Visa Immonen, Tanja Ratilainen, Jussi Kinnunen, Kari O. Eskola & Markku Oinonen

THE CONSTRUCTION DATE OF THE DOMINICAN CONVENT OF ST OLAF IN TURKU, FINLAND – A RE-EVALUATION

Abstract

The foundation of the medieval Dominican Convent of St Olaf in Turku, South-West Finland, marked the connection of the country to an international network of contacts with the Latin West, and the establishment of taught education in Finland. However, the chronology of its construction has been a subject of scholarly debate since the early 20th century. The archaeological material from the convent is scant, and the only properly datable finds are a sample of timber from the structures and a collection of bricks recovered from the site. In this article we present the results of a wiggle-match dating of the timber, and OSL dating of eight bricks. The bricks were also analysed by pXRF. The building phase of brick masonry seems to date to the second half of the 14th century or around 1400AD.

Keywords: Chronology, Dominicans, Finland, medieval archaeology, monastic architecture, Turku

Visa Immonen, University of Bergen, Department of Archaeology, History, Cultural Studies and Religion, P.O. Box 7805, NO-5020 Bergen, Norway: visa.immonen@uib.no

Tanja Ratilainen, Turku Museum Center, P.O. Box 286, FI-20101 Turku, Finland: tanja.ratilainen@turku.fi

Jussi Kinnunen, Department of Archaeology, Akatemiankatu 1, FI-20014 University of Turku, Finland: jpkinn@utu.fi

Kari O. Eskola, Laboratory of Chronology, Finnish Museum of Natural History, P.O. Box 64, FI-00014 University of Helsinki, Finland: kari.o.eskola@helsinki.fi

Markku Oinonen, Laboratory of Chronology, Finnish Museum of Natural History, P.O. Box 64, FI-00014 University of Helsinki, Finland: markku.j.oinonen@helsinki.fi

Received: 30 April 2020; Revised: 23 May 2022; Accepted: 6 October 2022

Immonen, V., Ratilainen, T., Kinnunen, J., Eskola, K. O. & Oinonen, M. 2022. The construction date of the Dominican Convent of St Olaf in Turku, Finland – A re-evaluation. *Fennoscandia archaeologica* XXXIX: 118–138.

INTRODUCTION

The Dominican Convent of St Olaf in Turku, South-West Finland, had a special importance among the medieval monastic institutions in Finland, which had been integrated into the medieval Kingdom of Sweden by the mid-13th century. The convent left a major impression on the cultural and liturgical makeup of the Diocese of Turku, comprising the area of present-day Finland (e.g., Malin 1925: 184; Bonniwell 1945: 205–6; Lehmijoki-Gardner 2004: 240). Moreover, according to Markus Hiekkanen (2002; 2003a; 2003b: 90–1), Dominicans played a crucial role in the foundation of the town of Turku itself, and throughout the Middle Ages they had a considerable impact on its urban life.

Yet, despite the significance of the convent, its physical remains are no longer visible in the urban landscape of Turku, and scholars have failed to determine the exact age of the ruins laying underground. This is partly because of the patchy history of research at the site. The location of the convent was identified at the turn of the 19th and 20th centuries, and since then, the site was explored in a series of poorly documented excavations. In addition, the documented architectural features and archaeological finds saved in museum collections are not easy to date, making the chronology of the convent's ruins difficult to establish.

To break away from the current deadlock, this study will present the results of the scientific analysis of eight bricks and a sample of timber obtained from the convent site. These provide an indication of the age of the brick structures and the possible origins of the building material. The article will also provide a summary of the complex research history of the site and meagre archaeological material available, and set this research in context within the architectural development of the medieval town of Turku, especially regarding the use of brick for urban constructions.

Although the new dates obtained by this study are not unambiguous with regard to their context, they can nevertheless be compared with published scholarly hypotheses on the architectural chronologies of the convent and of the town, in order to assess the likely accuracy of the latter. The findings suggest that the brick structures were erected in the latter part of the 14th century or around 1400, at a time of intensive masonry construction within the urban area.

THE FALL AND REDISCOVERY OF ST OLAF'S CONVENT

The Dominican Convent of St Olaf has been of particular interest to Finnish scholars because so few monastic foundations are known to have existed in the country during the Middle Ages. While 200 monasteries or convents were founded in Scandinavia during the Middle Ages (on the Nordic terminology, see Lovén 2001), only six are known from the Diocese of Turku (Hiekkanen 1993: 123). In addition to the Dominican Convent, which hosted a community of monks, the remainder of these were friaries – modest buildings that served as a base for itinerant preaching by friars. Another Dominican convent, as well as a Franciscan convent, were also established in Viipuri, an important urban centre controlling Sweden's eastern frontier with the Novgorod Republic (Immonen 2019). Two Franciscan friaries also existed in the town of Rauma, on Finland's western coast, and on the island of Kökar, in the Åland Islands. The only actual monastery in the diocese was in Naantali, located c. 15 km north-west from Turku. This belonged to the Bridgettine Order and accommodated both nuns and monks.

The monastic houses of Turku were closed in 1536 as a consequence of the Reformation, with brothers dispersing across the diocese to serve as ordinary parish priests. In 1537, the Convent and the town were damaged by fire, and the friary along with its lands were taken over by the Crown (Leinberg 1890: 79; Ruuth 1909: 108, 122; Nikula 1987: 99; Salminen 2003: 39–40; Gardberg 2005: 67–9). Townspeople began to exploit the Convent's ruins as a source of building materials, and in 1543 King Gustavus Vasa ordered some of the bricks and other architectural elements of the convent to be used in the renovations of the castles of Kastelholm and Turku (Ruuth 1909: 108; Nikula 1987: 99; Hiekkanen 2018: 183).

During the same period, some of the plots of land belonging to the Convent were rented to burghers and ended up in private ownership. These plots were situated on Kaskenmäki Hill, about 100 meters from the present-day bank of the River Aurajoki in a dell formed by the steep slopes of Vartiovuori Hill and Samppalinna Hill. During the Middle Ages, the river served as a major waterway for the region, flowing through the town to meet the Baltic Sea. Due to the landscape's challenging topography, height differences across the site of the Dominican Convent are quite significant (Rinne 1908: 107–8). Nonetheless, following its destruction, the site began to be occupied by new buildings, although the Convent's church and cemetery were initially excluded from construction activities. By 1609, this area had become an herb garden (Ruuth 1909: 116–8; Brusila 2001: 107; Laaksonen & Lahtinen 2011: 26), and the exact location of the Convent was forgotten.

The Great Fire of 1827 destroyed most of the City of Turku. In the following year, a completely renewed urban plan was introduced. During the subsequent years, as the remains of old buildings were torn down and foundations for new ones were excavated, ancient brick walls and graves were found around the city (von Bonsdorff 1894: 43). When human bones and brick structures were discovered on Kaskenkatu Street, at the site of the Dominican Convent, these were assumed to be the remains of the monastic cemetery, although no direct evidence of this was apparent (Brusila 2001: 81, 84; Gardberg 2005: 74).

Despite ancient remains being regularly found and destroyed, building activities during the 19th century and in previous eras was relatively light and did not drastically disturb buried archaeological remains (Ruuth 1909: 122; Gardberg 2005: 72). The situation changed at the turn of the 20th century with the introduction of modern building techniques and the boom of erecting multi-storey buildings. In 1901, excavations for a new stone building at 1 Kaskenkatu Street revealed the ruins of the Dominican Convent. The first archaeologist to investigate was Hjalmar Appelgren (1902). The structures he observed were built exclusively of brick, reaching a height of three meters in the best-preserved areas.

Based on these early observations, archaeologist Juhani Rinne (1908) presented the first reconstruction of the convent's plan in 1908 (see also Ahl 2007). He identified an almost triangular garth and surrounding cloistered ambulatory and proposed the space on the north and north-west side of the north range as the site of the Convent's church (Rinne 1928: 91; 1952: 199–201). During subsequent decades, as more stone buildings were erected in this area, archaeologists and architects documented as much as they could and deposited some of the revealed finds in museum collections, but soil removed during these works was not sifted. In 1909, architect Alex Nyström made a few rough notes and sketches of the brick structures and graves that were uncovered during the construction of a large building at 2 Kaskenkatu Street and in 1927–1928, Rinne monitored the discovery of further ancient structures that emerged when another major building was constructed on the site of 1 Kaskenkatu. This led him to publish a revised reconstruction of the Convent's lay-out in 1928 (Rinne 1928; 1952: 201).

It was not until the 1960s, however, that the first modern archaeological excavations were undertaken at the site of the Convent. These took place mostly on Kaskenkatu Street, the modern road that divides the site into two parts. Even this fieldwork was problematic, however, since no excavation reports were filed. The aim of the excavations seems to have been to reveal and document merely the existence of architectural features. As a result, the fieldwork stopped when the uppermost floor level was uncovered (Kolehmainen 2008: 67–9).

The 1960s excavations nevertheless revealed that Rinne's reconstruction and interpretations needed updating, and a new plan was published in 1986 (Pihlman 1986). Hiekkanen (1993; 2003a; 2003b) would later argue that, based on other medieval Finnish church sites, the Convent's church would have been in the eastern-north-eastern corner of the complex. In the 2010s, a group of archaeologists compiled a new critical plan of the site and presented a revised interpretation of its spatial use (Fig. 1) (Immonen et al. 2014a; 2014b; Immonen 2015; Harjula et al. 2016). Based on the revised architectural plan and on the distribution of fragments of mortar painted with typical ecclesiastical murals, the group concluded that Hiekkanen's idea of the church's location was very likely, whereas the location identified by Rinne for the church does not seem to have been occupied by a roofed building at all: the walls surrounding it are too irregular to have been a covered space, and no signs of flooring have been documented there. In addition, the group concluded that the vaulted room with two pillars underneath Kaskenkatu Street seemed to have been the chapterhouse. The plan of the convent complex could therefore be reconstructed satisfactorily, but the age of the buildings still remained an unresolved issue.

