimenetelmällä. Näytteet ovat:

Koroinen 570 josta analysoitiin 570Li eli pelkkä kalkkipaakku laastissa

Koroinen 1436 koko laasti

Koroinen 1448 josta kalkkipaakku 1448Li

Menetelmä mittaa koska laasti on kovettunut rakennusvaiheessa, koska kovettuessa se sitoo hiilidioksidia (CO_2) ilmakehästä, eli laasti otaa näytteen ilmkehästä. CO_2 sitoutuu laastin sidoskarbonaattiin. Tämän radiohiilipitoisuus (C-14) vastaa radiohiilipitoisuutta tietyn ajanjakson puiden vuosirenkaissa joista on olemassa kalibrointikäyrä. Näytteet preparoitiin ns. ”sequential dissolution” menetelmällä (Lindroos et al. 2007), jolla tietty raekokofraktio näytteestä liuotetaan fosforihappoon ja kustakin näytteestä otetaan talteen useita hiilidioksidifraktioita C-14 analyysejä varten. Menetelmällä pyritään saamaan mahdollisimman totuudenmukainen ikä laastin kovettumisajankohdalle, ja sen lisäksi käsitys siitä kuinka hyvin näyte soveltuu C-14 ajoitukseen. Ennen liuotusta (hydrolyysiä) näytteiden pH mitattiin indikaattorilla, koska selvästi emäksiset näytteet eivät ole vielä täysin kovettuneet eivätkä sovellu C-14 analyysiin. Laastinäyte 1436 oli ”normaali” eli ei-alkalinen, siis sovelias ikämääritykseen. Jos näytteissä on pehmeitä, valkoisia kalkkipaakkuja niitä kannattaa käyttää ikämääritykseen koska ne ovat muodostuneet ennen kuin laastiin on sekoitettu täyteainetta. Täyteaine voi sisältää geologista karbonaattia, joka vanhentaa määrityksen tuloksena saatavaa ikää (noin 80 v/%). Näytteet 570 ja 1448 sisälsivät tarpeeksi isoja paakkuja.

Näyte 1436 murskattiin pieniksi (< 10 mm) paloiksi ja murske seulottiin. Raekoko 46–75 µm pestiin puhtaaksi hienommasta pölystä ja kuivattiin hydrolyysiä varten. Murskauksen yhteydessä tehtiin havaintoja mineraalikoostumuksesta: Mineraalit ovat tavalliset: kvartsi, kalimaasälpä, kiille. Alla on laboratoriopöytäkirja näytteiden hydrolyysistä.

Taulukko 1. Hydrolyysidataa. Parametri F on hiilidioksidifraktion suhteellinen koko mittakaavassa 0–1. Esim. F = 0,182 tarkoittaa että tässä fraktiossa on 18,2 % koko näytteen hiilestä.

Sample	**grain-size** C content	**Sample aliquot**	**CO2 fraction**	**Diss. time**	**P in the CO2 line**	**F**	**calculated C content**	**C-14 vial**	**C-13/O-18 vial**	**Dating**
	(µm)	***mg***	***(nr)***	***(s)***	***(mbar)***		***(mg)***	***(mg)***	***(mg)***	
Århus										
1436.1	**46-75**	**105**	**1**	**n.r**	**<20?**		Too small			
85% H_3PO_4	**7 .0% C**		**2**	**n.r**	**103**	**0.182**	**1.33**	**1.12**	**0.21**	**O**

0° C			**3**	**n.r**	**95.7**	**0.169**	**1.23**	**0.91**	**0.32**	**O**
			4	**756**	**173**	**0.305**	**2.23**	**1.16**	**0.22**	
			5	**1867**	**120**	**0.212**	**1.54**	**not**	**collected**	
			6	**2990**	**55.3**	**0.098**	**0.71**	**not**	**collected**	
			7	**3300**	**19.4**	**0.034**	**0.25**	**not**	**collected**	
					566.4					
1436.2	**46-75**	**95.1**	**1**	**8**	**51.7**	**0.101**	**0.67**	**0.50**	**0.17**	**O**
85% H_3PO_4	**"7 % C"**		**2**	**157**	**126**	**0.246**	**1.62**	not	collected	
0° C			**3**	**790**	not	completed		not	collected	
570Li.2	**Unsieved**	**43.0**	**1**	**10**	**25.1**	**0.136**	**0.32**	**0.32**	too small	**O**
85% H_3PO_4	**5.52 % C**		**2**	**40**	**49.7**	**0.270**	**0.64**	**0.64**	too small	**O**
0° C			**3**	**140**	**42.0**	**0.228**	**0.54**	**0.54**	too small	
			4	**1060**	**47.9**	**0.260**	**0.62**	**0.46**	**0.16**	
			5	**1480**	**19.6**	**0.106**	**0.25**	**not**	**collected**	
					184.3					
1448Li.1	**Unsieved**	**25.0**	**1**	**15**	**56.9**	**0.261**	**0.73**	**0.55**	**0.18**	**O**
85% H_3PO_4	**11.2 % C**		**2**	**85**	**77.4**	**0.355**	**1.00**	**0.74**	**0.26**	**O**
0° C			**3**	**700**	**54.7**	**0.251**	**0.70**	**0.51**	**0.19**	
			4	**1320**	**22.1**	**0.101**	**0.28**	**not**	**collected**	
			5	**1920**	**6.9**	**0.032**	**0.09**	**not**	**collected**	
					218.0					
Zürich										
1448Li.2	**Unsieved**	**14.7**	**1**	**13**	**16.5**	**0.150**	**0.21**	**0.21**		
85% H_3PO_4	9.54 % C		**2**	**50**	**36.6**	**0.333**	**0.47**	**0.47**		**O**
0° C			**3**	**130**	**23.0**	**0.209**	**0.30**	**0.30**		
			4	**420**	**20.0**	**0.182**	**0.26**	**0.26**		
			5	**1530**	**9.75**	**0.089**	**0.13**	**0.13**		
			6	**3090**	**3.95**	**0.036**	**0.05**	**not**	**collected**	
					109.8					

Näyte 1436 preparoitiin kahdesti koska ensimmäisellä kerralla ensimmäisestä CO_2 -fraktiosta tuli liian pieni C-14 analyysiin. Toisella kerralla preparoitiin vain ensimmäinen CO_2 -fraktio. Kun tulokset Århusista saapuivat, osoittautui, että kalkkipaakku 1448Li näyttäisi olevan 1200-luvulta, mutta oli hieman epäilyttävää, että ensimmäinen CO_2 -fraktio oli hieman vanhempi kuin toinen CO_2 -fraktio, mikä on harvinaista. Oli syytä tarkistaa, oliko näytteessä helposti liukenevia karbonaattisaostumia esim. pintavedestä. Näyte preparoitiin uudestaan siten, että annettiin näytteen ensiksi reagoida 13 s ja otettiin CO_2 talteen vasta ajassa 13–50 s.

Laastissa 1436 oli 7,0 % hiiltä, mikä on normaali/hyvä. Paakun 570Li: 5,53 % hiiltä on melko vähän, mikä viittaa siihen, että siinä on myös huonosti liukenevia epäpuhtauksia epätäydellisen kalkinpolton jäljiltä. Paakun 1448Li:n 11,2 % hiiltä on hyvä tulos ja oli syytä

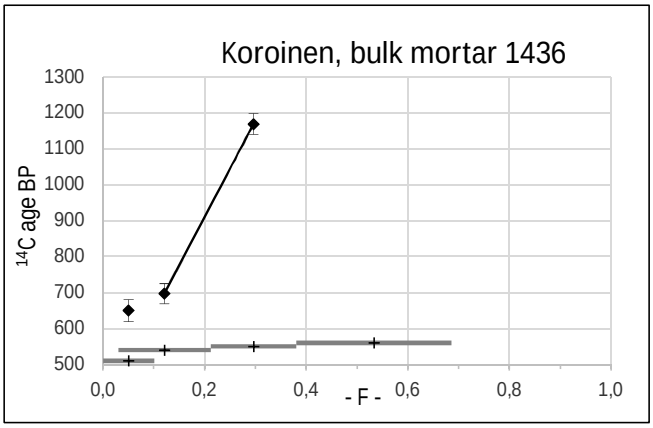
odottaa onnistunutta ikämääritystä. Kun jäännös näytteestä preparoitiin uudestaan (Zürichiä varten) saanti oli 9,54 % mikä on myös hyvä. Ero ensimmäiseen preparointiin johtuu lähinnä siitä, että toisessa preparoinnissa oli vain 14,7 mg näytettä jolloin mittausvirhe on suurempi.

