Andres Tvauri

Late medieval hypocausts with heat storage in Estonia

Introduction

As often happens with archaeologists, the stimulus for writing this article was a discovery unexpectedly brought to light from under the ground. In autumn 2007, I had the opportunity to study a large medieval heat storage furnace (Figs. 1 and 2) constituting the central part of the hot air heating system, or hypocaust, of a former grooms' building. It was unexpectedly unearthed in the course of construction work in the outer bailey of the medieval Order Castle of Viljandi.[1]

The furnace found in the Viljandi Castle was a nice but, in the context of Estonian medieval finds, rather ordinary discovery. In Old Livonia, roughly corresponding to the territory of present-day Estonia and Latvia, hot air heating systems in which the core was a furnace filled with large stones, making it possible to store heat and rid oneself of the need to constantly heat the furnace or the fireplace, was used in the 13th to the 16th centuries before the introduction of Dutch tile stoves in castles, monasteries and in residential and public buildings in towns. Starting in the 1930s, such furnaces, or their archaeologically studied remains, have been found in numerous medieval buildings in Estonia.

The furnace found in Viljandi induced me to look for literature about hypocausts with heat storage. With the assistance of my colleague Erki Russow, the most thorough paper on medieval hot air heating systems ever written soon landed on my desk – a thesis published by the German researcher Klaus Bingenheimer in 1998, *Die Luftheizungen des Mittelalters*. To my surprise, I found that he had information regarding 154 hypocausts with heat storage from all over Europe, including two

[1] Andres Tvauri, *Aruanne arheoloogilistest uuringutest Viljandi ordulinnuse kolmandal eeslinnusel (Tasuja pst 6 hoone ümbruses) 2007. aastal* (Tartu, 2007, Report in the Archives of the National Heritage Board).

Fig. 1. Heat storage hypocaust of the grooms' house in the third outer ward of the Viljandi Order Castle. Photo by Andres Tvauri.

heat storage hypocausts in the territory of Estonia.[2] Although not having earlier been familiar with the subject of hypocausts, I immediately remembered remains of heating systems of that type in Estonian medieval buildings. In the course of more detailed research, I managed to get information from specialist literature and archives about nearly a hundred heat storage hypocausts in the territory of Estonia that still stand, or have been documented at their original location. The exact number depends on whether the remains of poorly preserved furnaces or the remains of furnaces dating from different periods but standing in the same location should be regarded as one furnace or two furnaces. Apart from those, there are accidental finds of numerous fragments of perforated hypocaust "hot plates" and their covers. There is a lot of information about heat storage hypocaust finds also in many publications on medieval archaeology in Latvia.

[2] Klaus Bingenheimer, "Die Luftheizungen des Mittelalters. Zur Typologie und Entwicklung eines technikgeschichtlichen Phänomens", *Antiquitates. Archäologische Forschungsergebnisse*, 17 (Hamburg, 1998).

There are several reasons why there are so many extant hypocaust furnaces in Estonia. A large number of private residences were preserved in their medieval form in Tallinn, as in the period from the 17th to the 19th centuries there were no economic resources for the building of new residences or their extensive reconstruction. In the Middle Ages, Estonia had numerous stone castles, of which a considerable number were destroyed and remained in ruins during the Russian-Livonian War in the second half of the 16th century, during the Polish-Swedish wars at the beginning of the 17th century and during the Northern War at the beginning of the 18th century at the latest. On the other hand, it is quite likely that more hot air heating systems were used in Old Livonia than in Germany, where winters are considerably shorter and milder. In the Baltic countries winters are so cold that it is not possible to live in a stone house without a good furnace with heat storage in winter.

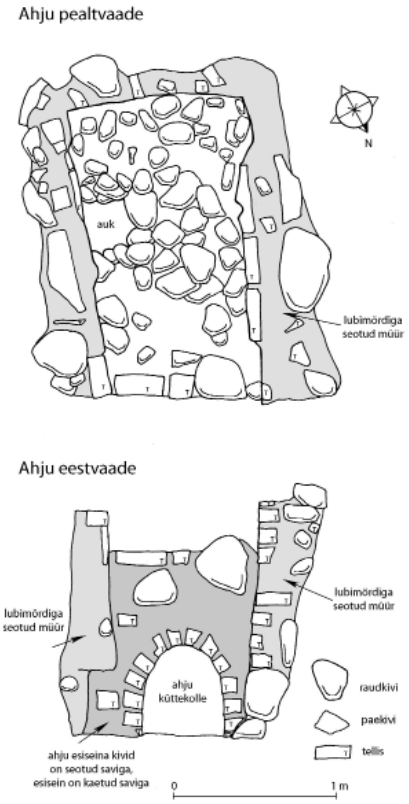

Fig. 2. Heat storage hypocaust of the grooms' house in the third outer ward of the Viljandi Order Castle. Sketch by Kristel Külljastinen and Andres Tvauri.

As the Estonian medieval heat storage hypocausts seem to be totally unknown to foreign researchers, I decided to write an article about medieval heat storage hypocausts in the territory of Estonia. Among other things, the aim is to draw archaeologists' and architecture historians' attention to this exciting, but rather locally and briefly used heating system.