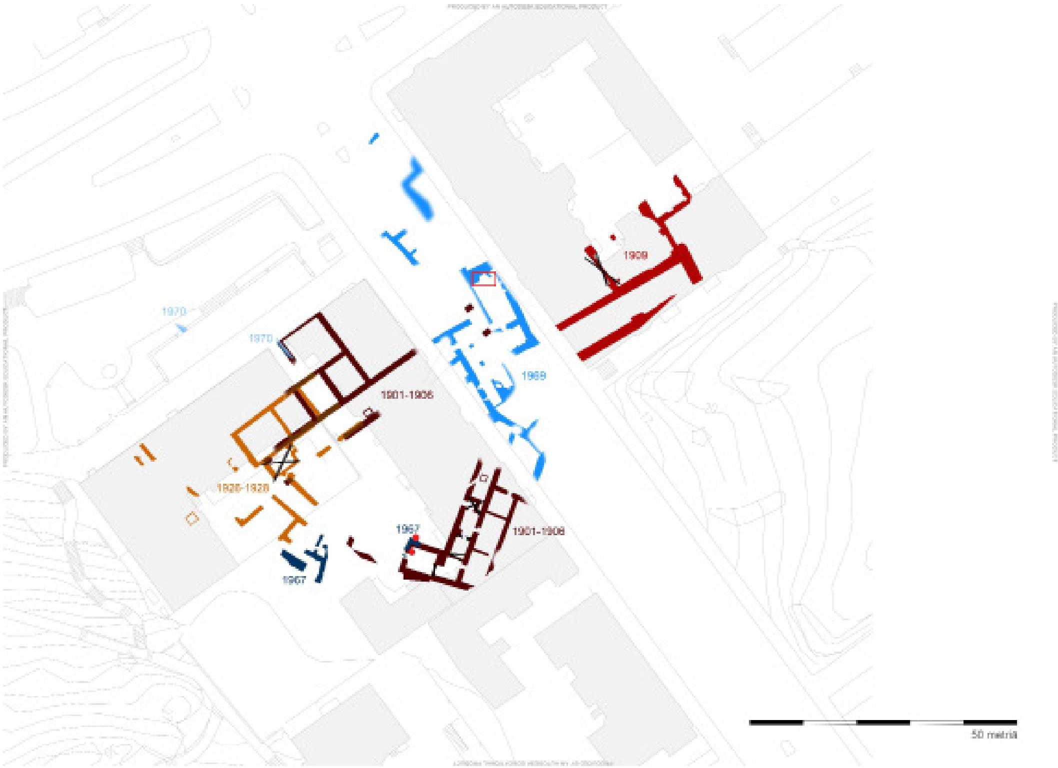


Figure 1. Plan of the Dominican Convent of St. Olaf based on archaeological documentation. Red dots indicate the location of bricks ID 1–2. The rest of the ceramic objects sampled were found underneath Kaskenkatu Street in 1969. Rectangular red box in the street area indicates the location of the dated timber. Plan by Panu Savolainen, modified by Tanja Ratilainen.

THE PROBLEM OF AGE

According to the Annals of the Dominican convent of Sigtuna, the Dominicans arrived in Finland in 1249 (DF 98; Maliniemi 1947: 87–8). This passage has been used to support the equation of the first Dominican convent with the structures identified archaeologically on Kaskenmäki Hill (Salminen 2003: 38). Based on archaeological excavations made during the last three decades, however, it has become apparent that, in the latter part of the 13th century, the site of the later medieval town was rural in character, with Turku itself not founded until around 1300 (Hiekkanen 2001: 627; 2002: 157–8; 2003a: 42–8; Pihlman 2007; Seppänen 2009: 242–3; Pihlman 2010; Seppänen 2011; 2012: 941; Pihlman et al. 2022). When the convent was established in 1249, therefore, the town of Turku did not yet exist. This is problematic considering that Dominicans usually founded their convents in urban areas. Perhaps the first convent lay somewhere other than in the location later identified as its site.

The most likely site for the foundation of the first convent is the fortified site of Koroinen, situated two kilometres up the River Aura from the site of the later Dominican Convent of Turku. Archaeology has confirmed that Koroinen was once the site of a 13th-century cathedral and two secular buildings that formed the bishop's residence (Harjula et al. 2018). In around 1300, the cathedral was moved to its present location within Turku. Problematically, however, no structures or finds from Koroinen indicate the existence of a Dominican convent there.

In addition to the possible transfer of the Dominican convent from elsewhere to its present location, another issue that has puzzled scholars is the dating of the architectural features on

Kaskenmäki Hill. The structures excavated there are made of brick, but earlier buildings at the site may have been constructed of other materials. The surviving literary sources do not record the material of the friary's first buildings (DF 259; 466), and it may well be that these were constructed of wood and only later rebuilt using more durable materials (Hiekkanen 2003b: 92; Gardberg 2005: 48, 52). However, there is a written record that the town along with the Convent burned down in 1429, and in 1431 the master mason Simon of Tallinn directed some construction work at the Convent (DF 1901, 1902, 1910, 1917, 1977, 2005; Ruuth 1909: 107–8; Kuujo 1981: 180). Hiekkanen (1993: 128; 2003b: 92; 2018: 182) suggests that the architectural features documented during the 20th century are probably from this period, while Liisa Seppänen (2012: 647–9, 668) argues that they may be even earlier, since the first masonry structures appear in Turku in the first half of the 14th century (Ratilainen 2010; 2020).

To date, four separate hypotheses have been proposed regarding the age of the remains of the Dominican Convent on Kaskenmäki Hill:

1. The first convent was constructed of wood at the same site, and later rebuilt in brick.

2. The brick structures found at the site were erected before Turku was founded around 1300.

3. The brick structures were erected after 1300 but before Convent's destruction by fire in 1429.

4. The brick structures were constructed after the 1429 fire.

These four hypotheses do not entirely exclude one another, and do not represent the only scenarios possible. However, they provide a framework against which to evaluate archaeological and written sources and the results of scientific analyses. These hypotheses will now be assessed, in light of (1) a brief examination of other archaeological evidence from the site, and (2) the results of the modern scientific analyses.

Hypothesis 1 (as listed above) is quite difficult to evaluate, but there are indeed faint signs of a building phase prior to the masonry structures on Kaskenmäki Hill. Firstly, a deposit of burned wood was discovered near a pillar inside the building identified as the Convent's church in 1909 (Kolehmainen 2008: 52). This deposit rests directly on the bedrock but beneath a demolition layer containing pieces of bricks. Secondly, in the excavations of 1967 across Kaskenmäki Street, in the western or north-western corner of the cloister ambulatory, a layer of clay coloured by organic matter was discovered in two places. The layer was 2–8 cm in thickness and sandwiched between natural clay and a demolition layer with brick fragments (Kolehmainen 2008: 62, 66). No calendar date has yet been obtained for this organic layer and that will not be possible before new excavations in future, but it remains a feasible, though insecure, indication of an initial phase of building that used wood.

The Convent's brick architecture is also rather challenging to date stylistically, partly because the features documented are quite generic and partly because some post-medieval building activities took place even after the Convent was dissolved (Appelgren 1902: 57; Rinne 1908: 110, 122–34; 1928: 91; Hiekkanen 2003b: 92 note 28). The use of Monk bond in the brickwork (consisting of a consecutive pattern of brick header and two stretchers) is a medieval feature (Rinne 1908; Gardberg 1957: 33, 63; Brusila 2001: 100–1; Hiekkanen 1994: 214–5; Kolehmainen 2008), while the use of dovetail notches in some of the documented timber structures could be dated to the 15th century at the earliest (Rinne 1908: 126, Figs. 14, 131; Seppänen 2012: 636).

Any further architectural dating remains dubious, while archaeological finds are of limited use given the small number of datable objects recovered. Two coin hoards have been discovered at the site, with the *terminus post quem* date of one being 1558 (Brusila 2001: 91), and of the other being the 1450s (Talvio 2011: 161). In addition to the miniature stoneware jug in which the latter hoard was deposited, only two pieces of medieval pottery are known from the site (Pihlman 1995: 348; pers.comm. 2012). A few other late medieval and early modern finds survive (Immonen et al. 2014b: 14–6), but nothing appears older than the 15th century. This challenging age profile is probably due to coarse fieldwork practices and to the buildings' long history of use after the convent ceased to function. A more accurate dating of the architecture would require either new archaeological finds or the application of modern scientific analyses to extract information from the existing material (see, e.g., Atlıhan et al. 2018; Gueli et al. 2018). The latter option involves the dating and analysis of bricks and wood from the site.

In the following, we will first describe the sampling and analysis of brick samples and a timber post from the Convent site. After that we will proceed to the optically stimulated luminescence dating of the samples, and the wiggle-match dating of a timber post. Combining the datings of the bricks and the timber provide a basis to argue that hypothesis 3 is the most likely chronology for the masonry structures at the Convent site.

THE MATERIALS AND THEIR TREATMENT

The most abundantly available material for scientific dating from the Convent site is comprised by bricks. Eight pieces of masonry out of 113 (TMC 16768) collected from the convent site were selected for further dating and material analysis. The selection criteria were as follows:

1. The bricks were already broken so that it was not necessary to sample intact objects;

2. The shape of the bricks, and thus their function, had to be easily identifiable;

3. The bricks sampled were not block-shaped, but moulded, and thus more likely to have belonged to the medieval Convent than the more easily recyclable, block-shaped wall bricks.

Following these criteria, we selected six bricks (ID 1–6), a floor tile (ID 7) and a curved roof tile with a notch (ID 8). Three of the bricks were rib bricks used in vaulting (ID 1–2, 5), three were round-moulded bricks (ID 3–4) and one was a concave moulded brick usually applied in window jambs and portals (ID 6). All these were found in the late 1960s excavations and deposited in the collections of the Turku Museum Centre. Some of their find locations were roughly documented, but no precise context information was recorded for any of them. Since no excavation reports are available, we had to resort to the information provided by the find catalogues, which gave the find location of two bricks with some accuracy. Although the context data is highly problematic, there is still more information on these items than on the material excavated earlier.

The first of the bricks (ID 1) was discovered in 1967 within a building waste layer inside a test pit dug north of a wall in the inner courtyard of the building at 1 Kaskenkatu Street. The brick was recovered at a depth of 50 cm from the top of a medieval wall. The second brick (ID 2) was found on the other side of the same wall, inside a room, within a 70-cm thick archaeological layer. The brick was found 20 cm above the clay layer lying beneath this. The rest of the ceramic objects sampled were found underneath Kaskenkatu Street in 1969. Despite the limited information available, it seems very likely that also these bricks and tiles were discovered loose in layers of building waste, and not extracted from standing structures. Moreover, the type of floor (evidenced by ID 7) and roof tiles (evidenced by ID 8) found are typical of the medieval period (cf. Antell 1986: 29; Seppänen 2012: 698–9), supporting the conclusion that these formed part of structures belonging to the Dominican Convent.