C-14 tuloksia

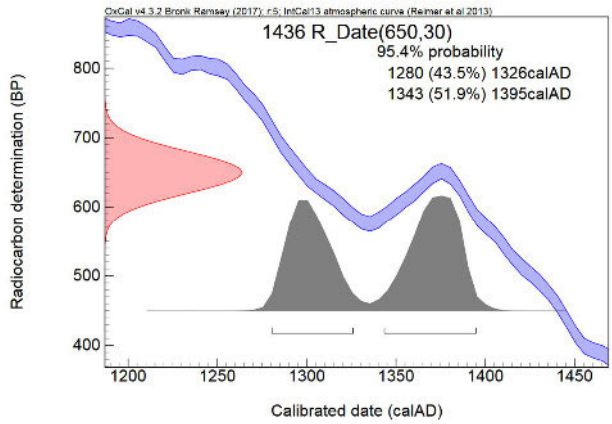
Taulukko 2. Osa Århusin ja Zürichin C-14 raportista. Delta C-13 mittaukset jäivät suorittamatta teknisten ongelmien takia (Århus).

Näyte	Fraktio	C-14 ikä BP	±	$\delta^{13}C$	Kalibrointi, 2σ, 95.4%
1436.2	1; 0–0,101	650	30	n.d.	AD 1280–1326 (43,5 %) AD 1343–1395 (51,9 %)
1436.1	2; 0,18–0,35	697	28	n.d.	
	3; 0,35–0,66	1169	29	n.d.	
570Li.2	1; 0–0.14	577	31	n.d.	AD 1300–1369 (62,0 %) AD 1381-1420 (33,4 %)
	2; 0,14–0,41	619	28	n.d.	
1448Li.1	1; 0-0.26	791	26	n.d.	
	2; 0.26–0,62	721	31	n.d.	
1448Li.2 Zürich	2; 0,17–0,53	690	25	-15,6	AD 1269–1306 (73,8 %) AD 1363-1385 (21,6 %)

Näytteen 1436 C-14 profiili, kuva 2, on tyypillinen kontaminaatioprofiili, jossa profiilin kaltevuus jyrkkenee aluksi (kuva 1). Ensimmäinen CO_2 -fraktio antaa melko luotettavan ajoituksen, ja fraktiot 2 ja 3 osoittavat, että kontaminaatio suurenee vähitellen. Liukenemisnopeus viittaa marmorikontaminaatioon täyteaineessa. Kuva 2 on toisen preparoinnin ensimmäisen CO_2 -fraktion iän kalibrointi.

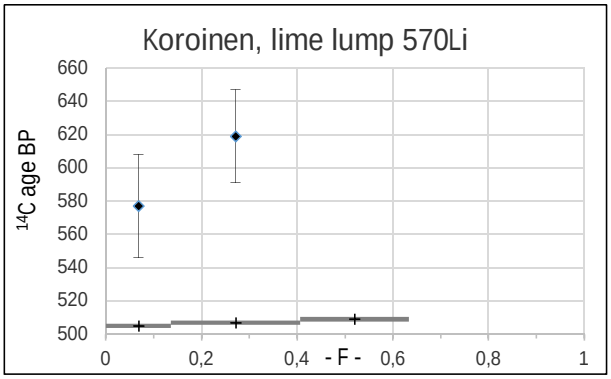


Kuva 1. C-14 ikäprofiili näytteelle 1436. Näyte on preparoitu kahteen kertaan koska ensimmäisellä kerralle CO_2 -fraktio 1 jäi liian pieneksi. Jyrkkenevä trendi tarkoittaa, että kontaminaatio liukenee hitaammin kuin sidoskarbonaatti ja ne tulokset, jotka sijoittuvat lähelle Y-akselia ovat lähellä oikeaa ikää.

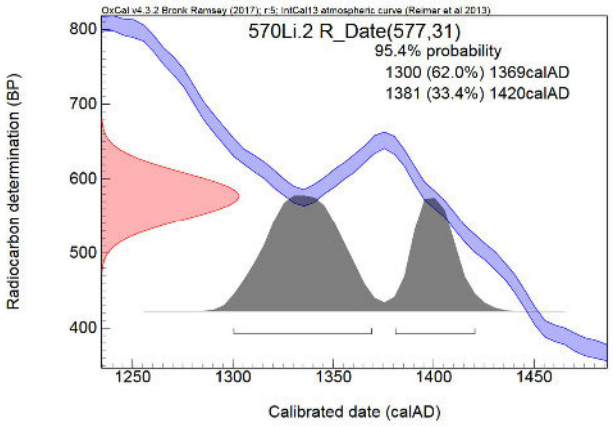


Kuva 2. Ensimmäinen CO_2 -fraktio toisesta preparoinnista; kalibroitu ikä. Koska kontaminaatiolla saattaa olla pientä vaikutusta, ikäjakauman 1343–1395 painoarvo korostuu.

Kalkkipaakku 570Li ei ole selvästi kontaminoitunut vaan profiilissa (kuva 3) mittaustulosten virhemarginaalit ovat päällekkäin. Huonosti poltettu marmori tai kalkkikivi liukenee joka tapauksessa niin hitaasti, että jos siitä ei ole selviä merkkejä toisessa CO_2 -fraktiossa, niin sen merkitys ensimmäisessä CO_2 -fraktiossa on olematon. Koska hiilen pitoisuus (taulukko 1) on melko alhainen, on kuitenkin syytä epäillä, että toinen CO_2 -fraktio on jonkin verran kontaminoitunut eikä ole syytä tehdä yhteistä kalibrointia. Kuva 4 esittää ensimmäisen CO_2 -fraktion kalibrointia. Kolmaskin CO_2 -fraktio on olemassa ampullissa (Århus mitoituksella) jos haluaa paremman käsityksen kontaminaation suuruudesta.

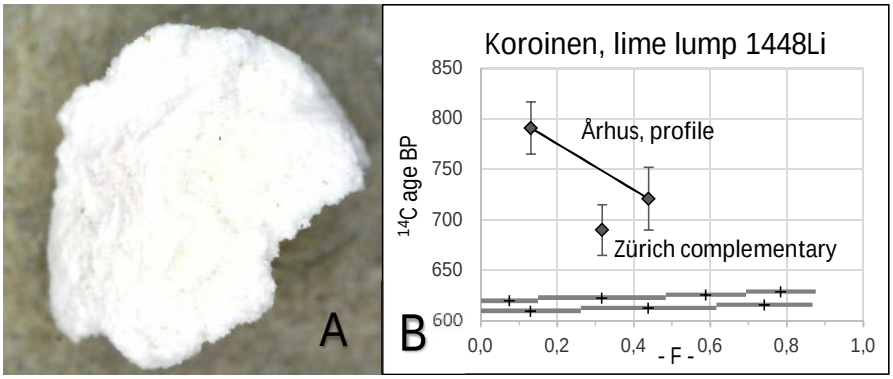


Kuva 3. ^{14}C –profiili kalkkipaakusta 570Li. Analyysitulokset eivät eroa merkittävästi toisistaan, joten ikämääritys on onnistunut.

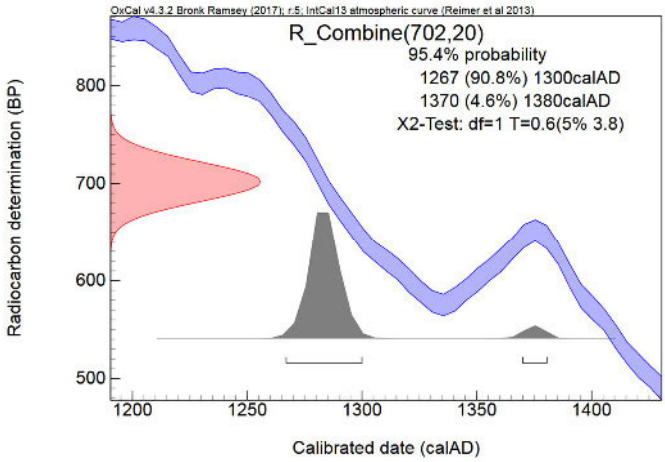


Kuva 4. Kalkkipaakun 570Li:n ikä jos kalibroi ensimmäisen CO_2 -fraktion C-14 ikää.