About the study of heat storage hypocausts in Estonia

No special paper has been written about the hot air heating systems in Estonian medieval buildings. Probably the first to describe the medieval

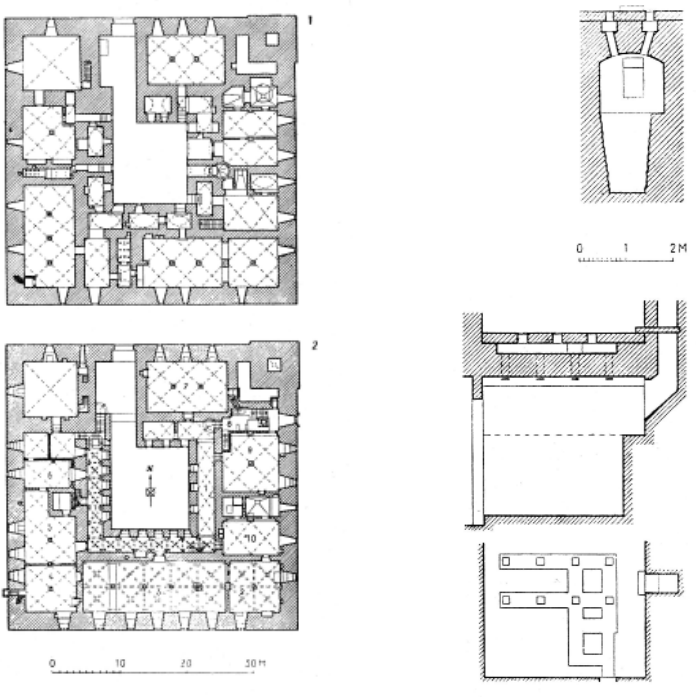

Fig. 3. Heat storage hypocaust furnaces in the Kuressaare Castle in Saaremaa (after Seuberlich, "Das Schloss zu Arensburg"). 1 – basement, 2 – ground floor, frame and air vents of the hypocaust furnace.

heat storage hypocaust and its work principle, and also to publish a drawing of the hypocaust (Fig. 3), was the architect Hermann Seuberlich in an extensive article on the Kuressaare Bishop's Castle in 1907.[3] Relying on Seuberlich's information and using the illustrations he published, the art historian Voldemar Vaga also described two heat storage hypocausts of the Kuressaare Castle in a small book published in 1957.[4]

The first and the most detailed overview of heat storage hypocausts in medieval buildings of Tallinn's Lower Town was published by Voldemar Vaga in a paper on the Tallinn medieval private residence in 1960.[5] The archaeologist Toivo Aus wrote a paper on the hypocaust furnaces of the

[3] Hermann Seuberlich, "Das Schloss zu Arensburg", *Jahrbuch für bildende Kunst in den Ostseeprovinzen* (Riga: Rigaer Tageblatt, 1907), 85–92.

[4] *Kuressaare linnus*, ed. by Voldemar Vaga (Tallinn: Eesti Riiklik Kirjastus, 1957).

[5] Voldemar Vaga, "Tallinna keskaegne elamu", *Eesti NSV ajaloo küsimusi I*, TRÜ Toimetised, 87 (Tartu: Tartu Riiklik Ülikool, 1960), 41–88.

Rakvere Order Castle, but it remained in manuscript form.[6] The most extensive treatment of heat storage hypocausts in Estonia is the original version of this paper, describing the above-mentioned Viljandi heat-storage hypocaust find. It was published in Estonian in the yearbook of the Viljandi Museum.[7] A lot of information can be found about different heat storage hypocausts, and their details, in literature on Estonian building history and archaeology. It is also common to find the remains of heat storage hypocausts mentioned in such literature or shown in drawings or photographs, but the type of furnace has not been identified.

The largest number of extant medieval heat storage hypocausts known in Estonia are in Tallinn – at least 53 of them. The first furnaces of that type were already documented in the 1920s in the course of the demolition of several medieval houses.[8] I have managed to get information from literature and public archives about heat storage hypocausts situated or documented in at least 26 medieval residences in the Lower Town of the Hanseatic city of Tallinn. Parts of several of them were skilfully displayed after the restoration of the houses. Of medieval merchant houses in public use today, for example, there is a well-preserved heat storage hypocaust, complete with its hot plate cover, in the house at Kuninga Street 6. The body of a hypocaust furnace can be viewed on the basement floor of Raekoja Plats 12 (Fig. 4). Hypocausts found and documented in Tallinn naturally make up only a fragment of those that were in use in the city in the medieval period. In medieval Tallinn, a heat storage hypocaust was not an exception but the rule. In Tallinn, hypocaust furnaces were used not only to heat big and stately merchants' houses (such as Lai Street 23 and 40, Raekoja Plats 18 and Viru Street 11), but even very modest and small craftsmen's houses, of which Aida Street 6, only 11 meters long and five meters wide, is a good example.[9]

From Toompea, an area of noblemen's houses, only two hypocaust furnaces are known in private residences (Kiriku Põik 4 and Kohtu Street 2).[10]

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[6] Toivo Aus, *Rakvere linnuse hüpokaustahjude uurimine* (Tallinn, 1981, Report in the archives of the National Heritage Board).

[7] Andres Tvauri, "Õhkküte keskaegses Viljandis ja mujal Eestis", *Viljandi Muuseumi Aastaraamat 2007* (Viljandi, 2008), 75–100.

[8] Vaga, "Tallinna keskaegne elamu", 69–71.