Samples for OSL dating were extracted from the bricks and tiles in accordance with the instructions by the Laboratory of Chronology at the Finnish Museum of Natural History. To avoid contamination from exposure to light, the original surfaces were scraped away. Before sampling, the bricks and tiles were also photographed. Samples were removed using a water-colled diamond blade and separated with a hammer and chisel. The preferred size for samples was 4 cm x 4 cm x 4 cm. After samples for OSL dating had been removed from the selected ceramic objects, a study of their composition was undertaken. For each ceramic, a freshly cut and cleaned surface was examined under a stereo microscope (Table 1).

In tiles ID 1–7, temper was found to be composed mainly of light coloured and sharp-edged mineral fragments and few rock fragments under 1 mm in diameter size. The amount of the temper

Table 1. The features of the sampled ceramics and the results of stereo microscope examination. Hbl = hornblende, Mca = mica, Or = orthoclase/potash feldspar, Pl = plagioclase, Qz = quartz (Siivola & Schmid 2007).

Id	Sample (TMC inv. no.)	Description	Measured brick size (cm)	Brick colour	Temper particle form	Temper minerals/rocks
1	16768:29	vault rib brick	(21) x 15 x 7.5–8	dark red	sharp crushed fragm. + rounded sand	Pl, Qtz, Or, Mca, carbon inclusions
2	16768:30	vault rib brick	(20.5) x (14.5) x 8	orange	sharp crushed fragm. + rounded sand	Qtz, Pl, Or
3	16920:62	profiled brick	thickness 13.5, round part ø 6.5	orange	sharp crushed fragm. + rounded sand	Qtz, Pl
4	16920:64	profiled brick	thickness 13.5, round part ø 6.5	orange	sharp crushed fragm.	Qtz, Pl
5	16920:78	vault rib brick	(14.5) x 11.5 x (6.0)	orange	sharp crushed fragm.	Qtz, Pl, Mca, rock frag. granodiorite
6	16920:92	moulded brick	(18) x 12 x 8.5	orange	sharp crushed fragm.	Qtz, Or, Mca, Hbl
7	16920:131	floor brick	21.5 x 21.5 x 7	orange	sharp crushed fragm.	Qtz, Pl, Mca, rock frag. granite
8	16920:132	roof brick/tile	12.5 x 11.5 x 6.6, tile thickness 2–3	orange	sharp crushed fragm. + rounded sand	tiny Qtz and Pl, tiny carbon inclusions

was estimated to be 10–15%. The main mineral fragments were quartz and plagioclase, with the remainder composed of potassium feldspar and dark mafic minerals, mostly mica and hornblende. The rock fragments, meanwhile, consisted of all the above minerals in approximately equal proportions, and can thus be identified as leucocratic granite or granodiorite. This, in addition to the results of a pXRF-analysis strongly suggested that temper consisted of crushed granite or granodiorite (see Appendix 1). This type of rock exists in Finland, Sweden, and parts of southern Norway. To a minor extent, rounded sand grains, mainly quartz, were also observed in bricks ID 1, 2, 3, and 8. There were no sharp granitic mineral fragments in the roof tile (ID 8). Instead, traces of organic material were detected as dark carbon inclusions.

A macroscopic inspection of the bricks and tiles revealed mortar remains on all their original surfaces, except for one rib brick (ID 2). The colour of their firing was mostly a reddish orange, but in one case was dark red (ID 1). The mixture of the bricks' ceramic material appeared to be well-fired, and the consistency appeared solid and compound, except for the fragile floor tile (ID 7). No additives, such as fragments of burnt bone or charcoal, were present, but traces of an iron spike, used to attach a cutting board to the surface of the brick, were detected on two round-moulded bricks (ID 3–4) and one of the rib bricks (ID 5). Consequently, we concluded that two kinds of techniques, based on a cutting board and moulds, were used in shaping the bricks. No traces of glazing or severe fire were detected.

In addition, a wood sample for radiocarbon dating was obtained from the area of the Convent. This was extracted from a timber 'located next to a stone basis of a room adjacent to 2 Kaskenkatu Street, facing the Aura River' in 1969 (TMC 16920:150). The room, situated between the church and the chapterhouse, had a large window in its north-east wall (see Fig. 1). It has been identified either as a passage between the church and the convent area (Immonen et al. 2014) or as a kitchen and washing room (Stenlund 2010: 64). However, since no hearth was found, the interpretation of the room as a passage seems more plausible.

Material from this wood sample was sent to two separate dendrochronological laboratories, and they both independently concluded that the wood was too deformed for a proper dendrochronological analysis (Zetterberg 2015; Daly 2017). Consequently, the only possibility for dating the timber was a Carbon-14 wiggle-match dating (WMD) based on a series of radiocarbon dates. This analysis was conducted at the Laboratory of Chronology, University of Helsinki (following a procedure described in Uusitalo et al. 2018; see also Oinonen et al. 2013).

Optically stimulated luminescence dating of the sampled bricks

Samples from the eight ceramics in this study were dated by OSL at the Laboratory of Chronology at the Finnish Museum of Natural History, University of Helsinki (Oinonen & Eskola 2016). The analyses were made on coarse (150–300µm) quartz grains using the SAR protocol (Murray & Wintle 2000) with 260°C preheat temperature. Outer layers of the quartz grains were etched with hydrofluoric and hydrochloric acid treatments to consider the alpha radiation component to be unessential (cf. Liritzis et al. 2013). Beta radiation dose rates were measured with a Risø GM-25-5 beta multicounter from crushed brick samples. The beta count rates were converted to beta dose rates based on a linear relationship obtained from beta count rate measurements of known activities. Since it was not possible to measure gamma radiation dose rate at site, the rate was estimated based on measurements of dose rate ratios of beta and gamma radiation on reference samples collected by the laboratory and following the approach of Ankjærgaard and Murray (2007). For all the samples a luminescence light distribution was measured and thus a paleodose could be defined (Fig. 2). Eventually, OSL ages were deduced as a ratio of paleodose to total dose rate (Table 2). The uncertainties of the dose rate determinations, including reference measurement-based beta and gamma dose-rate ratio, and paleodose measurements were included in OSL ages through law of error propagation. Eventually, the uncertainties on a 1σ level were ranging from 13–18% thus being fairly conservative largely due to estimated c. 10–12% uncertainties within dose rate determinations.

Moisture content (Zimmermann 1971; Aitken 1985) is an essential feature in determining the OSL age uncertainty (Bailiff 2007) due to absorption of radiation by water. Based on site location 100m uphill from the River Aura, the assumed history of brick samples consisted of their presence in the Convent's structure and an over 100-year storage time after excavations, and thus the average water content of bricks was estimated to be small. Particularly, we adopted a saturation water content $W=0.12$ of a wet masonry wall (Hoła et al. 2017) and fractional water uptake $F=0.25$ to characterize fairly dry conditions with c. 3% mass moisture content. Potential increase of water content decreases the dose rate due to absorption and thus increases the age estimates. As a sensitivity analysis, change of F ranging from 0.25 to 0.8 (neglecting water absorption during >100 years of storage time) yielded to a c. 50-year increase in age, still within the conservative uncertainty estimates.

Sample	Laboratory Code	Palaeodose (Gy)	Age a, round	(+/-) a, round	1σ (calAD)	2σ (calAD)
Turku 2015 16768:29	Hel-TL04303	3.18±0.30	650	100	1293–1476	1205–1565
Turku 2015 16768:30	Hel-TL04304	3.00±0.13	560	70	1403–1546	1335–1615
Turku 2015 16920:62	Hel-TL04305	3.48±0.39	620	100	1313–1517	1215–1615
Turku 2015 16920:64	Hel-TL04306	3.47±0.25	690	90	1263–1446	1175–1535
Turku 2015 16920:78	Hel-TL04307	3.37±0.15	620	80	1333–1496	1255–1575
Turku 2015 16920:92	Hel-TL04308	3.60±0.33	670	100	1263–1467	1165–1586
Turku 2015 16920:131	Hel-TL04309	3.29±0.20	690	100	1253–1436	1165–1525
Turku 2015 16920:132	Hel-TL04310	2.35±0.32	450	90	1493–1656	1415–1735

Table 2. The eight OSL dates from the Dominican Convent in Turku.