Kalkkipaakku 1448Li (kuva 5A) antoi selviä viitteitä, että se olisi 1200-luvulta mutta koska ensimmäinen CO_2 -fraktio oli vanhempi kuin toinen tulokset olivat epäilyttäviä. Oli mahdollista, että näyte oli kontaminoitunut helposti liukenevilla kalkkisaostumilla pinta- tai pohjavedestä. Koska oli olemassa vain kaksi mittausta ei voinut olla varma, että koko kontaminaatio olisi liuennut CO_2 -fraktioon 1. Tehtiin täydentävä mittaus Zürichissä, koska sieltä saa tuloksia muutamassa viikossa. Preparoinnissa tehtiin pienempi CO_2 -fraktio 1 kuin ensimmäisellä kerralla ja lähetettiin CO_2 -fraktio 2 analyysiin. Jos tulos olisi sama kuin CO_2 -fraktiosta 2 ensimmäisellä kerralla kyseessä olisi todella nopeasti liukenevasta kontaminaatiosta joka ei vaikuta kumpaankaan toiseen CO_2 -fraktioon. Näin olikin (kuva 5B) ja näin ollen näistä voi tehdä yhteisen kalibroinnin (kuva 6). Tulos on selvä 1200-luvun jälkipuoliskon ikä. Jos profiilia haluaa vielä täydentää, niin ampullit Århus 1448Li-3 ja Zürich 1448Li.1, 3 ja 4 ovat tallessa.



Kuva 5A. Kalkkipaakku 1448Li (2 mm); Jäännös molempien preparointien jälkeen. B. Århusin C-14 profiili ja täydentävä analyysi Zürichistä.



Kuva 6. Molempien preparointien toinen CO_2 fraktio kalibroituna yhdessä (”combined calibration”).

Yhteenveto

Moderni AMS analyysilaitteisto antaa mahdollisuuden tehdä ikämäärityksiä todella pienistä näytteistä. Tässä raportissa on analysoitu kaksi pientä kalkkipaakkua ja molemmat antoivat luotettavan näköisiä tuloksia. Toinen paakku on ajalta AD 1267-1300 mikä on ainakin yhtä vanha kuin mitä on toistaiseksi saatu vastaavasta näytteestä Turun Tuomiokirkon vanhimmista rakenteista. Analysoitiin myös isompi laastipala. Siinä näkyy selvästi, että täyteaineessa on ollut marmoripitoista hiekkaa, joka on kontaminaatio. Se ei kuitenkaan ole pilannut koko analyysiä.

Viite

Lindroos A, Heinemeier J, Ringbom Å, Braskén M, Sveinbjörnsdóttir Á. 2007. Mortar dating using AMS ^{14}C and sequential dissolution: Examples from medieval, non-hydraulic lime mortars from the Åland Islands SW Finland. *Radiocarbon* 49(1): 47-67.

Turussa 14. Joulukuuta 2017

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20500 Åbo

Turku 14. 03. 2019

Radiohiilimäärityksiä, Koroinen Turku

Kahdelle laastinäytteelle Koroisista, Kansallimuseon kokoelmista tehtiin täydentäviä radiohiilianalyysejä. Näytteet ovat:

> Koroinen 570 josta aiemmin analysoitiin 570Li eli pelkkä kalkkipaakku laastissa, nyt analysoitiin koko laasti Århusissa ja lisäksi kolmas hiilidioksidifraktio edellisestä preparoinnista.
>
> Koroinen 1448, josta kalkkipaakusta 1448Li tehtiin täysi profiili neljällä mittauksella Zürichissä.

Alla on laboratoriopöytäkirja näytteiden hydrolyysistä.

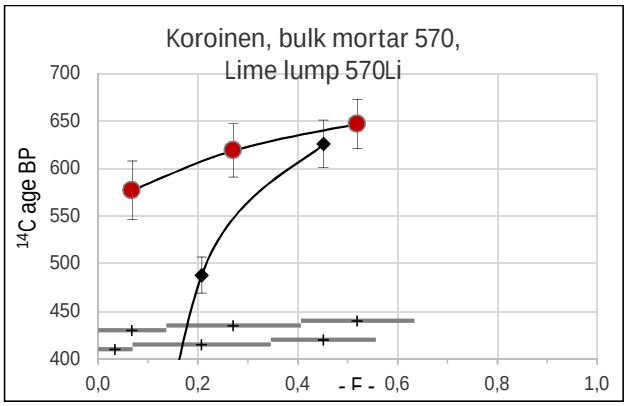
Taulukko 1. Hydrolyysidataa. Parametri F on hiilidioksidifraktion suhteellinen koko mittakaavassa 0–1. Esim. F = 0,069 tarkoittaa että tässä fraktiossa on 6,9 % koko näytteen hiilestä.

	(µm)	**aliquot**	**fraction**	**time**	**CO_2**	**F**	**C cont.**	**in vial**	**To be**
	C content	***mg***	***(nr)***	***(s)***	***(mbar)***		***(mg)***	***(mg)***	***dated***
Århus									
Koroi 570.1	46-75	51,6	1	7	19,9	0,069	0,26	0,26	O
85% H_3PO_4	7.20% C		2	60	80,1	0,277	1,03	1,03	O
0° C			3	280	60,8	0,211	0,78	0,78	O
			4	610	48,1	0,167	0,62	0,62	
			5	1460	41,8	0,145	0,54	0,54	
			6	2190	28,1	0,097	0,36	0,36	
			7	3300	6,22	0,022	0,08	not	collected
			8	4920	3,80	0,013	0,05	not	collected
			sum		*288,82*				
Zürich									
1448Li.2	Unsieved	14,7	1	13	16,5	0,150	0,21	0,21	O
85% H_3PO_4	9.61% C		2	50	36,6	0,333	0,47	0,47	O
0° C			3	130	23	0,209	0,30	0,30	O
			4	420	20,0	0,182	0,26	0,26	O
			5	1530	9,75	0,089	0,13	not	collected
			6	3090	3,95	0,036	0,05	not	collected
			sum		*109,8*				

Taulukko 2. ^{14}C tuloksia. Uudet tulokset lihavoidulla fontilla.

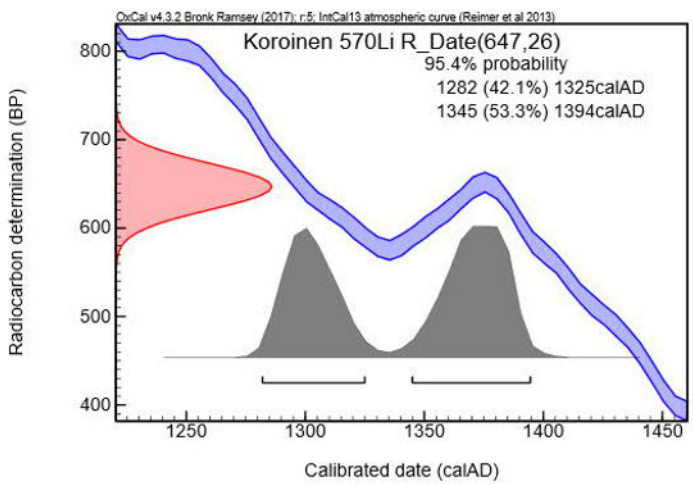
Koroi 570.1	CO_2 fraktio	Osuus, %	^{14}C ikä BP	±	
(Århus AAR-29195,1)	1	6,9	**”Modern”**		
(- ” - ,2)	2	27,7	**488**	**19**	
(- ” - ,3)	3	21,1	**626**	**25**	
Koroi 570Li.2	1	13,6	577	31	
	2	27.0	619	28	
(Århus AAR-24762,3)	3	22,8	**647**	**26**	
1448Li.2					$\delta^{13}C$
(Zürich ETH-93893,1)	1	15,0	**706**	**29**	-30,9
	2	33,3	690	25	-15,6
(- ” - ,2)	3	20,9	**731**	**27**	-13,9
(- ” - ,3)	4	18,2	**747**	**28**	-19,1

Alla on täydennetty graafi näytteestä Koroi 570 (kuva 1): Paakku Koroi 570Li analysoitiin jo aiemmin (kaksi ensimmäistä punaista palloa). Uudet tulokset osoittavat, että näyte on vielä osittain alkalinen ja se sitoo vieläkin hiilidioksidia ilmakehästä koska ensimmäinen fraktio antaa modernin iän (=1950 jälkeen). Kun noin puolet näytteestä on liuennut molemmat profiilit antavat yhtenäisiä tuloksia, noin 650 BP (before present).