[9] Helmi Üprus, "Das Wohnhaus in Tallinn vor 1500", *Häuser und Höfe im Ostseegebiet und im Norden vor 1500, Acta Visbyensia, V* (Visby, 1976), 141–162, Fig. 17.

[10] Toivo Aus, Jaan Tamm, "Über den Anfang der Besiedlung im südostlichen teil des Tallinner Dombergs", *TATÜ*, 4 (1983), 339.

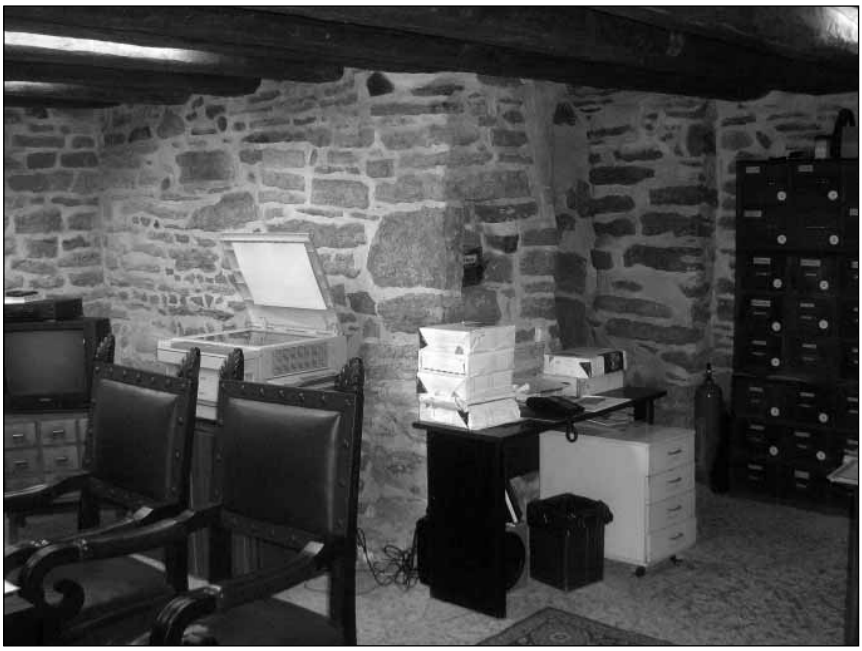

Fig. 4. Frame of a hypocaust furnace on the basement floor of the Tallinn Cultural Heritage Department (Raekoja Plats 12). Photo by Andres Tvauri.

The apparent reason is that Toompea's medieval buildings were destroyed in a great fire in 1684, and in the course of later rebuilding.

In addition to Tallinn's private residences, heat storage hypocausts have also been studied in the Town Hall[11], in the House of the Great Guild and in St Michael's Cistercian Convent[12]. Of these, the restored hot air vents can be conveniently observed in the Great Guild House. In addition to private residences, several towers of the town wall were heated with heat storage hypocausts as well – parts of the heating system can be seen at least in the Bremen and the Hellemann Towers.[13]

In addition, both of the monastic buildings within the city walls were heated with heat storage hypocaust furnaces. In St Michael's Cistercian Convent, the body of a furnace has been excavated in the north wing of

[11] Teddy Böckler, "Tallinna raekoja kütte- ja sanitaarseadmed 15. sajandi algul", *Ehitus ja Arhitektuur*, 2 (1978), 54–62.

[12] Jaan Tamm, Jaak Mäll, "Building Archaeology Investigations in the Cistercian St. Michael's Nunnery in Tallinn", *Arheoloogilised välitööd Eestis 1998. Archaeological field works in Estonia 1998* (1999), 73–87, Fig. 3.

[13] Villem Raam, "Toompea linnuse ja lossi ehitusloolisest minevikust", *Tallinn. Toompea linnus ja loss* (Tallinn: Kunst, 1978), 30–46.

the compound.[14] In the Dominican Friary, a hypocaust furnace is known in the basement under the east wing of the cloister.[15] There could have been a hypocaust also in the north wing of the friary, as indicated by fragments of a hot plate with hot air vents in the soil removed from the basement of the Catholic church of St Peter's and St Paul's, built in the area in 1841.[16] To these, we must add twelve heat storage hypocausts dated to two different periods of use in the Pirita Convent of the Brigittines, built in the 15th century.[17] Besides these, remains of a heat storage hypocaust have been found in the ruins of a 15th–16th century private residence situated between the convent and the river.[18] At least three hypocaust furnaces have been excavated in the building complex of St John's Almshouse in the territory of Tallinn's former outskirts.[19]

Fig. 5. Heat storage hypocaust found in a room under the dörnse in Tallinn Pikk Street 34 in early spring 2009. Photo by Andres Tvauri.

Heat storage hypocausts have also been found in numerous Estonian medieval castles. Based on the drawings of the basement floor of the Tallinn Order Castle of 1828, there was at least one heat storage hypocaust in the keep and at least two hypocaust systems in the buildings of

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[14] Tamm, Mäll, "Building Archaeology Investigations", Fig. 3.

[15] Anneli Randla, "Tallinna dominiiklaste kloostri ehitusloo ülevaade", *Vana Tallinn, V(IX)* (Tallinn, 1995), 35–57.

[16] Tallinna Linnaarhiiv [The City Archives of Tallinn, TLA], R-242-1-270, 98.