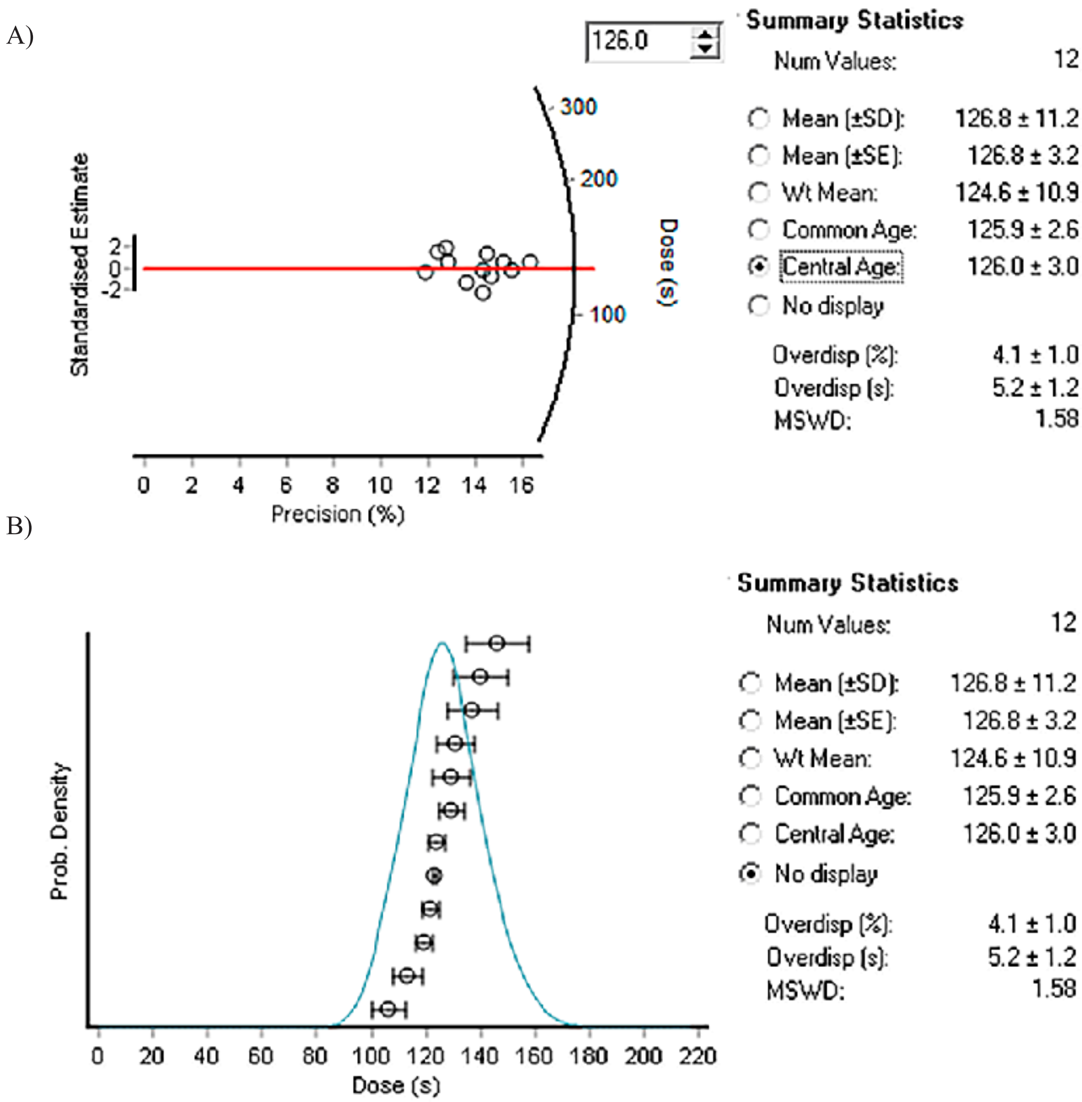


Figure 2. An example of a a) growth curve and b) equivalent dose determination for an OSL measurement (sample 16920:92, Hel-TL04308). The figures are an output of the analysis with the Analyst software (Duller 2007).

Moreover, since SAR protocol was adopted for the OSL measurements, it intrinsically involved quality criteria for recycling ratio limit (<10%), maximum test dose error (<10%) and maximum palaeodose error (<20%). For instance, results for ID 2 and ID 8 include only four successful measurements of aliquots, since half of them were rejected due to exceeding of the recycling error limit of 10%, meaning that the first and last test doses were differing more than 10%. The small number of aliquots is intrinsically taken into account within the statistical uncertainty estimate.

Although the OxCal software (Bronk Ramsey 2021) is typically used for radiocarbon date calibrations, we adopted it to present OSL dates consistently as calendar years. Results for the eight sampled ceramics, with probability ranges of 68.2% and 95.4%, are presented in Table 2. We also made a combined modelling of the dating results with OxCal. Since the OSL results of the samples ID 2 and ID 8 were based only on four light measurements and clearly younger than other results, they were excluded from the model. In OxCal, the *terminus post quem* date was set to 1249, when the Dominican Order arrived in Finland (DF 98), which can be considered as the earliest possible time for building the convent. The *terminus ante quem* date was set to the Great Fire of 1827. The combined model of the five bricks and the floor tile resulted in a probability range of 1329–1404 AD.

The evaluation of the OSL dating results is complicated for four main reasons. Firstly, the original samples were not taken directly from the brick structures identified with the Dominican Convent (Fig. 3), and only for two ceramics has a precise find location recorded. Secondly, if masonry elements, such as bricks, are found in building waste within an urban area, these do not necessarily derive from the closest standing structure to them but may originate from elsewhere. Thirdly, the wide margins of the calibrated OSL dates obtained from the ceramics analysed in this study are problematic. This is particularly significant in the case of Turku's Dominican Convent, because radiation data could not be obtained on site. However, this difficulty can be addressed to some degree through the combined modelling of the dating results, acknowledging the limitations imposed by imprecise contextual data. Fourthly, we must take into account that the dating results might indicate either the time of the firing of the bricks, or some later fire to which the bricks were subjected.

This fourth problem can be resolved by extracting further information from the bricks and the dating procedure. There were no indications of severe damage by fire on the surfaces of the sampled bricks. Moreover, the OSL light distribution curves for several measurements were narrow, and deviations from these results were estimated to be caused mainly by contamination from the brick surface or local variations in the background radiation. Consequently, the dating results seem to indicate the time when the bricks were produced, not some later fire.

When considering individual dating results, the curved roof tile (ID 8) appears to be clearly younger than all the other objects sampled. It was produced in the late medieval period, or, more likely, in the early modern period. This finding is interesting, considering the production and use of curved roof tiles. Traditionally these are expected to date to the Middle Ages, or at least to the period before the 17th century (e.g., Antell 1986: 10–1, 29; Andersson & Hildebrand 2002: 198). The dating result is based on only four measurements of light, but, on the other hand, they provide a high-quality luminescence signal. Except for this sample, all the other samples seem to date to the Middle Ages with the probability of 68.2%.

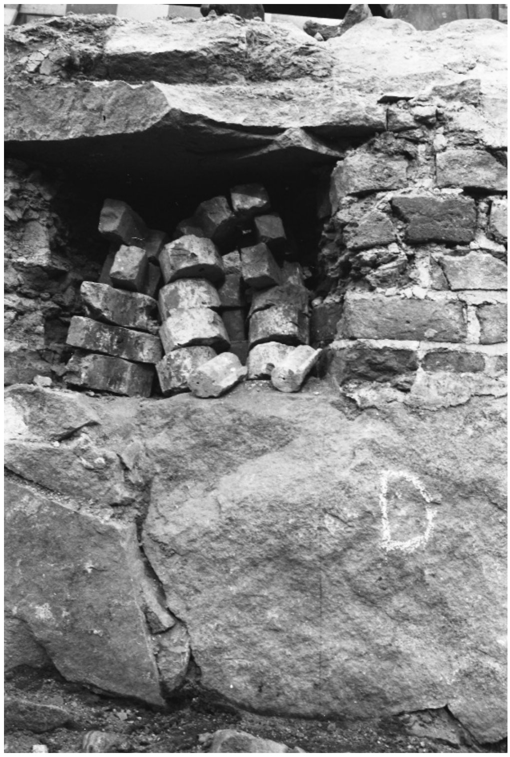


Figure 3. Bricks stacked in a niche revealed underneath Kaskenkatu Street in 1969. (Photo by Per-Olof Welin/Turku Museum Centre.)

If we assume that the two similar rib bricks (ID 1–2) and two similar round-moulded bricks (ID 3–4) originated from the same structures, the former pair from the vaults, and the latter pair from a portal, for instance, their dating results should be similar, if they came from the same production batch. However, this does not seem to be the case as their dating results differ

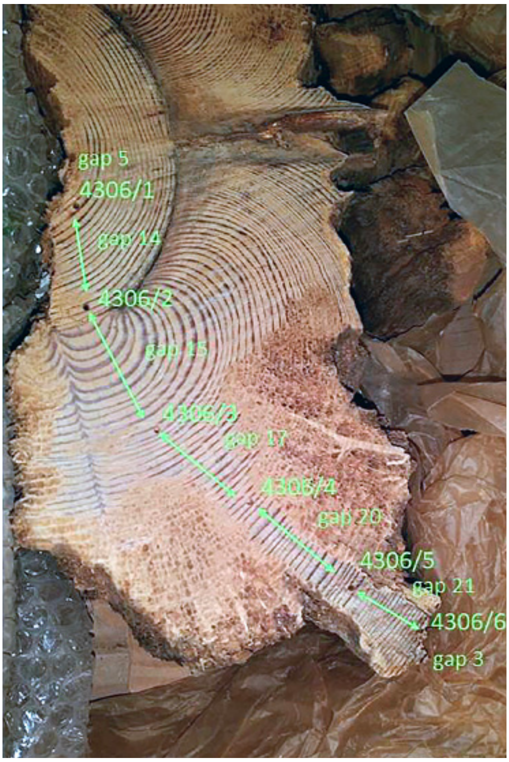


Figure 4. Altogether six wood samples were extracted from the timber post and radiocarbon dated. (Photo by Markku Oinonen.)

considerably: ID 1 is much older than ID 2, and ID 4 is older than ID 3. These conclusions are supported by the pXRF analysis results.

The OSL datings of the ceramics in this study are best summarised using by a combined model that groups the five bricks and a floor tile, resulting in a probable date range of 1329–1404 AD. This suggests that construction of the masonry remains of Turku's Dominican Convent began during the last three quarters of the 14th century. In contrast, the two youngest samples from the rib brick (ID 2) and roof tile (ID 8) may relate to post-medieval building activities in the area.

Wiggle-match dating of the wooden post from the foundations of a brick wall

Altogether six wood samples were extracted from the timber post and radiocarbon dated (Fig. 4, Table 3). The wiggle-match was initiated with these six dates and an agreement index (A-index) values provided by OxCal (Bronk Ramsey 2017), after which the most unlikely dates were removed until three radiocarbon dates were left. The A-index value describes the differences between individual dates and the results given by the model. The higher the A-index value, the larger is the overlap and thus the better the model, since it does not change the original dating result too much.

The model based on six radiocarbon dates gives an A-index value smaller than the required threshold value (A=18.5% vs. An=28.9%), which is unsatisfactory. The reason is the deviation of dates 2 and 3 from the model. Although A-index-based limitations do not affect results considerably, we adopted a model with 5 dates that provided a high-enough A-index value (A=38.5% vs. An=31.6%) by excluding date 2 (Hela-4306/2). Eventually, based on the data at hand, the model with 5 dates provides a result of 1310±10calAD, which is the date of the youngest annual ring on the sample.

The WMD was based on a dendrochronological measuring line (A) with c. 95±10 annual rings of reddish heartwood, but another measuring line (B) provides c. 135 annual rings plus two destroyed rings (Pentti Zetterberg, pers. comm. 2019). Consequently, there has been at least 42+2 annual rings in the sapwood, and thus the actual youngest annual ring dates to c. 1350AD, which is the *terminus post quem* for the wood. This suggests that the timber was laid in the foundations in the latter part of the 14th century, which overlaps with the OSL datings of the sampled bricks.

DISCUSSION ON THE CONVENT'S CONSTRUCTION CHRONOLOGY

Because the archaeological documentation and finds from the Convent are scanty and problematic, using the material to create a chronology for the discovered structures is a rather complex and demanding exercise. The interpretation of these new scientific dates is therefore a balancing act between different probabilities. The significance of the dating results will now be summarized in relation to the four hypotheses presented earlier, followed by the presentation of an approximate dating of the Convent's masonry structures, which will be compared with

Table 3. The six AMS dates of the timber sample (TMC16920:150) from the Dominican Convent in Turku.