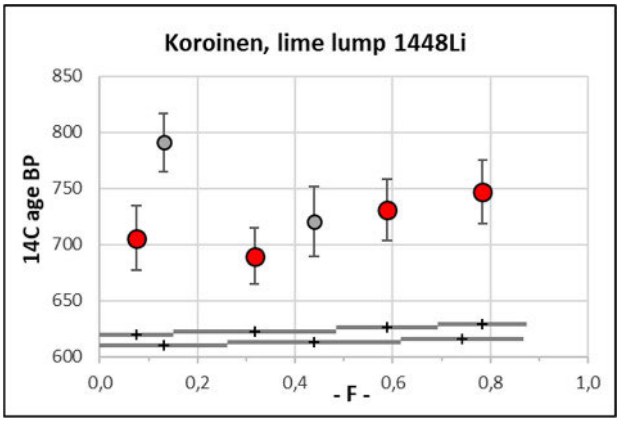
Kuva 1. Laastinäyte josta on analysoitu sekä koko sidoskarbonaatti (mustat neliöt), että yksittäinen valkoinen paakku (punaiset pallot). Ensimmäinen hiilidioksidifraktio sidoskarbonaatista sisälsi enemmän radiohiiltä kuin standardi vuodelta 1950, eli se on ollut osittain alkalinen ja sitonut hiilidioksidia 1950 jälkeenkin. Paakusta kolmas pallo vasemmalta edustaa uutta mittausta. Ilmeisesti se edustaa parhaiten laastin ikää koska molemmat profiilit näyttävät ”konvergoivan” sen kohdalla.

Paakun kolmas CO_2 fraktio antaa kalibroidun iän 1282-1325 42,1 prosentin todennäköisyydellä ja 1345-1395, 53,3% todennäköisyydellä 95,4% merkitsevyystasolla (kuva 2).



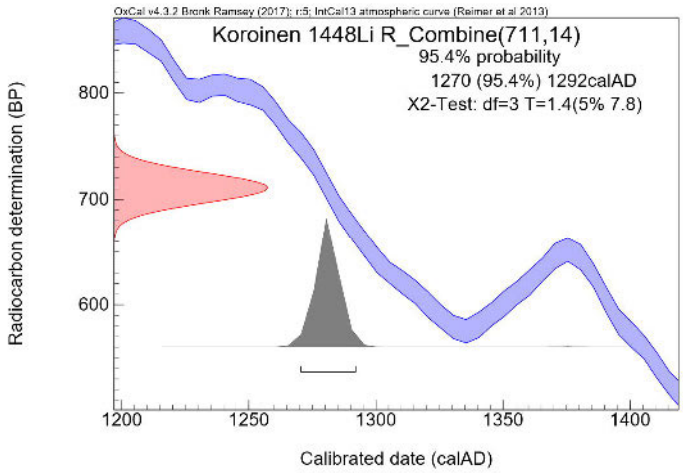
Kuva 2. Mittaustulos Koroi 570Li.2,3 kalibroituna. Koska sidoskarbonaatti ja kalkkipaakku antavat yhtenäisiä tuloksia kolmannelle CO_2 fraktiolle valittiin paakun kolmas fraktio edustamaan näytettä ja sen ikää.

Paakusta 1448 oli aiemmin kaksi mittausta Århusista ja yksi täydentävä mittaus Zürichistä hiilidioksidiampulli nro 2:sta. Koska preparoinnista Zürichiä varten oli otettu talteen myös ampullit 1, 3 ja 4 nekin analysoitiin nyt. Alla päivitetty graafi (kuva 3).



Kuva 2. Tuloksia paakkuanalyysistä. Aiemmin oli tehty kaksi mittausta Århusissa (harmaat pallot) ja yksi mittaus Zürichissä (toinen punainen pallo oikealta). Uudet mittaukset ovat samasta preparoinnista Zürichiä varten.

Koska mittaustulokset ovat varsin yhteneväiset niistä tehtiin yhteinen kalibrointi, josta jätettiin pois vain Århusin ensimmäinen mittaus. Kalibrointi antaa iän 1270-1292, 95,4%:n merkitsevyystasolla (kuva 4).



Kuva 4. Paakku 1448Li ”combined calibration”.

Turussa 19.3. 2019

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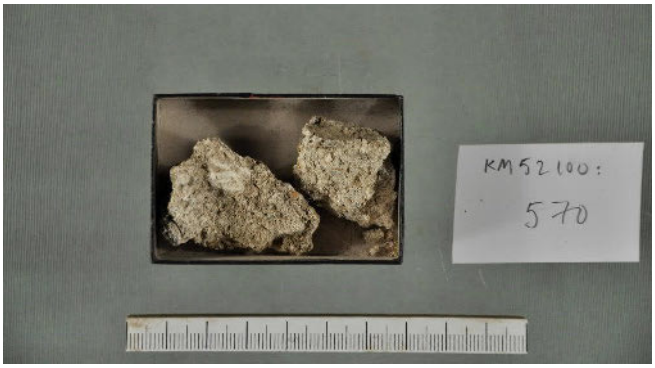
Appendix 7. Photos of mortar samples before and after the dating analyses. Photos by Ratilainen.

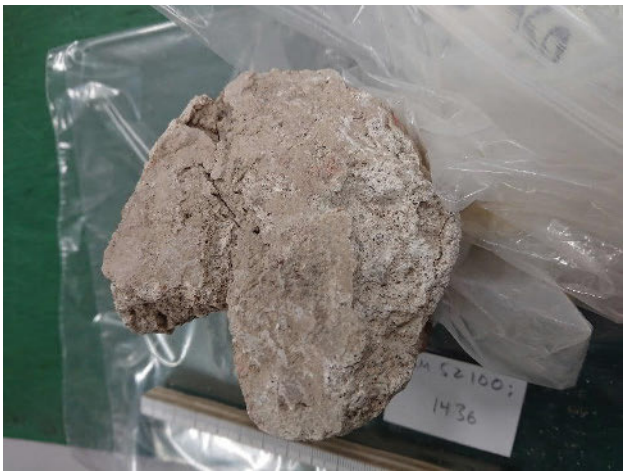


a) KM52100: 570 before.

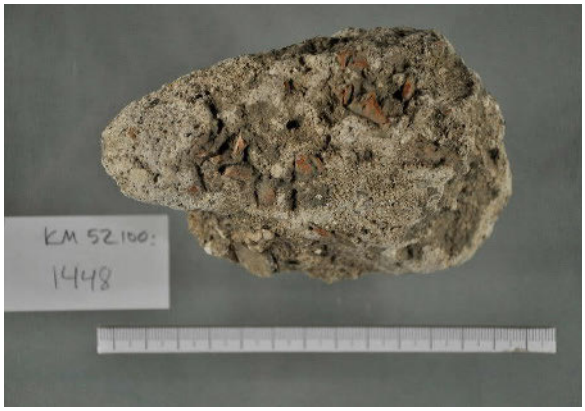
b) KM52100: 570 after.

a) 52100: 1436a before, from the side.

b) KM52100: 1436a before, top.



c) KM52100: 1436a after, top.



a) KM52100: 1448, piece of mortar before sampling. Note the pieces of brick in the mortar.

b) It was likely attached to a stone.

c) KM52100: 1448, piece of mortar after sampling.

Appendix 8. Original dendrochronological report on HCCH by Zetterberg.

Tanja Ratilainen

Turun yliopisto, Arkeologia

Selostus Hattulan Pyhän Ristin kirkon dendrokronologisten ajoitusnäytteiden uudelleentutkimuksen tuloksista

Tutkimuksen tausta

Dendrokronologia on ajoitusmenetelmä, jolla puumateriaalin kaatamisajankohta voidaan määritellä parhaassa tapauksessa vuoden tarkkuudella. Kuitenkin on tärkeätä hyväksyä se tosiasia, että kaikkea puumateriaalia ei tällä menetelmällä voida ajoittaa. Tässä mielessä dendrokronologinen menetelmä eroaa radiohiilimenetelmästä, jolla käytännössä kaikelle puumateriaalille saadaan ikä, jos vain puuainesta on tarpeeksi. Radiohiilimenetelmän erona dendrokronologiseen menetelmään on kuitenkin se, että ajoitukset eivät ole vuodentarkkoja.