[17] Villem Raam, *Pirita klooster* (Tallinn: Eesti Raamat, 1984).

[18] V. Kadakas, H. Nilov, "Various Investigations in Tallinn and Harjumaa", *Arheoloogilised välitööd Eestis 2003. Archaeological field works in Estonia 2003* (Tallinn, 2004), 160–175.

[19] Villu Kadakas, Jaak Mäll, *Tartu maantee läbimurde Kivisilla–Tornimäe tn. lõigus avastatud hoonekompleksi arheoloogiliste päästekaevamiste vahearuanne* (2001, Manuscript in the Archives of the Tallinn Cultural Heritage Board).

the outer bailey.[20] Particular mention is due to the heat storage hypocaust in the Pikk Hermann[21] and Landskrone[22] Towers of the Toompea Castle. That furnace is special for its location in a defence tower. Probably after the example of Pikk Hermann, the building of hypocausts was also begun in the wall towers of the Lower Town of Tallinn.[23]

The biggest number of hypocaust furnaces have been studied in the Rakvere Order Castle, a total of six of them.[24] The keep of the Narva Order Castle, which was destroyed in 1944, was heated with at least three heat storage hypocaust furnaces, the location of which appears in old drawings of the castle.[25] In the Order Castle of Paide, the remains of one hypocaust furnace have been excavated.[26] In Viljandi, a hypocaust furnace was found in the grooms' house in the third outer ward of the castle.[27] An exceptionally well-preserved heat storage hypocaust was found in a private residence in the outer ward of the Haapsalu Bishop's Castle.[28] In Saaremaa, parts of two hypocausts have been found in the keep of the Kuressaare Bishop's Castle, and one was discovered in the course of an archaeological dig in a building in the territory of the outer ward.[29] There is a heat storage hypocaust in the main building of the Maasilinna Order Castle[30] and the remains of three hypocaust furnaces have been found in

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[20] Russian State Historical Archive [Российский государственный Исторический архив, RGIA], 1488-4-1036, 1.

[21] Raam, "Toompea linnuse ja lossi ehitusloolisest minevikust", 37–38, Figs. 14 and 16; drawings published in Rein Zobel, "Toompea loss keskajal (*ca* 1030–1525). Ehitusajalooline ülevaade", *Toompea loss* (Tallinn: Riigikogu kanstelei, 2008), 25.

[22] Aleksandr Pantelejev, "Toompea endise arhiivi hoone ja Landskrone torni restaureerimine, Lossi plats 1a", *Muinsuskaitse aastaraamat 2008* (Tallinn 2009), 32–33.

[23] Raam, "Toompea linnuse ja lossi ehitusloolisest minevikust", 38.

[24] Aus, *Rakvere linnuse hüpokaustahjude uurimine*.

[25] Helmi Üprus, *Narva, Hermanni linnus. Ajalooline õiend* (1955, Report in the Archives of the National Heritage Board).

[26] Kaur Alttoa, Toivo Aus, Kalle Lange, Jaan Tamm, "Neue Angaben zur Baugeschichte der Burgen in Rakvere, Paide und Narva", *TATÜ*, 4 (1987), 391–398.

[27] Tvauri, "Õhkküte keskaegses Viljandis", 75–100; Andres Tvauri, Aivar Kriiska, Rivo Bernotas, "Archaeological research in Viljandi", *Arheoloogilised Välitööd Eestis 2007. Archaeological Fieldwork in Estonia 2007* (Tallinn, 2008), 161–171.

[28] Erki Russow, "Archäologische Forschungen in der Bischofsburg zu Haapsalu" *Arheoloogilised Välitööd Eestis 2001. Archaeological Fieldwork in Estonia 2001* (Tallinn, 2002), 121–134; Erki Russow, "Weitere Forschungen in der Stadt und Burg Haapsalu", *Arheoloogilised Välitööd Eestis 2003. Archaeological Fieldwork in Estonia 2003* (Tallinn, 2004), 148–159.

[29] Tõnu Sepp, "Uusi andmeid Kuressaare linnuse vanemast ehitusloost", *Saaremaa Muuseumi Kaheaastaraamat 1995–1996* (Kuressaare, 1997), 18–26.

[30] Kalvi Aluve, *Eesti keskaegsed linnused* (Tallinn: Valgus, 1993).

the Koluvere Bishop's Castle. In south-east Estonia, at least two hypocausts in good shape were excavated in the Otepää Bishop's Castle[31]. A heat storage hypocaust, complete with a stoker's room, was found in the territory of a small stronghold in Keila, near Tallinn, but it apparently was part of a wooden building erected earlier than the stone castle.[32] The remains of a hypocaust furnace were also found in the medieval manor house of Kose-Uuemõisa[33], and one at the location of the medieval fortified manor of Pulmetz, near Vana-Piigaste in southern Estonia[34].

Apart from Tallinn, heat storage hypocausts were also in use in private residences of other medieval towns in Estonia. Five of them are known in Tartu[35], four in Haapsalu[36], one in Pärnu[37] and one in Rakvere[38]. In Viljandi, one hypocaust furnace has been found in the territory of the medieval town and two other such furnaces in the cloister of an earlier Franciscan monastery.[39]

Numerous hypocaust furnaces used in medieval private residences have also been found and documented in the course of the archaeological study of medieval towns and castles in the southern part of Old Livonia, in the

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[31] See O. Saadre, "Arheoloogilised välitööd Eesti NSV-s 1956. ja 1957. aastal", *TATÜ*, 2 (1958), 141–148, 145, Plate III:2.