Lab. Code	Sample	Radiocarbon date (BP)
Hela-4306/1	Annual ring 5	761±28
Hela-4306/2	Annual ring 19	721±36
Hela-4306/3	Annual ring 34	877±42
Hela-4306/4	Annual ring 51	754±45
Hela-4306/5	Annual ring 71	704±48
Hela-4306/6	Annual ring 92	702±46

the current chronology of urban architecture in Turku, based on existing evidence.

Hypothesis 1 conjectured that the Convent was initially built of wood, with brick only used in later phases of construction. At this stage, this hypothesis cannot be rejected or accepted. As a result, it is not possible to evaluate hypotheses regarding the existence and dating of the first building phase. Instead, one must focus exclusively on the dating of the brick structures surviving from the site.

OSL analysis of eight ceramic masonry elements from the 1960s excavations produces a wide range of dates. However, the modelling of these suggests that the majority belongs to the probability range of 1329–1404 AD. The chronology suggested by OSL dating is supported by the WMD of the timber sample to the *terminus post quem* of c. 1350 AD. It seems that the Convent's brick walls were constructed in the latter part of the 14th century or around 1400 AD. Since the sampled bricks and the timber are from different parts of the Convent, we can assume that the new chronology is relevant for the whole complex. This conclusion is supported by the pXRF analyses which reveal that, except for one roof tile, the sampled ceramics originated from the same local or Swedish source. The brick material is quite homogenous.

In the Turku region, the earliest masonry architecture is from Koroinen, where the first structures of brick and stone were erected in the second half of the 13th century or early 14th century (Ratilainen 2016; Ratilainen et al. 2017; 2021). As Ratilainen (2018: 90–121; 2020) points out, these are among the first masonry structures in mainland Finland. The oldest known evidence of masonry architecture in Turku date to the 14th century. Bricks used in the door jambs of the sacristy of Turku Cathedral date to the first half of the 14th century. Construction of the cathedral in stone began probably in the latter part of the 14th century, and the cathedral was completed in brick by 1425 (Drake 2003a: 137–8; 2003b: 86–8; 2005: 483–4; 2006: 242–3).

In urban secular buildings, hearths and ovens were made of brick in the earlier part of the 14th century (Ratilainen 2014), and a possible gate house was built of brick near the cathedral after the mid-14th century (Ratilainen 2010: 41–3). The Town Hall of Turku was built in the early 14th century, but brick was not used until its second building phase, which is dated to 1350–1430 (Uotila 1991: 132–8; 2002: 8–10; 2003: 125). The oldest town houses with proper brick features, like vaults and niches, date to the last decade of the 14th century (Saloranta & Seppänen 2002; Uotila 2003: 128; 2006: 352–3; 2007: 25; Ratilainen 2010: 43–4). In sum, the use of brick in Turku began in the earlier part of the 14th century, but architectural features of brick became common in public buildings only after the mid-14th century, and in private buildings only at the very end of the 14th century.

CONCLUSIONS

In all, of the four hypotheses outlined above, the hypothesis that the Dominican Convent's brick masonry predates the town of Turku and the hypothesis that it dates to after the 1429 fire both appear to be false, whereas the hypothesis that the Convent complex was built between 1300 and 1429 seems correct. In fact, scientific dating suggests that the structures were erected in the latter part of the 14th century or around 1400 AD. This chronology corresponds well with the development of brick architecture in Turku since it is known that masonry structures were constructed intensively in the town during the same period.

Since the available archaeological finds from the Convent have been searched thoroughly for datable material, and the documentation of previous fieldworks remains scant, the material that survives will probably not provide any surprises in future. Dating more bricks scientifically might help narrow and stabilise the results acquired so far but making further analyses from this problematic material is not economical in terms of its input-output ratio. Therefore, the most effective line of inquiry is to gather new archaeological material from the site. The excavations in the 1960s along the Kaskenkatu Street were halted when the first structures were revealed after which they were covered over and left under the street surface. In addition, some parts of the Convent might still be intact in the easternmost corner of the complex up on the hill, or in the strip of land between the known structures and the River Aura. These three areas are the most likely to reveal material relevant for dating the convent's buildings. In the meantime, however, the present study provides best chronological framework available.

REFERENCES

Personal communications

Pihlman, A., archaeologist, personal communication to Tanja Ratilainen, 4 September 2012.

Zetterberg, P., dendrochronologist, e-mail to Visa Immonen, 18 March 2019.

Unpublished sources

Daly, A. 2017. Dendrochronological analysis of a timber from the Dominican convent in Turku, Finland. Dendro.dk Report 69: 2017.

Kolehmainen, H.-L. 2008. Turun Pyhän Olavin dominikaanikonventti: Asiakirja-aineisto ja arkeologiset lähteet. Unpublished MA dissertation, Department of Archaeology, University of Turku.

Oinonen, M. & Eskola, K. O. 2016. Pyhän Olavin Konventti 2016: Ajoitustuloksia/Luminesenssi. Dating report, Finnish Museum of Natural History, Helsinki.

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

Saloranta, E. & Seppänen, L. 2002. Kaupunkiarkeologiset kaivaukset, Turku, Rettiginrinne, Hämeenkatu 24–26. Excavation report, Turku Museum Centre, Turku.

Stenlund, P. 2010. Dominikankonventets byggnader i Åbo under medeltiden. Unpublished MA dissertation, Church History, Åbo Akademi University.

TMC. The Inventory of Archaeological Finds. Turku Museum Center.

Uotila, K. 1991. Turun raatihuoneen rakennushistoria keskiajalta vuoteen 1734. Unpublished Licentiate thesis, Finnish history, University of Turku.

Zetterberg, P. 2015. Turun dominikaanikonventin puulöydön TMM 16920 dendrokronologinen tutkimus, näytteet F1T2201A ja F1T2201B. Itä-Suomen yliopisto Joensuu, Luonnontieteiden ja Metsätieteiden tiedekunta, Metsätieteiden osasto, Dendrokronologian laboratorion ajoitusseloste 413: 1–3.

Literature

Ahl, E. 2007. Kloster och konvent i Finland under medeltiden: Dominikanerna. *Arkeologia NYT!* 1/2007: 5–10.

Aitken, M. J. 1985. *Thermoluminescence dating.* London: Academic Press.

Atlıhan, M. A., Koralay, T. & Sahiner, E. 2018. Luminescence dating and mineralogical investigations of bricks from Erikli basilica in Stratonikeia ancient city (SW Turkey). *Mediterranean Archaeology and Archaeometry* 18(1): 77–91. 10.5281/zenodo.1069527.

Andersson, K. & Hildebrand, K. 2002. *Byggnadsarkeologisk undersökning: Det murade huset.* 2nd edition. Stockholm: Riksantikvarieämbetet.

Ankjærgaard, C. & Murray, A. S. 2007. Total beta and gamma dose rates in trapped charge dating based on beta counting. *Radiation Measurement*s 42: 352–9.

Antell, O. 1986. *Taktegel – Tegeltak.* Stockholm: Byggforskningsrådet & Riksantikvarieämbetet.

Appelgren, H. 1902. Det underjordiska Åbo. *Finskt Museum* 1901: 49–65.

Autere, E. 1976. Tutkimus Suomessa käytettävistä kvartsihiekoista. Helsinki: Geologian tutkimuskeskus. <https://tupa.gtk.fi/raportti/arkisto/p13_5_2_014.pdf> Accessed 29 July 2020.

Bailiff, I. K. 2007. Methodological developments in the luminescence dating of brick from English Late-Medieval and Post-Medieval buildings. *Archaeometry* 49: 827–51.

Bezur, A., Lee, L., Loubser, M. & Trentelman, K. 2020. *Handheld XRF in Cultural Heritage:*

A Practical Workbook for Conservators. Los Angeles: The Getty Conservation Institute.

Bonniwell, W. R. 1945. *A History of the Dominican Liturgy 1215–1945.* 2nd edition. Joseph F. Wagner: New York.

von Bonsdorff, C. 1894. *Åbo stads historia under sjuttonde seklet:* Första bandet. Åbo: Åbo stad.

Borgström, L. H. 1924. Suomen kvartsihiekka. Helsinki: Suomen geologinen komissioni. <https://tupa.gtk.fi/julkaisu/geoteknillinen/gt_s_023.pdf> Accessed 29 July 2020.

Bronk Ramsey, C. 2017. Methods for summarizing radiocarbon datasets. *Radiocarbon* 59(2): 1809–1833.

Bronk Ramsey C. 2021. Oxcal v4.4.4. <https://c14.arch.ox.ac.uk/oxcal/OxCal.html> Accessed 3 April 2022.

Brusila, H. 2001. Pyhän Olavin dominikaaniluostarin raunioista. In H. Soiri-Snellman & H. Brusila (eds.) *Kaskenlinna: Asunto Oy Kaskenlinnan rakennushistoria ja Pyhän Olavin luostarin rauniot*: 79–111. Turku: Turun maakuntamuseo.

Cuomo di Caprio, N. 2017. C*eramics in Archaeology: From Prehistoric to Medieval Times in Europe and the Mediterranean: Ancient Craftsmanship and Modern Laboratory Techniques*. Rome: L'Erma di Bretschneider.

DF. Diplomatarium Fennicum. <http://df.narc.fi/> Accessed 17 March 2020.

Drake, K. 2003a. Åbo domkyrka och byggnadsarkeologin. In L. Seppänen (ed.) *Kaupunkia pintaa syvemmältä: Arkeologisia näkökulmia Turun historiaan*: 135–52. Turku: TS-Yhtymä & Suomen keskiajan arkeologian seura.

Drake, K. 2003b. Åbo domkyrkas äldre byggnadshistoria. *Taidehistoriallisia tutkimuksia – Konsthistoriska studier* 27: 83–2.

Drake, K. 2005. Der Dom zu Turku/Åbo. *Kunsthistorische Arbeiter der Kulturstiftung der deutschen Vertriebenen*: Band 4: 480–90.

Drake, K. 2006. Åbo domkyrkas första murade sakristia. *Hikuin* 33: 239–48.

Duller, G. 2007. Assessing the error on equivalent dose estimates derived from single aliquot regenerative dose measurements. *Ancient TL* 25: 15–24.

Gardberg, C. J. 1957. *Med murslev och timmerbila: Drag ur det finländska byggnadshantverkets historia.* Helsingfors: Svenska byggmästareföreningens i Helsingfors.