Dendrokronologisen ajoitusmenetelmän käytössä puunäytteiden laadulla on ratkaiseva osa. Ajoitusten onnistuminen edellyttää, että a) vuosilustojen määrä on riittävä, b) näytteen lustosarjan mittauskelpoisuus on riittävä (ei lahonneisuutta tai puuainesta käyttävien hyönteisten aiheuttamia vaurioita), c) lustosarjassa ei ole kasvuhäiriöitä (puun vahingoittumisesta ja/tai palamisesta elinaikanaan eikä kasvisairauksista johtuvia). Em. seikkoja arvioidaan aina, jos mahdollista ns. esitutkimuksella. Esim. hirsirakennusten ikiä selviteltäessä kaikki saatavissa oleva materiaali läpikäydään ennen lopullista näyteaineiston valintaa. Keskiaikaisten kivikirkkojen puurakenteiden sijainti rakennuksessa on monesti sellainen, että esitutkimusta eli näytteen soveltuvuutta ajoitukseen, ei voida kaikissa tapauksissa selvittää ennen varsinaista näytteenottoa.

Hattulan Pyhän Ristin kirkon aineisto

Kohteesta on tutkittu näytteet kahdessa tutkimuksessa, joiden tulokset on aiemmin julkaistu (Zetterberg, P., 1995, Zetterberg, P. & Zetterberg, T., 2011). Tutkimukset käsittivät näytteet yhteensä 12 kohteesta. Näistä kahdeksan oli mahdollista ajoittaa. Tässä kolmen näytteen aineisto on kokonaan v. 1995 julkaistussa tutkimuksessa käsiteltyä. Toista v. 2011 ajoittamatta jäänyttä ei tässä käsitellä, koska sen vuosilustomäärä oli riittämätön dendrokronologiseen ajoitukseen (näyte FIH1112).

Vuonna 1995 julkaistu aineisto (näytteenotto 29.5.1991 – 29.8.1995):

Näyte FIH1101 (tekstilainaus v. 1995 raportista): "tasakertarakenteeseen liittyvässä sidoshirressä (FIH1101) on alkuperäinen kuorenalainen pinta jäljellä ja sen kaatoajankohta voitaisiin näin ollen ajoittaa vuoden tarkkuudella. Kyseessä on alkuperältään muista tasakertarakenteista poikkeava puunkappale, jonka puulaji on mäntyä, kun kaikki muut tutkitut osat ovat kuusta. Näytteen ajoitus on ongelmallinen. Sarja näyttää sopivan varsin hyvin Pernajan kirkosta aikaisemmin tutkittuun aineistoon (Zetterberg 1991b) asemassa jossa näytehirren FIH1101 viimeinen vuosilusto olisi vuodelta 1186. Koska rinnastusajanjakso on kuitenkin suhteellisen lyhyt, vain 72 vuotta (Pernajan aineisto alkaa vuodesta 1115), ei rinnastusta voida pitää ehdottoman varmana. Tämä sama ajoitusasema saa heikkoa tukea myös eräistä Turun arkeologisista puulöydöistä tehdyistä ajoituksista (Zetterberg 1990a, 1990b), joissa niissäkin rinnastus on kuitenkin liian heikko varmaan ajoitukseen. Koska mainitulle ajoitukselle ei saada riittävää tukea myöskään paikallisesta aineistosta (ainoa tälle ajalle ulottuva lustosarja on peräisin kastemaljasta), jätetään näyte FIH1101 tässä vaiheessa ajoittamatta. Jos näytteen ajoitus olisi tuo edellä mainittu 1186, täytyisi kyseessä olla uudelleenkäytetty hirrenpätkä, joka on peräisin jostakin tuntemattomasta huomattavasti varhaisemmasta puurakenteesta."

Ylläesitetylle näytteen FIH1101 mahdolliselle ajoitukselle ei saatu ehdottoman varmaa varmistusta tässä raportissa esitetyissä 2010-luvun tutkimuksissa, vaikka näytteen lustosarjaa verrattiin ristiinajoitusmenetelmällä tuhansiin eteläisestä ja lounaisesta Suomesta absoluuttisesti ajoitettuihin muihin näytteisiin sekä näistä muodostettuihin satoihin ns. lustokalentereihin.

Näyte FIH1109 (tekstilainaus v. 1995 raportista): " Näytteet ajoitusta varten otettiin myös runkohuoneen päätyoven salpakourupuusta (FIH1109) sekä sakariston pohjoispäädyn lännenpuoleisesta kitapuusta (FIH1110), jotka molemmat olivat osittain rakenteen muurauksen sisässä ja näin ollen mitä ilmeisimmin alkuperäistä rakentamisen aikaista puumateriaalia. Kumpikin puuosa on kuitenkin jo melko lahonnut, eikä näytteisiin tämän takia saatu mukaan riittävää määrää vuosilustoja varmaa iänmääritystä varten."

Salpakourupuusta (FIH1109) näytteet otettiin ns. viistokairauksella, mutta lahonneisuuden takia ne olivat käytännössä mittauskelvottomia. Lainaus laboratorion 31.8.1995 päivätyltä mittauslomakkeelta: "Surkea näyte, lahonnut, puolittaisia lustoja, katkeillut. Voi puuttua tai olla liikaa (lustoja) läpi koko näytteen". Käsillä olevan uusintatutkimuksen myötä Dendrokronologian laboratoriossa tutkittiin mikroskoopin avulla Tanja Ratilaisen salpakourupuun päästä ottamia valokuvia. Osoittautui, että valokuvien erotuskyky oli aivan liian heikko ajoitusmenetelmän käyttämisen ehdottomana edellytyksenä olevaan millimetrin sadasosan tarkkuudella tehtäviin mittauksiin. Lisäksi osoittautui, että salpakourupuun kuluneisuuden takia vuosilustot ovat vääntyneet. Tämä johtunee siitä, että itse salpapuuta kouruun aikoinaan asetettaessa salpa on osunut kourun reunoihin ja näin ollen vääntänyt lustorakenteen kelvottomaksi. Näin ollen ns. "in situ"-mittaus paikalle tuotavalla laboratorion siirrettävällä mittauslaitteella ei ole mahdollista. Dendrokronologian laboratorion esittämä ainoa ratkaisu mittauskelpoisten lustojen esille saamiseksi olisi isomman kappaleen irrottaminen salpakourupuusta, joka kappale sitten preparoitaisiin ja mitattaisiin laboratoriossa. Tämä ei kuitenkaan liene museaalisista syistä mahdollista.

Näyte FIH1110 (tekstilainaus v. 1995 raportista): "puuosa (sakariston ulkoseinä, länsipuolen kitapuu) on kuitenkin jo melko lahonnut, eikä näytteisiin tämän takia saatu mukaan riittävää määrää vuosilustoja varmaa iänmääritystä varten." Ko. näytteessä on vain 46 vuosilustoa, mikä määrä hyvin harvoin on riittävä. Käytännössä 50 vuosilustoa voi mahdollistaa ehdottoman varman iänmäärityksen.

Joensuussa 28.10.2016

FL Pentti Zetterberg

Dendrokronologian laboratorion vastuullinen erikoistutkija

Viitteet

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Zetterberg, P. & Zetterberg, T., 2011. Hattulan Pyhän Ristin kirkon puunäytteiden FIH1111 ja FIH1112 dendrokronologinen tutkimus. Itä-Suomen yliopisto Joensuu, Luonnontieteiden ja Metsätieteiden tiedekunta, Metsätieteiden osasto, Dendrokronologian laboratorio, ajoitusseloste 380: 1-3.

Appendix 9. Wiggle matching report on HCCH by Oinonen.