[32] Mati Mandel, "Die Ausgrabungen in Keila", *TATÜ*, 4 (1994), 393–395.

[33] See Villu Kadakas, "Investigations in Tallinn, and the counties of Harjumaa, Virumaa and Pärnumaa", *Arheoloogilised Välitööd Eestis 2006. Archaeological Fieldwork in Estonia 2006* (Tallinn, 2007), 197–209, Fig. 7.

[34] Jaak Mäll, Villu Kadakas, "Tellisehitise varemed Vana-Piigastes", *Arheoloogilisi uurimusi 1*, Tartu Ülikooli Arheoloogia Kabineti Toimetised, 9 (Tartu, 1997), 125–126.

[35] Kalle Lange, "Über die Mittelalterlichen Steinbauten an der Kompanie-Straße in Tartu", *TATÜ*, 4 (1994), 409–412; Gunnar Kuldvere, "Uppsala maja tuleb Tartu vanimasse puumajja", *Tartu Postimees*, 3.5.1995; Ain Mäesalu, "Die Haustypen im hansezeitlichen Tartu (Dorpat)", *Lübecker Kolloquium zur Stadtarchäologie im Hanseraum, III: Der Hausbau*, ed. by M. Gläser (Lübeck, 2001), 581–594; Peeter Piirits, *Tartu Küüni t. 5 arheoloogilised päästekaevamised (dets. 1993 – jaan. 1994)* (Tartu, 1994, Manuscript in the Tartu City Museum).

[36] Anton Pärn, "Forschungsarbeiten in der Altstadt und der Bischofsburg zu Haapsalu", *TATÜ*, 1 (1990), 438–445; Anton Pärn, "Archäologische Forschungen auf dem Territorium der Stadt Haapsalu: Forschungsstand und vorläufige Ergebnisse", *TATÜ*, 1 (1994), 49–59, Figs. 4, 1 and 2.

[37] S. Udam, "Über die archäologischen Ausgrabungen in Pärnu in der Hospidali-Straße (1990–1991)", *TATÜ*, 4 (1992), 284–287.

[38] Kadakas, "Investigations in Tallinn", 197–209, Figs. 2 and 4.

[39] Urmas Selirand, "Über die Untersuchungen des Franziskanerklosters in Viljandi", *TATÜ*, 4 (1982), 398, Plate XXI; Kaur Alttoa, *Lõuna-Eesti arhitektuur 15. saj.–16. saj. I poolel*, Magistritöö (Tartu Riiklik Ülikool, 1982, Manuscript at the Institute of History and Archaeology), 170; Tvauri, "Õhkküte keskaegses Viljandis", 75–100.

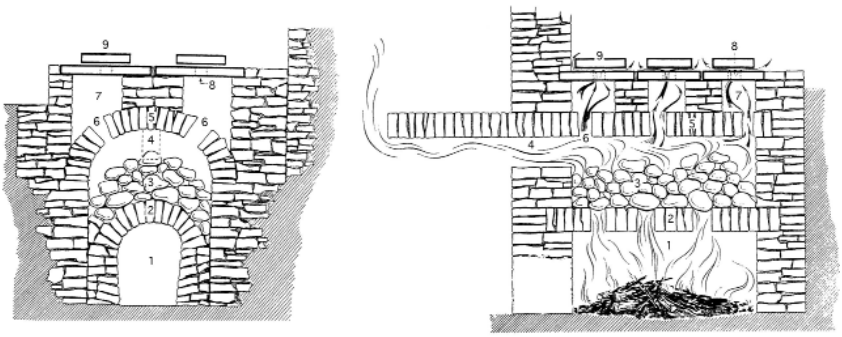

Fig. 6. Reconstruction of a hypocaust furnace studied in the Altene Order Castle in Latvia (after Graudonis, "Altene"): 1 – firebox; 2 – firebox vault; 3 – heat accumulation stones; 4 – smoke flue in the front wall of the furnace; 5 – roof of the furnace; 6 – air openings in the furnace roof; 7 – space between furnace roof and hot plate; 8 – air opening in hot plate; 9 – cover of air opening.

territory of Latvia. The highest numbers of them have been discovered in the Altene Order Castle (Fig. 6), on the left bank of the Gauja. The results of these studies have been published.[40] So it is possible to get a rather good overview of the hot air heating systems used in medieval Old Livonia.

Work principle of the heat storage hypocaust furnace

After German and Danish crusades had established control over the lands of tribes living on the eastern coast of the Baltic Sea – Estonians, Osilians, Livonians, Curonians, Zemgallians, Latgalians and Selonians – the new rulers erected numerous stone fortresses and monastic buildings in the area of present day Estonia and Latvia, known as Livonia in the Middle Ages. The first city, Riga, was founded in 1201, and several settlements granted city charters sprang up during the same century. The most important of these were the Hanseatic cities of Tallinn and Tartu. In contrast to the culture and language of the local peasantry, the world of the Livonian nobles, the clergy, merchants and city craftsmen was clearly part of the German cultural space. Also, architectural ideals arrived in these lands from northern Germany. However, a peculiar building tradition became established in Livonia due to the joint influence of natural and political circumstances. One of the most important differences compared with the

[40] J. Graudonis, "Altene", *Archeoloģia un etnogrāfija*, XIV (Rīga, 1983), 40–85.