Gardberg, C. J. 2005. *Veritas – Sanningen! Dominikanerna i Åbo under medeltiden.* Esbo: Schildt.

Gueli, A., Garro, V., Pasquale, S. & Stella, G. 2018. Chronology of the crypt of Sant'Agata la Vetere in Catania obtained by thermoluminescence. *Mediterranean Archaeology and Archaeometry* 18(1): 27–35.

Harjula, J., Hukantaival, S., Immonen, V., Salonen, K. & Ratilainen, T. (eds.) 2018. *Koroinen: Suomen ensimmäinen kirkollinen keskus*. Turku: Turun Historiallinen Yhdistys.

Harjula, J., Immonen, V. & Savolainen, P. 2016. Voimatekijästä unohdetuksi raunioksi – Turun dominikaanikonventti. In M. Heinonen & M. Räsänen (eds.) *Pohjoinen reformaatio*: 281–98. Turku: TUCEMEMS.

Hiekkanen, M. 1993. De finska klostren under medeltiden: Arkeologiskt och byggnadshistoriskt perspektiv. *Hikuin* 20: 123–54.

Hiekkanen, M. 1994. *The Stone Churches of the Medieval Diocese of Turku: A Systematic Classification and Chronology.* Helsinki: Suomen Muinaismuistoyhdistys.

Hiekkanen, M. 2001. Domestic building remains in Turku, Finland. In M. Gläser (ed.) *Lübecker Kolloquium zur Stadtarchäologie im Hanseraum III: Der Hausbau*: 627–33. Lübeck: Schmidt-Römhild.

Hiekkanen, M. 2002. Die Gründung der Stadt Turku. In Ē. Mugurēvičs & I. Ose (eds.) *Civitas et castrum ad Mare Balticum: Baltijas arheoloģijas un vēstures problēmas dzelzs laikmetā un viduslaikos*: 156–77. Riga: Latvijas vēstures institūta apgāds.

Hiekkanen, M. 2003a. Turun kaupungin perustaminen – Tulkintayritys uusien arkeologisten tutkimusten perusteella. In L. Seppänen (ed.) *Kaupunkia pintaa syvemmältä: Arkeologisia näkökulmia Turun historiaan*: 42–52. Turku: TS-Yhtymä & Suomen keskiajan arkeologian seura.

Hiekkanen, M. 2003b. Turun Pyhän Olavin konventti ja sen rakennusmuistot. T*urun maakuntamuseo: Raportteja* 18: 89–104.

Hiekkanen, M. 2018. *Suomen keskiajan kivikirkot.* 4th edition. Suomalaisen Kirjallisuuden Seuran toimituksia 1117.

Hoła, A., Matkowski, Z. & Hoła, J. 2017. Analysis of the moisture content of masonry walls in historical buildings using the basement of a medieval town hall as an example. *Procedia Engineering* 172: 363–8.

Holmqvist, E. 2017. Handheld portable energy-dispersive X-ray fluorescence spectrometry (pXRF). In A. M. W. Hunt (ed.) *The Oxford Handbook of Archaeological Ceramic Analysis*: 363–81. Oxford: Oxford University Press.

Immonen, V. 2015. Buried in the archives: Medieval graves at the Dominican convent of St Olaf in Turku, Finland. *Mirator* 16 (1): 29–51. <http://www.glossa.fi/mirator/pdf/i-2015/buriedinthearchives.pdf> Accessed 17 March 2020.

Immonen, V. 2019. Monasticism in a border landscape: Religious orders in medieval Finland. In E. Bhreathnach, M. Krasnodębska-D'Aughton & K. Smith (eds.) *Monastic Europe: Medieval Communities, Landscapes, and Settlements*: 303–28. Turnhout: Brepols.

Immonen, V., Harjula, J., Kirjavainen, H. & Ratilainen, T. 2014a. The Dominican convent of St Olaf in Turku, Finland. In M. Gläser & M. Schneider (eds.) *Lübecker Kolloquium zur Stadtarchäologie im Hanseraum IX: Die Klöste*r: 545–58. Schmidt-Römhild: Lübeck.

Immonen, V., Harjula, J., Kirjavainen, H. & Ratilainen, T. 2014b. Turun Pyhän Olavin dominikaanikonventti: Aineksia tilankäytön tulkintaan. *SKAS* 3/2013: 3–23.

Kuujo, E. 1981. *Turun kaupungin historia 1366–1521.* Turku: Turun kaupunki.

Laaksonen, H. & Lahtinen, R. 2011. Bostadsaktiebolaget Asunto-osakeyhtiö Pantern 100 vuotta. In P. Toivanen & N. Ekholm (eds.) *Pantern: Talo luostarin raunioilla*: 15–134. Turku: Turun museokeskus.

Lehmijoki-Gardner, M. 2004. Mendikanttisääntökunnat, etuoikeutena köyhyys. In T. Heikkilä & M. Lehmijoki-Gardner (eds.) *Keskiajan kirkko: Uskonelämän muotoja läntisessä kristikunnassa*: 198–288. Helsinki: Suomalaisen Kirjallisuuden Seura.

Leinberg, K. G. 1890. *De finska klostrens historia.* Helsingfors: Svenska litteratursällskapet i Finland.

Liritzis, I., Stamoulis, K., Papachristodoulou, C. & Ioannides, K. 2013. A reevaluation of radiation dose rate conversion factors. *Mediterranean Archaeology & Archaeometry* 13(3): 1–15.

Lovén, C. 2001. Kloster, klosterliknande inrättningar och klostertraditioner. *Fornvännen* 96: 243–66.

Malin, A. 1925. *Der Heiligenkalender Finnlands: Seine Zusammensetzung und Entwicklung.* Helsinki: Suomen kirkkohistoriallinen seura.

Maliniemi, A. 1947. Grundandet av dominikankonventet i Åbo och dess förhållande till Sigtuna: Några kritiska randanmärkningar. In H. Arbman, W. Holmqvist & R. Hillman (eds.) *Sigtuna Mariakyrka 1247–1497*: 83–95. Sigtuna: Sigtuna Fornhems förlag.

Montana, G. 2017. Ceramic raw materials. In A. M. W. Hunt (ed.) *The Oxford Handbook of Archaeological Ceramic Analysis*: 87–100. Oxford: Oxford University Press.

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

Nikula, O. 1987. *Åbo stads historia 1521–1600*. Åbo: Åbo stad.

Oinonen, M., Hilasvuori, E., Mehtonen, H., Uotila, K., & Zetterberg, P. 2013. On the eve of urbanization: Bayesian model dating for medieval Turku. *Radiocarbon* 55(2–3): 1265–77. <https://doi.org/10.2458/azu_js_rc.55.16244> Accessed 17 March 2020.

Pihlman, A. 1986. Materialsamling. In A. Pihlman & J. Kostet (eds.) *Åbo (fi. Turku): Medeltidsstaden* 3: 63–190. Åbo: Åbo landskapsmuseum.

Pihlman, A. 2007. Varhainen Turku -tutkimushanke: Uusia arkeologisia tulkintoja Turun kaupungin muodostumisesta. In K. Majantie & K. Motuste (eds.) *HIT – History in Turku: Tietoja, taitoja ja löytöjä: Näyttely Turun linnassa 15.6.–23.9.2007*: 10–15. Turku: Turun maakuntamuseo.

Pihlman, A. 2010. Turun kaupungin muodostuminen ja kaupunkiasutuksen laajeneminen 1300-luvulla. *Turun museokeskus: Raportteja* 22: 9–29.

Pihlman, A., Saloranta, E., Krappala, K. & Ratilainen, T. 2022. Turun kaupunkia vanhempi asutus ja kaupungin synty: Tulkinta varhaisen keramiikka-aineiston ja luonnontieteellisten ajoitustulosten perusteella. *SKAS* 2/2021 (2022): 2–37.

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

Ratilainen, T. 2014. Unfired bricks used for a medieval oven in Turku, Finland. *British Archaeological Reports: International Series* 2611: 93–101.

Ratilainen, T. 2016. At the dawn of masonry architecture: Church remains and associated