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TUTKIMUSRAPORTTI 2019-5-7 27.5.2019

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RADIOHIILIMÄÄRITYKSIÄ

Lab. koodi	Näyte	Radiohiili-ikä (BP)	±
Hela-3995/1	Hattula, kirkko, hirsi PRK, lusto 1 (uloin + 7), puu (laho)	614	35
Hela-3995/2	Hattula, kirkko, hirsi PRK, lusto 2 (+27), puu (laho)	594	36
Hela-3995/3	Hattula, kirkko, hirsi PRK, lusto 3 (+24), puu (laho)	785	37
Hela-3995/4	Hattula, kirkko, hirsi PRK, lusto 4 (+19), puu (laho)	815	35

Puusta on otettu poraamalla 4 näytettä kuvan 1 mukaisesti siten, että niiden väleissä on 19-27 vuoden aikaero (gap) ja aikaero uloimpaan havaittuun lustoon on 7 vuotta. Puunäytteille on käytetty AAA käsittelyä (Higham 2002, de Vries & Barendsen 1954). Käsitellyt näytteet on pakattu tyhjiöityihin kvartsiampulleihin yhdessä CuO-rakeiden kanssa ja niistä on erotettu hiili hiilidioksidina palamisprosessin avulla. Syntyneet CO_2 -näytteet on kerätty kryogeenisesti ja muunnettu kemiallisen pelkistysreaktion (Slota et al 1986) kautta kiinteiksi grafiittinäytteiksi. Kohtioista on mitattu radiohiilipitoisuus AMS (Accelerator Mass Spectrometry)-menetelmällä käyttäen Helsingin yliopiston hiukkaskiihdytintä (Tikkanen et al 2004).

Tulosraportointi noudattaa kansainvälisen radiohiiliyhteisön suosituksia (Millard 2014). Kukin tulos on annettu vuosina vuodesta 1950 AD lukien ja perustuu ^{14}C:n puoliintumisaikaan 5568 vuotta. Radiohiili-iän epätarkkuuteen (± 1σ) sisältyvät näytteiden mittauksista ja tarpeellisista vertailumittauksista aiheutuvat tilastolliset virheet. Radiohiili-ikä on normitettu isotooppifraktioitumisen suhteen AMS-tekniikalla mitattua $\delta^{13}C_{AMS}$ –arvoa käyttäen vastaamaan $\delta^{13}C$ -arvoa -25 ‰. Tulos on korjattu kalenterivuosiksi käyttäen Intcal13-korjauskäyrää (Reimer et al 2013) ja Oxcal 4.2 ohjelmistoa (Bronk-Ramsey 2009).

Mittaussarjan lisäksi mitattiin samassa näyte-erässä ja samalla tekniikalla hyvin vanha (~45 000 radiohiilivuotta) puu, joka antoi tulokseksi 45510 ± 2410 BP. Mittaus osoittaa, että prosessi itsessään ei tuota määrityksiin kontaminaatiota ja on siten luotettava.

Yksittäiset määritykset tuottavat kalenterivuosien todennäköisyysjakaumia (kuvat 2a-d), jotka painottuvat 1200-1300–luvuille. Jakaumat ovat yleisesti yhden tai jopa kaksi vuosisataa leveitä, mikä johtuu ilmakehän radiohiilipitoisuuden vaihtelusta ja sen mukaan vaihtelevasta kalibraatiokäyrästä.

Määritysten ja aikaerojen perusteella on luotu ajoitusmalleja (wiggle match), joiden pohjalta pystytään paremmin arvioimaan puunäytteen kasvun ajankohtaa. Mallit 4 ja 3 ajoituksen pohjalta on annettu kuvassa 3 ja niiden tulokset kuvissa 4 (koko malli) ja 5 (viimeisimmän havaitun luston kasvuhetki). On huomioitava, että jos hirrestä on veistetty vuosilustoja tämän ulkopuolelta, arvioitu kaatovuosi on vastaavasti tätä myöhäisempi.

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TUTKIMUSRAPORTTI 2019-5-7 27.5.2019

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VIITTEET:

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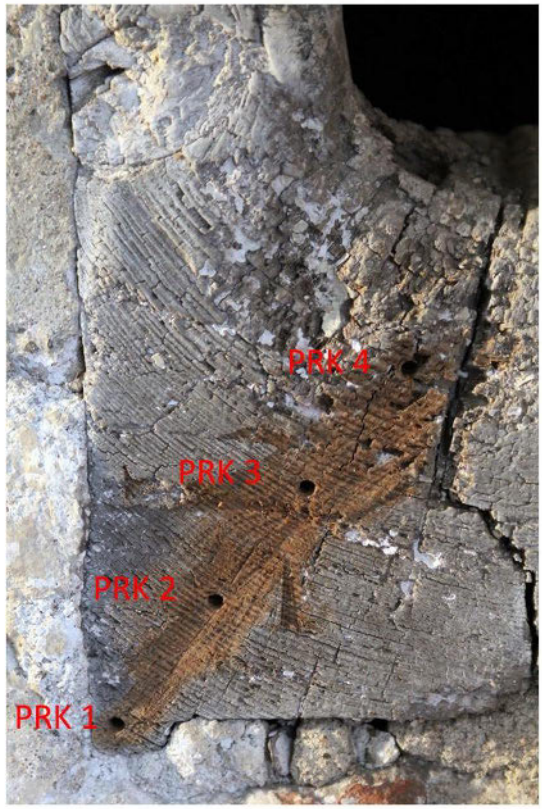
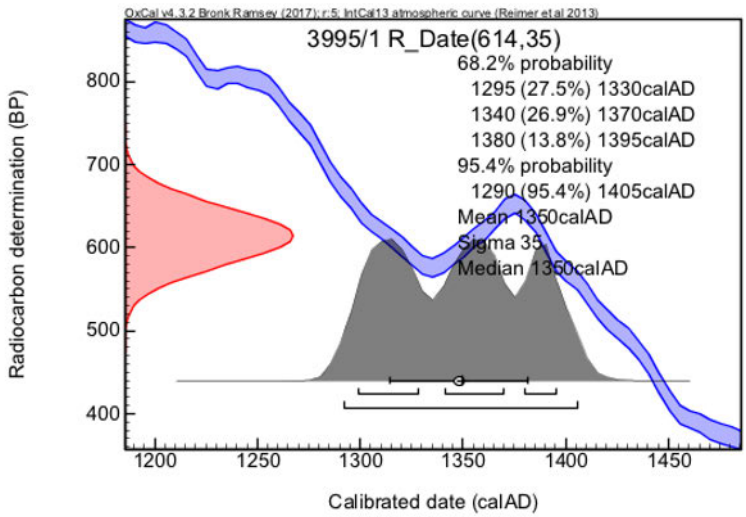
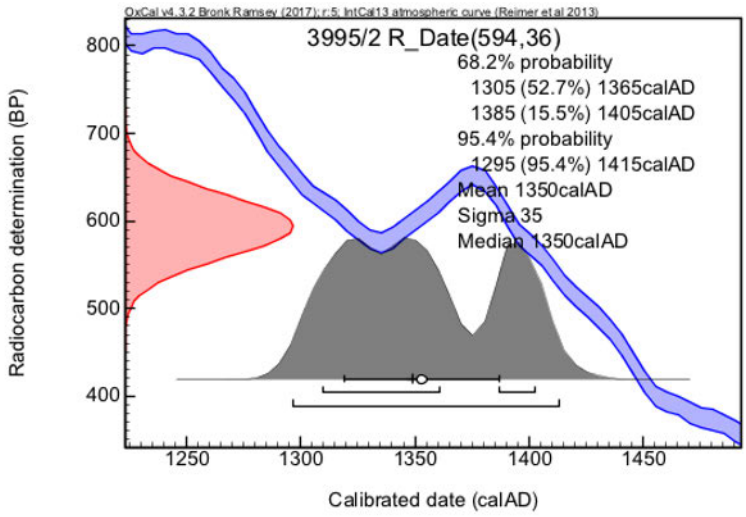
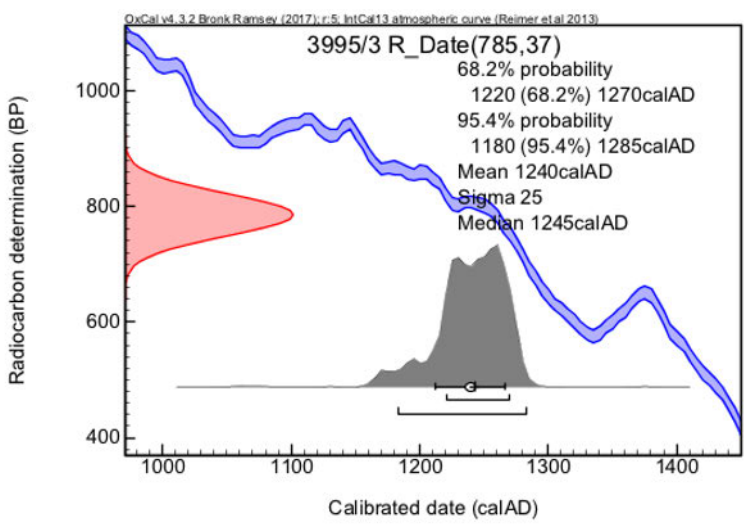
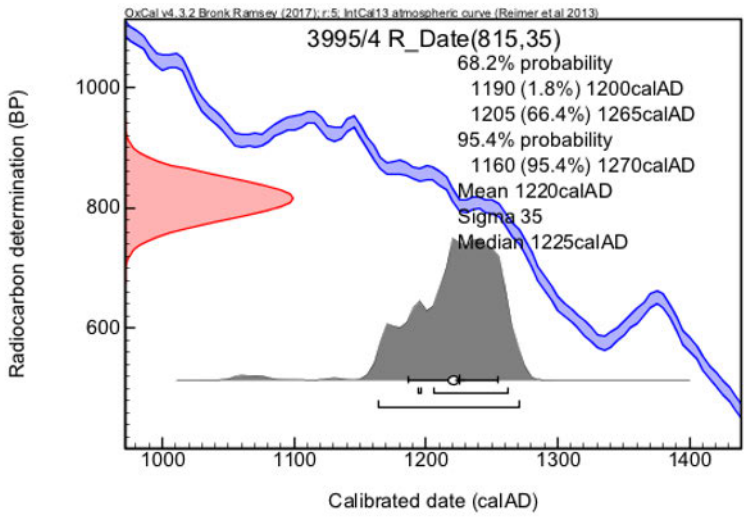