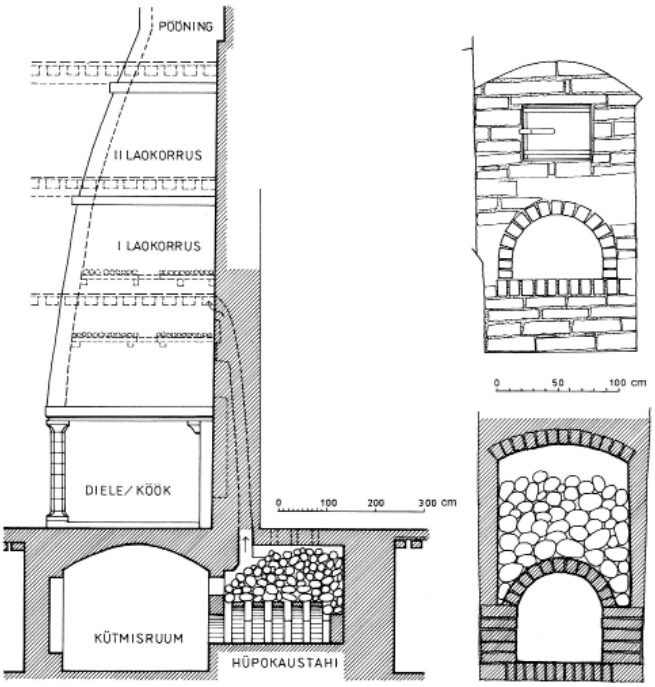

Fig. 7. Hot air heating system in the medieval merchant's house at No 23 Lai Street in Tallinn (after Teddy Böckler and Juhan Maiste, *IX kvartal, Vanalinn Tallinn* (Tallinn: Tallinna Linnateater, 1995)).

contemporary building tradition of central and western Europe was a more efficient heating of buildings, due above all to the local climate, which was considerably cooler compared with that of northern German areas.

Only a part of the building was heated in the medieval buildings of Old Livonia. The type of Tallinn private residence which developed by the second half of the 14th century[41] was a long and narrow stone building with a high gable, built against neighbouring houses with the narrow end lining the street. The main floor of the house usually had two large rooms. The end facing the street had a large entrance hall (Low German *diele*). The residence also served as the merchant's office or the craftsman's workshop. One of the corners of the room was taken up by a black kitchen under a smoke hood and the warmth from its open hearth also heated the rest of

[41] Rein Zobel, *Tallinn (Reval) keskajal. Linnaehitus 13.–14. sajandil* (Tallinn: Eesti Entsüklopeediakirjastus, 2001).

the room. The bedroom (*dörnse*), the only warm room in the house in the winter, heated by means of a heat storage hypocaust, was situated at the back of the front room. In addition, there could have been other unheated chambers in the back part of the house. The upper floors of the buildings were used as storage and warehouse space. There was a basement under the ground floor and, in addition to other rooms, it had the stoker's room of the hypocaust furnace (as a rule under the black kitchen) and a hypocaust furnace (under the heated room) (Fig. 7).

Tallinn guild houses were similar to the private residence in structure. So a clear *diele-dörnse* division can be found in the building, completed in 1410, of the most important merchants' organisation, the Great Guild, and only the function of holding meetings and festive events was different from that of a private residence. In the Tallinn Town Hall, which was mainly completed in 1404 in its present shape, only the Council Chamber was heated by means of a heat storage hypocaust. The heating system of the Tallinn Town Hall was also different from other medieval buildings in Tallinn in that the heat storage furnace and the stoker's room were situated on the first floor.

In castles and monasteries, too, only bedrooms or dormitories and festive chapter halls and refectories were heated by means of heat storage hypocausts. In the case of monastic buildings and castles, more variety can be noticed in the location and structure of the heating system than in the case of private residences. It was possible to heat at least two separate rooms by means of one furnace. For example, a hypocaust furnace by which two refectories were heated has been unearthed in the north wing of the Pirita Convent.[42] There are two separate hot air vents coming out of a hypocaust furnace in the Rakvere Castle, which gives us reason to believe that they were used to heat two rooms.[43] But, as a rule, the hypocaust furnace was always situated under the heated room or rooms.

The hypocaust furnace was a large furnace with a pile of stones for the retention of heat and with a connection between the heat-accumulating pile and the heated room. The heated room had a perforated hot plate above the furnace (Fig. 10). The openings were closed while the furnace was heated, and the smoke escaped into the chimney through the pile. When the heating was completed, the smoke flue was closed by means of a damper, the holes in the hot plate were opened and hot air rose from the pile and through the stones into the heated room. The principle of the

[42] Raam, *Pirita klooster.*
[43] Aus, *Rakvere linnuse hüpokaustahjude uurimine.*

heat storage hypocaust actually was that the heat accumulated in the pile of stones was transferred to air, which surged into the heated room by means of natural convection after the vents were opened.

Structure of the medieval heat storage hypocaust furnace

Generally only a part of the medieval hot air heating system has been preserved. Only the furnace itself is exposed in archaeological excavations – the hot plate, air vents, smoke flues and the chimney have been destroyed along with the building or have been removed in the course of later rebuilding. Only the body of the furnace often remains in medieval buildings in Tallinn – the front wall and the vault of the firebox have been demolished and the stones for the accumulation of heat have been removed. Fragments of perforated hot plates or bricks are often found in excavations in medieval cities and castles.