brick structures at Koroinen, Turku. *Estonian Journal of Archaeology* 20(1): 54–80.
Ratilainen, T. 2018. Rakennukset ja rakenteet. In J. Harjula, S. Hukantaival, V. Immonen, T. Ratilainen & K. Salonen (eds.) *Koroinen: Suomen ensimmäinen kirkollinen keskus*: 85–16. Turku: Turun Historiallinen yhdistys.
Ratilainen, T. 2020. *Early Brick Use and Brick Building in Mainland Finland: Contribution of Koroinen, Early Phases of Turku project and Holy Cross Church of Hattula*. Turku: University of Turku. <https://www.utupub.fi/handle/10024/149739> Accessed 26 April 2021.
Ratilainen, T., Immonen, V., Salonen, K. & Harjula, J. 2017. The bishop's brick house: Remains of medieval buildings on the river bank of Koroinen. *Lund Archaeological Review* 23: 1–25.
Ratilainen T. & Kinnunen J. 2019. Identifying the origin of bricks and roof tiles with pXRF: A case study from medieval Turku, Finland. *Turun museokeskus: Raportteja* 23: 135–60.
Ratilainen, T., Oinonen, M., Lindroos, A., Harjula, J., Immonen, V. & Salonen, K. 2021. The Contribution of bricks and mortar in the chronology of the fortified site of Koroinen, Finland. *Castella Maris Baltici* XIV: 33–54.
Rinne, J. 1908. P. Olavin luostari ja rauniot Kaskenkadun ja Ison Hämeenkadun yhtymän tienoilla Turussa: Rakennushistoriallinen tutkimus. *Lännetär: Varsinaissuomalainen osakunta: Uusi jakso 1*: 106–68.
Rinne, J. 1928. Pyhän Olavin luostari Turussa. *Suomen Museo* 1928: 89–92.
Rinne, J. 1952. *Turun tuomiokirkko keskiaikana III: Turun tuomiokirkko hiippakunnan hallinnon elimenä.* Turku: Turun tuomiokirkon isännistö.
Ruuth, J.W. 1909. *Åbo stads historia under medeltiden och 1500-talet: Första häftet*. Bidrag till Åbo stads historia, Andra serien 9.
Salminen, T. 2003. Dominikaanit Tallinnassa, Viipurissa ja Turussa. *Turun maakuntamuseo: Raportteja* 18: 37–46.
Salminen, R., Kukkonen, M., Paukola, T. & Töllikkö, S. 1997. Chemical composition of clays in Southwestern Finland. *Geological Survey of Finland: Current Research* 23: 117–26.
Seppänen, L. 2009. Town in transition – Outlining the construction activities in medieval Turku. In H.-M. Pellinen (ed.) *Maasta, kivestä ja hengestä – Earth, Stone and Spirit: Markus Hiekkanen Festschrift:* 240–9. Turku & Helsinki: Arkeologia, Turun yliopisto; Taidehistoria, Helsingin yliopisto, Suomen kirkkohistoriallinen seura & Suomen keskiajan arkeologian seura.
Seppänen, L. 2011. Stadskulturens djuprotade rötter ligger vid Aura ås stränder. *Finsk Tidskrift* 10/2011: 475–87.
Seppänen, L. 2012. *Rakentaminen ja kaupunkikuvan muutokset keskiajan Turussa: Erityistarkastelussa Åbo Akademin päärakennuksen tontin arkeologinen aineisto*. Turku: Turun yliopisto. <https://www.utupub.fi/handle/10024/86116> Accessed 17 March 2020.
Siivola, J. & Schmid, R. 2007. Recommendations by the IUGS subcommission on the systematics of metamorphic rocks: Web version 01.02.07. Beijing: IUGS Commission on the Systematics in Petrology. <https://www.environmentalgeochemistry.org/scmr/products.html> Accessed 17 March 2020.
Talvio, T. 2011. A coin hoard from the Turku Dominican Convent (1901). In J. Harjula, M. Helamaa & J. Haarala (eds.) *Times, Things & Places: 36 Essays for Jussi-Pekka Taavitsainen*: 152–65. Turku: J.-P. Taavitsainen Festschrift Committee.
Uotila, K. 2002. Åbo medeltida rådhus: En stenbyggnad vid ett medeltida torg. *META* 4/2002: 3–18.
Uotila, K. 2003. Kivitaloja keskiajan Turussa. In L. Seppänen (ed.) *Kaupunkia pintaa syvemmältä: Arkeologisia näkökulmia Turun historiaan*: 121–34. Turku: TS-Yhtymä & Suomen keskiajan arkeologian seura.
Uotila, K. 2006. Muuratut talot keskiajan Turussa. In V. Immonen & M. Haimila (eds) *Mustaa valkoisella: Ystäväkirja arkeologian lehtori Kristiina Korkeakoski-Väisäselle*: 351–53. Turku: Turun yliopiston arkeologian oppiaine.
Uotila, K. 2007. Aboa Vetus -museon kivirakennusten tutkimukset v. 2002–2006. *SKAS* 2/2007: 18–27.
Uusitalo, J., Arppe, L., Hackman, T., Helama, S., Kovaltsov, G., Mielikäinen K., Mäkinen, H., Nöjd, P., Palonen, V., Usoskin, I. & Oinonen, M. 2018. Solar superstorm of AD 774 recorded subannually by Arctic tree rings. *Nature Communications* 9 (3495). <https://doi.org/10.1038/s41467-018-05883-1> Accessed 17 March 2020.
Zimmermann, D. W. 1971. Thermoluminescent dating using fine grains from pottery. *Archaeometry* 13: 29–52.

APPENDIX

Appendix 1. The pXRF analyses of the sampled bricks.

The sampled bricks were also examined with a portable XRF analyser. Analyses were conducted with a Thermo Scientific Niton XL3t-950 GOLDD+ (SN#:100535) pXRF at the Turku Museum Centre. The tube type of the analyser was 50kV Au anode with maximum 200µA electric current. The preset mode for the analyses was TestAll Geo, calibrated by the Finnish Niton importer, Holger Hartman Oy, on 8 November 2018 (Bezur et al. 2020: 160). The applied traceable calibration standards were defined by the National Institute of Standards & Technology (NIST) and Bureau of Analysed Samples Ltd (BAS). The number of the calibration certificate, stored in the pXRF instrument box, is 140-00072. It was issued in accordance with the specifications of the Thermo Fisher Scientific factory, and the measurements were found to be within specification limits at the time of the calibration. The total radiation time of one measurement was 120s, and the diameter of the beam window in the instrument was 3mm. The pXRF analyses were made on freshly cut and cleaned surfaces. The results of the analyses are presented in Appendix Table 1 (main elements) and Appendix Table 2 (trace elements).

Even though the factory calibration of TestAll Geo measurement mode passes to semiquantitative class, and the relative standard deviation (RSD) of results is nearly definitive (<±10%), the results of analyses presented here are intended to be used only for chemical comparison and classification of bricks, while the overall results are presented here 'as is'.

Overall, when studying analyses of ceramics (e.g., bricks and tiles), and fired and natural clay, some preliminary remarks should be presented:

1. Ceramics are fired which reduces the percentage of volatile elements in comparison with natural clay.

2. In ceramics, clay is tempered and mixed with fillers, and thus the composition of ceramic clay does not represent that of natural clay.

3. Different clays from different locations can be used within the same ceramic production batch, and thus the composition of its clay does not necessarily represent any natural clay. Geologically all clays in South-West Finland were stratified during the different sea-lake-phases of the Baltic Sea after the Ice Age. Dry land became exposed from the waters of the Baltic during thousands of years of seashore displacement. For these reasons, the composition of different clay types varies depending on its different sedimentation environments (deep–shallow, pelagic–littoral), different flora and fauna, and the changing salinity of the water.

4. When archaeological objects are exposed to natural substances in soil, it is possible for water-soluble elements to migrate from and into the porous ceramic and change its overall composition.

In general, clay and fired clay artefacts are one of the most suitable natural earthen materials for XRF analyses because of the substance's fine grain size and homogeneity. Yet the composition of even well-mixed clay has heterogeneities on a nano-micrometer scale, since the elements are chemically bonded to differently-sized and oriented mineral grains (Cuomo di Caprio 2017: 47–57; Montana 2017: 87–8, 90–5). Consequently, the XRF analysis of ceramics should be considered as a qualitative or semi-quantitative method (Cuomo di Caprio 2017: 588; Holmqvist 2017: 363). In the case of bricks, moreover, such tempering materials as sand, chamotte, chalk, graphite and slaked lime alter the final total composition of brick clay (Cuomo di Caprio 2017: 61–76; Holmqvist 2017: 365–7).

Regarding the results, it must be first pointed out that carbon (C), present as dark inclusions within several of the ceramics studied (see above), is not detectable by pXRF. Sodium (Na, Z=11) was also not possible to detect using the Niton pXRF. The percentages of light bulk elements magnesium (Mg, Z=12) and silicon (Si, Z=14) are usually over-represented in analyses and repeatability is poor. Consequently, their use in classification plots is unreliable. Aluminium (Al) and titanium (Ti) are usually the most stable elements in bedrock and soil samples, but the pXRF analysis of aluminium is also somewhat problematic and unreliable. Hence, the most useful major elements for interpreting pXRF analyses of rock or soil samples as well as clay products, like bricks and pottery, are iron (Fe), calcium (Ca) and potassium (K) (Holmqvist 2017: 368).

The sampled ceramics had been fired to a red colour, and thus it was expected that their iron content would be relatively high. The percentage of iron varied from c. 3.8% to 7.2%, and these readings are common both in local bricks and natural clay. In contrast, transported bricks were usually fired yellow, containing c. 2–4% iron (Salminen et al. 1997: 120; Ratilainen & Kinnunen 2019: 140).

The percentage of calcium in the sampled bricks varied from 0.16% to 1.22%, which is also common for local bricks (Ratilainen & Kinnunen 2019: 140). Many of the sampled ceramic objects are partly coated with mortar or plaster, in which calcium is normally an abundant element (c. 10–25%). Analysis of the freshly-exposed interiors of these ceramics showed very low calcium contents, which clearly indicates that calcium does not transport and absorb easily from the surface of these ceramics, not even by a few centimetres. In the sampled ceramics, the percentage of potassium varied from c. 2.3% to 3.2%, and these readings correspond approximately with the average Finnish potassium contents of natural clay, c. 3% (Salminen et al. 1997: 120).

Interestingly, high Z (>15) trace elements found in the samples are chlorine (Cl), sulphur (S), vanadium (V), nickel (Ni), copper (Cu), zinc (Zn) and heavy metals, including lead (Pb), cadmium (Cd), arsenic (As) and tin (Sn). The quantity of chlorine and sulphur is prone to post-depositional alterations, but the analyses were made on the freshly-exposed interiors of the ceramic objects studied (Holmqvist 2017: 368). The element contents of the ceramics analysed are presented in binary xy plots (Appendix Figs. 1 and 2). The variables and the order of the plots are the same as in the study of Ratilainen and Kinnunen (2019). Cluster fields in Appendix Figs. 1 and 2 demonstrate the general interpretation based on all data in its entirety.

The material of the roof tile (ID 8) is depleted of most analysed elements. This effect could be explained by the excessive use of the quartz sand, practically pure SiO2, in filler, which is also distinguishable in microscope. Generally, pure rounded natural quartz sand (SiO2) in Finland is rare (Borgström 1924: 3; Autere 1976: 36–43).

Overall, variations in the element compositions of the sampled ceramics are minor, and this is evident for each detected element. Silicon, aluminium, and magnesium are difficult elements for a pXRF detection, which can explain their slight variations. Other minor variations in the compositions of these ceramics can be a result of their internal structure, different firing temperatures and post-depositional processes. The analysis results of the moulded bricks (ID 1–6) form an evident cluster, indicating that these objects shared a similar origin. Meanwhile, the clay material of the floor tile (ID 7) is different and the roof tile (ID 8) significantly different from the others.