Kuva 1. Näytteiden porauskohdat.


OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
3995/1 R_Date(614,35)
68.2% probability
1295 (27.5%) 1330calAD
1340 (26.9%) 1370calAD
1380 (13.8%) 1395calAD
95.4% probability
1290 (95.4%) 1405calAD
Mean 1350calAD
Sigma 35
Median 1350calAD
Radiocarbon determination (BP)
800
700
600
500
400
1200
1250
1300
1350
1400
1450
Calibrated date (calAD)


OxCal v4.3.2 Bronk Ramsey (2017); r:5; IntCal13 atmospheric curve (Reimer et al 2013)
3995/2 R_Date(594,36)
68.2% probability
1305 (52.7%) 1365calAD
1385 (15.5%) 1405calAD
95.4% probability
1295 (95.4%) 1415calAD
Mean 1350calAD
Sigma 35
Median 1350calAD
Radiocarbon determination (BP)
800
700
600
500
400
1250
1300
1350
1400
1450
Calibrated date (calAD)





Kuva 2 a-d. Yksittäisten määritysten muunnokset kalenterivuosiksi.

a) 4 ajoituksen malli:

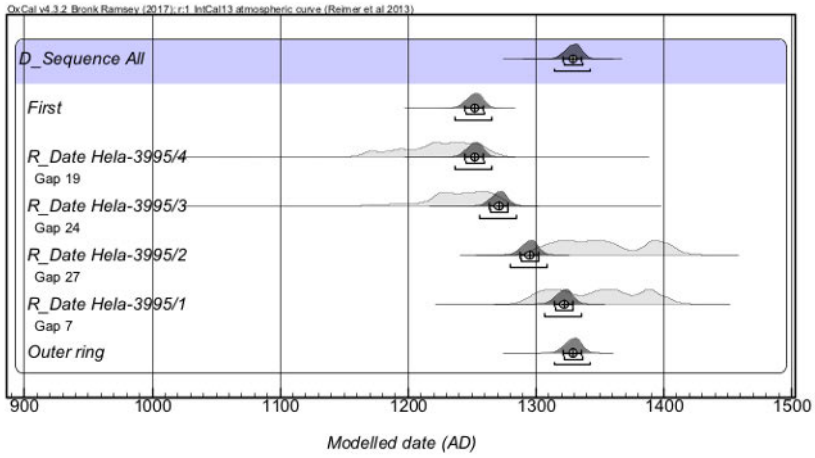
```
Options()
 {
  Resolution=1;
 };
 Plot()
 {
  D_Sequence( "All")
  {
   Outlier_Model("General",T(5),U(0,4),"t");
   First( );
   R_Date("Hela-3995/4", 815, 35){Outlier(0.05);};
   Gap(19);
   R_Date("Hela-3995/3", 785, 37){Outlier(0.05);};
   Gap(24);
   R_Date("Hela-3995/2", 594, 36){Outlier(0.05);};
   Gap(27);
   R_Date("Hela-3995/1", 614, 35){Outlier(0.05);};
   Gap(7);
   Date("Outer ring");
  };
 };
```

b) 3 ajoituksen malli:

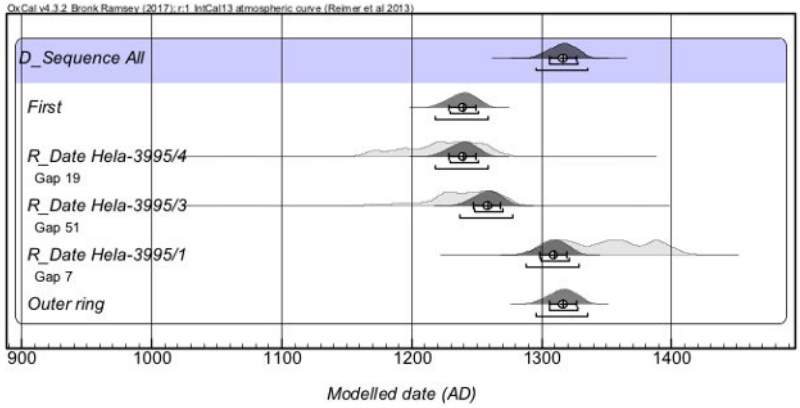
```
Options()
 {
  Resolution=1;
 };
 Plot()
 {
  D_Sequence( "All")
  {
   Outlier_Model("General",T(5),U(0,4),"t");
   First( );
   R_Date("Hela-3995/4", 815, 35){Outlier(0.05);};
   Gap(19);
   R_Date("Hela-3995/3", 785, 37){Outlier(0.05);};
   Gap(51);
   R_Date("Hela-3995/1", 614, 35){Outlier(0.05);};
   Gap(7);
   Date("Outer ring");
  };
 };
```

Kuva 3. Ajoitusmallit a) 4 ja b) 3 ajoituksella. 3 ajoituksen malli tehtiin, koska 4 ajoituksen mallin ns. Agreement Index-arvo (A_{model}) oli hieman kynnysarvoa matalampi ($A_{model,\ 4}$ = 56.6% < 60% vrt $A_{model,\ 3}$ = 133.1% > 60%).

a) 4 ajoituksen malli:

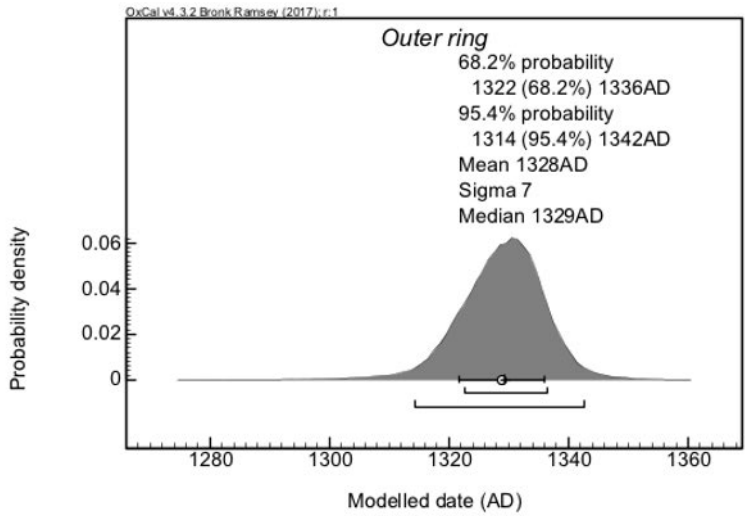


b) 3 ajoituksen malli:

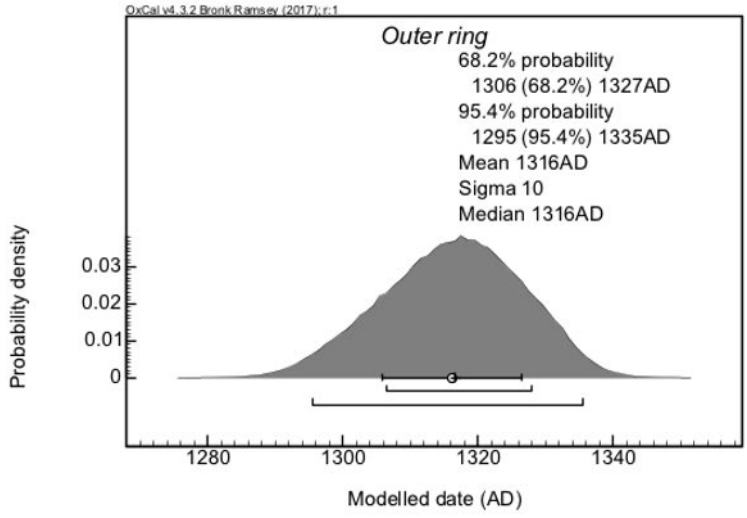


Kuva 4. a) 4 ja b) 3 ajoituksen mallien antamat tulokset kokonaisuudessaan.

a) 4 ajoituksen malli:



a) 3 ajoituksen malli:



Kuva 5. a) 4 ja b) 3 ajoituksen mallien antamat tulokset uloimman havaitun luston kasvuhetkelle.

Appendix 10. OSL dating report on HCCH by Oinonen and Eskola.

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Hattulan Pyhän Ristin kirkko

AJOITUSTULOKSIA / LUMINESENSSI

Lab.nro.	Näyte	Palaeodose (mGy)	Ikä (a)
Hel-TL04242	Asehuone itäpääty tiili1	2020 ± 90	450 ± 40
Hel-TL04243	Asehuone pohjoinen	990 ± 60	200 ± 20
Hel-TL04244	Alttaripääty	2960 ± 130	550 ± 50
Hel-TL04245	Irtotiili	2450 ± 140	490 ± 50
Hel-TL04246	Asehuone itäpääty tiili2	2550 ± 90	530 ± 50

Taulukko 1. Tulokset

Helsingissä 4.12.2012

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MITTAUSRAPORTTI / Hattulan Pyhänristin kirkon tiilenpalat

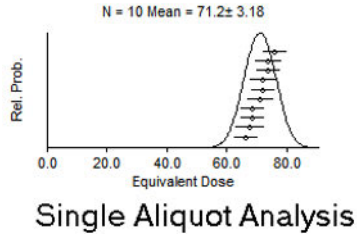
1.1 Näytteenkäsittely

Kvartsikiteet erotettiin tiilistä siten, että niiden pinnasta raaputettiin mekaanisesti pois pintakerros, joka on altistunut valolle. Tämän jälkeen varovaisella hienontamisella ja toistuvilla happokäsittelyillä (HF ja HCl) saatiin poistettua tiilien punertava saviaines, joka oli kvartsikiteitä pehmeämpää ja raekooltaan hienompaa. Lopuksi erotellut kvartsikiteet seulottiin 200–300 µm raekokoon ja suoritettiin lopullinen etsaus HF 40%/1h ja HCl 10%/30min.

1.2 Luminesenssimittaukset

Luminesenssimittaukset suoritettiin tiilistä erotetusta kvartsista OSL (optically stimulated luminescence) -menetelmällä käyttäen SAR-protokollaa (Murray & Wintle 2000). Mittaukset suoritettiin automatisoidulla Risø TL-DA-12 mittarilla (Botter-Jensen & Duller 1992), johon on vaihdettu halogeenilamppujen tilalle siniset LED-valot (Botter-Jensen et al 2000).

Saadut luminesenssimittausten tulosjakaumat olivat erittäin hyviä ja teräviä. Esimerkiksi kuvassa 1 esiintyvällä näytteellä (Asehuone itäpääty, tiili 1) on eri aliquoteista mitattujen tulosten hajonta luokkaa 4,5 %, joka vastaa suuruusluokaltaan muistakin näytteistä saatavaa hajontaa.



Kuva 1) OSL-mittausten tulosjakauma asehuoneen itäpäädystä kerätystä tiili1-näytteestä.

Luminesenssimittausten perusteella saadaan selvitettyä luonnon taustasäteilyn kokonaisannokset, jotka ovat vaikuttaneet mitattaviin näytteisiin niiden viimeisimmän kuumennuksen jälkeen (tiilen valmistus). Ensisijaisena mittaustuloksena saadaan luminesenssisignaaleita vertailemalla säteilytysaika jonka kuluessa, säteilytettäessä näytteitä annosnopeudeltaan tunnetulla säteilylähteellä, saadaan yhtä suuret säteilyannokset kuin mitä näytteet ovat keränneet luonnossa. Käyttämällä kalibroitua tietoa säteilylähteen voimakkuudesta, saadaan lopulta tieto näytteisiin historian aikana kertyneestä kokonaissäteilyannoksesta (Palaeodose taulukossa 1).

1.3 Taustasäteilyn mittaaminen

Betasäteilyn mittaus suoritettiin käyttämällä Risø GM-25-5 beta multicounter – laskuria (Botter-Jensen & Mejdahl 1988). Laskurilta saadut pulssimäärät muunnettiin annosnopeuksiksi lineaarisella sovituksella, joka pohjautuu pulssimittauksiin näytesarjasta, jonka radioaktiivisten alkuaineiden pitoisuudet ja siten myös β-aktiivisuus oli selvitetty neutroniaktivoinnilla.

Gammasäteilyn mittaus suoritettiin näytteenottopaikoilla icx-Identifinder -kannettavalla gammaspektrometrilla, jolla gammakvantteja havainnoidaan ∅ 1.4” × 2” kokoisella NaI(Ti) ilmaisimella. Gammaspektrometrillä saadaan suoraan näytteenottopaikalla vallitseva gammasäteilyn taso, johon sisältyy myös kosmisen säteilyn säteilyannosnopeus.

Erityisesti beta-mittauksissa kriittinen tekijä on näytemateriaalin kosteus. Vesi jarruttaa säteilykantamaa ilmaa tehokkaammin ja alentaa näin taustasäteilyn voimakkuutta. Gamma-mittauksissa saatiin vallitseva gamma-taso suoraan mittaamalla, mutta beta-mittauksissa piti arvioida tiilissä niiden elinkaaren aikana vallinnut keskimääräinen vesipitoisuus.

Näissä mittauksissa tehtiin oletus, että tiilet ovat olleet melko kuivia. Maksimaaliseksi vesimääräksi, mitä tiilet voivat imeä itseensä vettä arvioitiin 5 %. Tämän lisäksi tehtiin myös olettamus, että näytetiiliin olisi todellisuudessa sitoutunut vettä (esimerkiksi ilman kosteuden kautta) vain 10 % tästä maksimaalisesta määrästä. Tulokset ovat kuitenkin jossain määrin kriittisiä tälle vesipitoisuus arvolle. Jos ajatellaan esimerkiksi, että ulkoseinästä irrotetulla irtotiilellä olisikin ollut keskimäärin hieman sisältä kerättyjä tiiliä korkeampi vesipitoisuus, esimerkiksi 20 % maksimivesipitoisuudesta, niin tällöin se vanhentaisi näytettä n. 10 vuotta.

1.4 Iän määritys

Näytteen ikä määritettiin jakamalla luminesenssimittauksen perusteella saatu näytteen saama säteilyannos (paleodose) mitatulla taustasäteilyn annosnopeudella. Tulosten epätarkkuuden arvioinnissa huomioitiin sekä säteilymittauksen epätarkkuus että säteilyn annosnopeuden arvioinnista tuleva epätarkkuus.

$$Age = \frac{Paleodose}{Dose\ rate}$$

Määritysten perusteella saatiin ikä-arviot, jotka on esitetty talukossa 1.

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1.5 Viitteet:

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Bøtter-Jensen L, Bulur E, Duller G A T & Murray A S 2000: Advances in luminescence instrument systems. *Radiation Measurements 32*, 523–528.

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