The structures and modes of construction of the hypocaust furnaces found in Estonia and Latvia are rather similar (Figs. 6 and 7), with differences only in details. The furnace was built of limestone, large granite stones or bricks with lime mortar. The furnace had two side walls and a back wall and was usually covered with a brick barrel vault, the roof of the furnace. Generally brick side walls and a back wall resting on the furnace floor were built into the firebox. The brick vault of the firebox rested on the side vaults, on which the heat-accumulating stones were piled up. The front wall was usually built up between the side walls of the body after the rest of the work had been completed. The top of the furnace had openings from which hot air could rise to under the hot plate in the floor of the heated room.

The measurements of the furnace mainly depended on the size of the heated room. In private residences, where only the bedroom was heated, the furnace was smaller – the interior length of the body being 1.2 to 2 metres and the width 0.95 to 1.3 metres. In public buildings where large festive halls were heated with a heat storage hypocaust or in monasteries that had large bedrooms and workrooms, the furnaces were considerably bigger. In the Pirita Convent, the interior measurements of one furnace studied were 3.3 by 0.75 metres.[44] In the Rakvere Castle, the interior dimensions of the biggest heat storage hypocaust furnace of an irregular shape were

[44] Jaan Tamm, "Über die Untersuchungen der Klosterruine von Pirita 1978–1980", *TATÜ*, 4 (1981), 421.

252–275 by 136–170 cm.[45] The construction of the furnace was massive, because when heated the stones in the pile exerted strong pressure on the side walls of the furnace and could have toppled a thin brick wall.

The floor of the furnace was generally built of stone. In the Tallinn Town Hall, where it was possible to study a furnace that had been preserved in its original shape since the last heating, the floor was made of bricks. The layer of heat insulation under the floor of the firebox was remarkable – there was a layer of tightly pressed hay 3 to 4 cm thick between two layers of sand, and a layer of thin limestone shingles in the layer of sand under it.[46]

The walls of the firebox, which generally consisted of one row of bricks laid on clay mortar, were built on its floor. A space for air could be left between the walls of the firebox and the body of the furnace in order to better insulate the body from the heat of the firebox. In some cases, for example in the furnaces of the Rakvere Castle, the interior walls of the firebox were made of limestone with clay mortar and were rather thick, up to 55 cm.[47]

On top, the firebox was covered with a brick, or very rarely a limestone, vault on which the stones for the accumulation of heat were piled. The bricks in the vault were laid in three or four arches, with intervals of up to about 20 cm between them (Fig. 5). The interior height of the firebox of Estonian heat retention furnaces was generally 50 to 60 cm. The builder must have used some kind of aid to build the vaults. In later Estonian threshing barn furnaces, an old vat was used in building the arches of the vault.[48] It was laid on the floor of the firebox and the vault was built on the vat. When the furnace was completed, a fire was built in the vat. Medieval furnace builders must have known and used that method.

Several furnaces with the stones for the accumulation of heat still in place have been found. We know, based on these finds, that mostly rather big granite stones, 20 to 40 cm in diameter, were used in the furnace. The space between the arches of the firebox and the top of the furnace was filled about two thirds of the way with stones.

In hypocaust furnaces of the Viljandi, Rakvere, Otepää and Altene Order Castles, as well as of Riga private residences and many other buildings, the

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45 Aus, *Rakvere linnuse hüpokaustahjude uurimine*.

46 Böckler, "Tallinna raekoja kütte- ja sanitaarseadmed", 54–62.

47 Aus, *Rakvere linnuse hüpokaustahjude uurimine*, 18–19.

48 Karl Tihase, *Eesti talurahvaarhitektuur* (Tallinn: Tallinna Tehnikaülikooli kirjastus, 2007).

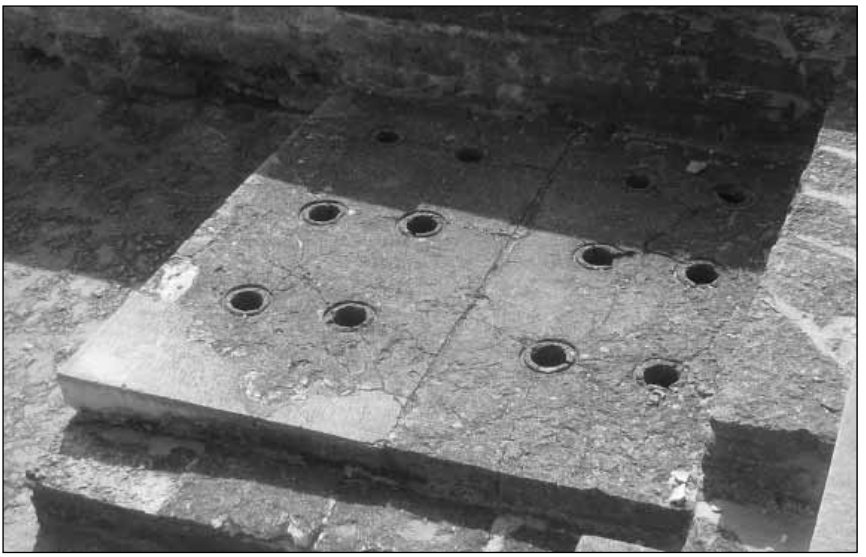

Fig. 8. Hot plate of a heat storage hypocaust in the Pirita Convent of the Brigittines. Photo by Andres Tvauri.

furnace had a vaulted roof[49] between the pile of stones and the perforated hot plate. It stood 1.5 to 2 metres from the floor of the furnace. The interior height of one Rakvere furnace has been measured at 204 cm.[50] The interior height of the furnace had to be sufficient in order to ensure full burning of the exhaust gases already between the stones in the pile. By using this method, fuel use was also more economical.