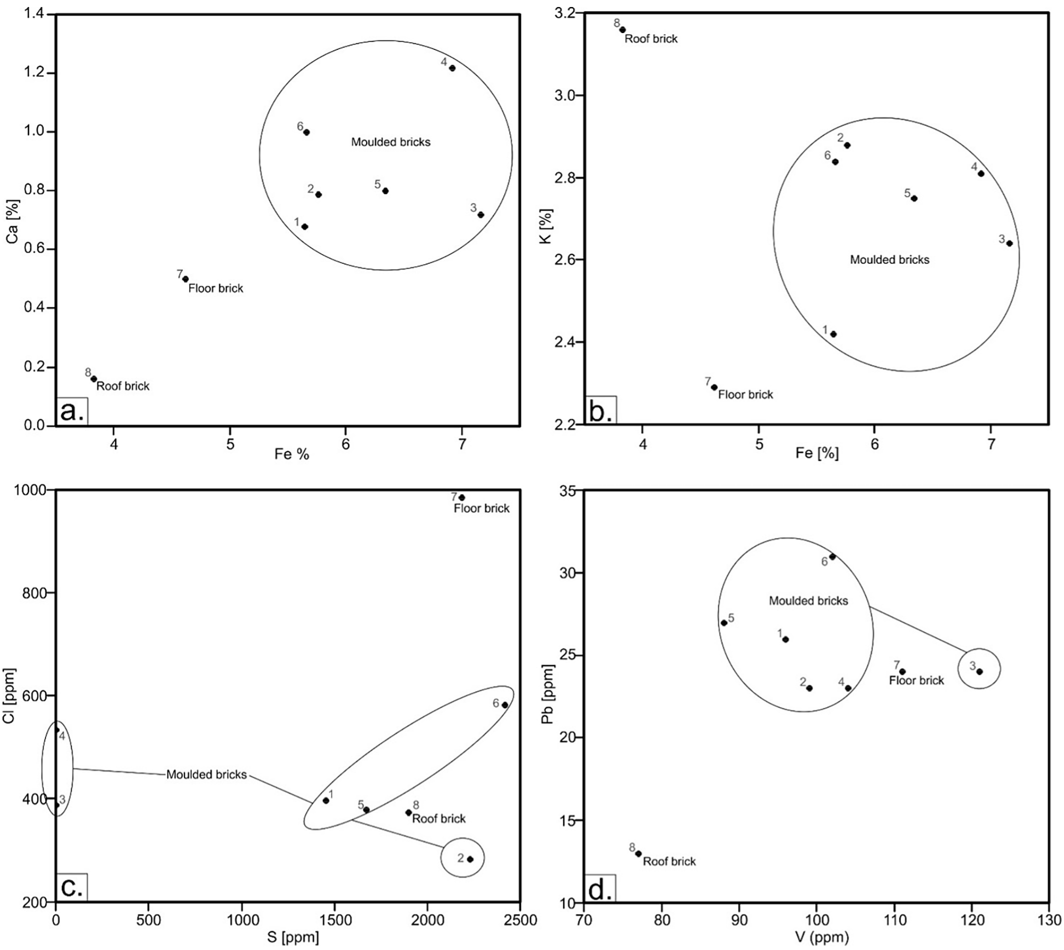
Based on the clustering of the pXRF element analyses and on the observation by microscopy of the sampled ceramics, these can be divided into three groups. Group 1 consists of the six round-moulded bricks (ID 1–6), while Groups 2 and 3 consist of one sample each: the floor tile (ID 7), and the roof tile (ID 8). The data suggests that the three groups were all made using the same clay recipe, and consequently may originate from the same source. Despite potential sources of error, also the results of the pXRF analyses, in addition to the identification of granitic temper, strongly suggest that the clay used in seven (ID 1–7) of the eight sampled items was acquired locally or in Sweden.

Appendix Table 1. The main element analyses of the sampled ceramic masonry elements from the Dominican Convent in Turku. All the values presented are in percentages. It should be kept in mind that the total sum of the element percentages in the same sample is not one hundred, since the pXRF instrument cannot detect all elements.

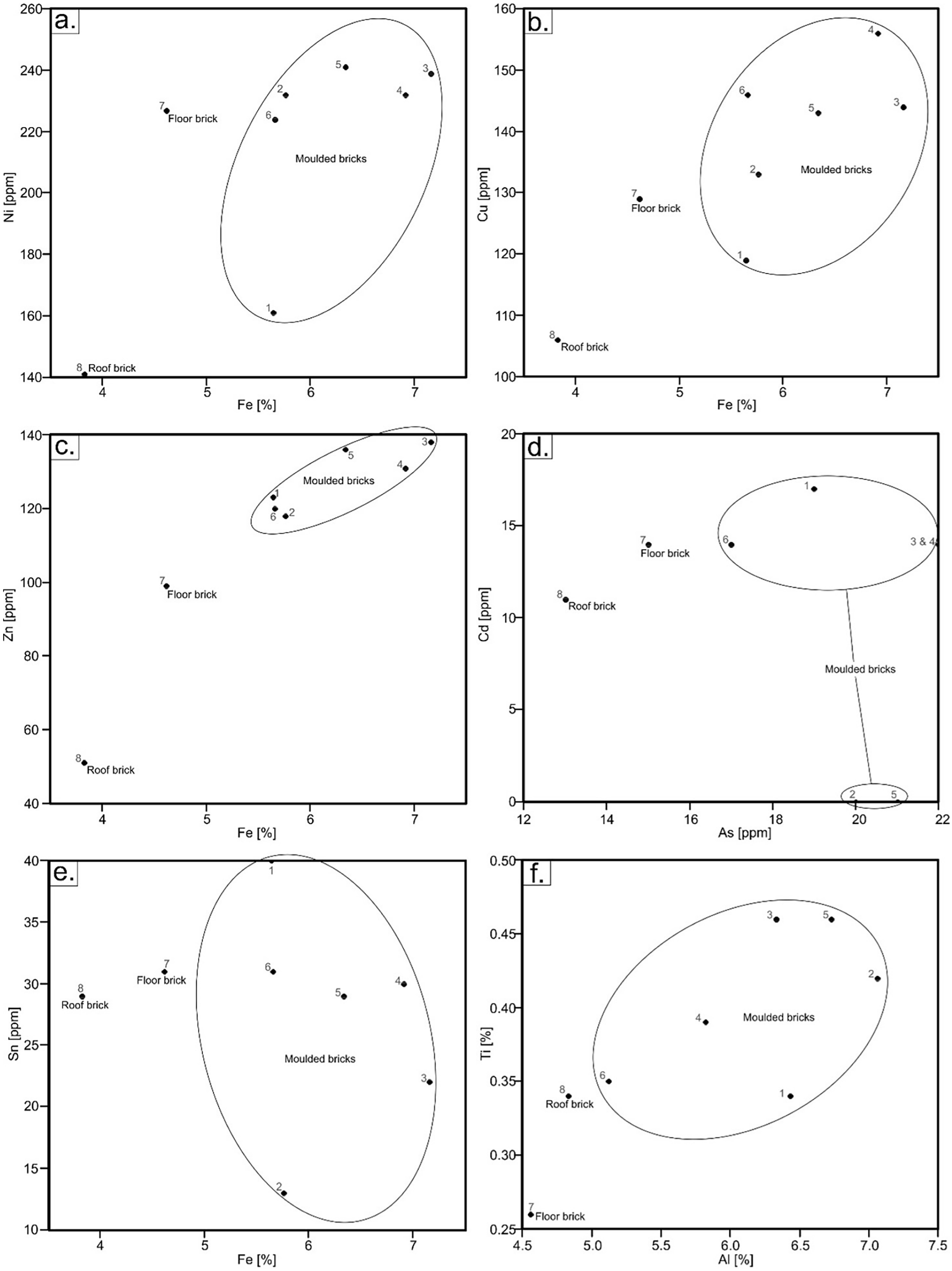
ID	Sample (TMC inv. no.)	Si %	Ti %	Al %	Fe %	Mn %	Mg %	Ca %	K %	P %
1	16768:29	25.89	0.34	6.43	5.64	0.08	1.58	0.68	2.42	0.14
2	16768:30	27.87	0.42	7.06	5.76	0.06	2.33	0.79	2.88	0.15
3	16920:62	24.92	0.46	6.33	7.16	0.07	1.90	0.72	2.64	0.15
4	16920:64	21.84	0.39	5.82	6.91	0.12	1.25	1.22	2.81	0.14
5	16920:78	25.25	0.46	6.73	6.34	0.07	2.13	0.80	2.75	0.13
6	16920:92	20.94	0.35	5.12	5.66	0.06	1.76	1.00	2.84	0.18
7	16920:131	21.46	0.26	4.56	4.61	0.04	1.01	0.50	2.29	0.19
8	16920:132	24.80	0.34	4.83	3.82	0.06	0.38	0.16	3.16	0.10

Appendix Table 2. Trace element analyses of the sampled bricks from the Dominican Convent in Turku. All the presented values are in ppm's (parts per million), and '<LOD' indicates that the result is under the pXRF instrument's limit of detection.

ID	1	2	3	4	5	6	7	8
Sample	16768:29	16768:30	16920:62	16920:64	16920:78	16920:92	16920:131	16920:132
V	96	99	121	104	88	102	111	77
Cr	197	213	242	262	301	206	194	178
Ni	161	232	239	232	241	224	227	141
Cu	119	133	144	156	143	146	129	106
Zn	123	118	138	131	136	120	99	51
As	19	20	22	22	21	17	15	13
S	1454	2228	<LOD	<LOD	1670	2416	2183	1897
Cl	397	283	388	534	379	582	986	374
Ba	776	657	673	700	708	692	709	540
Rb	99	100	103	101	101	104	89	75
Sr	163	134	130	138	130	134	141	48
Zr	184	160	172	142	167	148	123	247
Cs	168	117	145	144	143	142	150	142
Mo	6	4	<LOD	5	<LOD	5	5	6
Nb	18	19	19	20	21	16	15	18
Sn	40	13	22	30	29	31	31	29
Sb	47	21	34	42	30	27	30	42
Te	69	43	49	61	58	58	61	57
Pb	26	23	24	23	27	31	24	13
Bi	22	29	34	35	27	26	23	21
Th	11	12	17	18	13	14	10	11
Cd	17	<LOD	14	14	<LOD	14	14	11
Co	<LOD	<LOD	<LOD	<LOD	<LOD	108	<LOD	<LOD
Ag	10	7	<LOD	7	6	6	6	<LOD
W	169	199	207	228	209	214	223	203



Appendix Fig. 1. Results of pXRF analysis of eight ceramic masonry elements from the Dominican Convent in Turku: a) Iron (%) vs. calcium (%), b) iron (%) vs. potassium (%), c) sulphur (ppm) vs. chlorine (ppm) and d) vanadium vs. lead (ppm).



Appendix Fig. 2. Results of pXRF analysis of eight ceramic masonry elements from the Dominican Convent in Turku: a) Iron (%) vs. nickel (ppm), b) iron (%) vs. copper (ppm), c) iron (%) vs. zinc (ppm), d) arsenic (ppm) vs. cadmium (ppm), e) iron (%) vs. tin (ppm) and f) aluminium (%) vs. titanium (%).