The roof of the furnace had one or several air vents through which smoke and hot air rose to under the cover slab in the heated room. The vaulted roof of the hypocaust furnace in the medieval manor house of Kose-Uuemõisa has six openings in two rows,[51] which were probably located under the holes of the hot plate, which has not been found.

Hot air passed through the hot plate, a quadrangular stone slab (Fig. 8) that was level with the floor of the heated room or slightly higher, and the dimensions of which were nearly the same as those of the body of

[49] See: Aus, "Altene", *Rakvere linnuse hüpokaustahjude uurimine*; Graudonis, 40–85; Ieva Ose, "Heizanlagen in den mittelalterlichen Burgen Lettlands", *Castella Maris Baltici*, V (Rudkøbing: Langelands Museum, 2001), 129–136, Fig. 5; O. Saadre, "*Arheoloogilised välitööd Eesti NSV-s 1956. ja 1957. aastal*", *TATÜ*, 2 (1958), 141–148, Plate III: 2.

[50] Aus, *Rakvere linnuse hüpokaustahjude uurimine*, 19.

[51] Kadakas, "Investigations in Tallinn", 204, Fig. 7.

Fig. 9. Brick hot plate with air vent found in Lossi Street in Tartu (Tartu City Museum, A 36: 34888). Photo by Eero Heinloo.

Fig. 10. Ceramic cover of a hot plate with air vent from the keep of the Viljandi Order Castle (Museum of Viljandi, 4264). Photo by Erki Helves.

the furnace itself. The hot plates found in Tallinn, and for example also in the Haapsalu Castle, had been carved from one large block of limestone. This was a local peculiarity. In southern Estonia and in Latvia the hot plate was put together of smaller pieces of limestone, sandstone or brick, with an air hole in each of them.[52] Even the heating surfaces in the Marienburg Castle were made of slabs with one hole in each of them.[53] In Rakvere Castle, a fragment of hot plate measuring 53 by 47 by 7[54] centimetres, with one air hole, has been found. A similar brick hot plate (Fig. 8) has been found in a pit in Lossi Street in Tartu. The hot plate usually had four to six openings. There is only one hot plate of a heat storage hypocaust with just one opening. It was brought to light in the course of the restoration of a building at Kiriku Põik 4 in the Toompea area of Tallinn in 1992.[55] The cover slab with the biggest number of holes has been found in the Chapter Hall of the Pirita Convent. It has 12 holes, and the hot plate consists of two limestone slabs, with six perforations

[52] See, e.g.: Graudonis, "Altene", 40–85.

[53] Bingenheimer, "Die Luftheizungen des Mittelalters", Figs. 77, 78, 84.

[54] Toivo Aus, *Rakvere linnuse uurimis- ja projekteerimistööd. Köide I. Arhitektuur-arheoloogiliste uurimiste 1975–1978. a. tööde vahearuanne* (Tallinn, 1979, Report in the Archives of the National Heritage Board), 6, Figs. 1 and 2.

[55] TLA, R-242-1-270, 67.

in each, placed next to each other (Fig. 8).

The hot air openings were generally round, usually 10 to 12 cm in diameter. However, there are a few exceptions: the hot plate found in the Franciscan Monastery in Viljandi has a hot air opening measuring 16.5 cm across.[56] Also the perforation in the hot plate from the building at Kiriku Põik 4 mentioned above is larger than usual, 28 cm in diameter.[57] We know of only one fragment of a hypocaust hot plate with a square perforation, found at Viru Street 11 in Tallinn. The size of the hot air opening there was 22 by 23 centimetres.[58]

Fig. 11. Fragment of a stone cover of a hot plate with air vent from the keep of the Viljandi Order Castle (Museum of Viljandi, unnumbered). Photo by Erki Helves.

Many Tallinn heat storage hypocausts differ from others in that they had no roof on the furnace and the hot plate had been installed immediately over the heat accumulation stones.[59] This was probably due to the abundance of limestone in Tallinn. The hot plates of Tallinn hypocausts are generally monolithic limestone slabs with holes in them. The cover slabs of Latvian and southern Estonian hypocausts, however, consist of smaller worked pieces of limestone or ceramic tiles that needed additional support (Fig. 6).

Special covers were used to close the air vents in the hot plates; they were made of metal, stone or baked clay. Numerous ceramic covers of the air openings and their fragments have been found in the middens of medieval towns, such as Tallinn, Tartu and Viljandi. One ceramic cover of that type has also been found in the territory of the keep of the Viljandi Castle (Fig. 10). Also a stone cover was found there (Fig. 11). A bronze cover of a hot air vent was found in a hypocaust furnace in the Rakvere

[56] Urmas Selirand, *Viljandi Jaani kirik. Frantsiskaanlaste kloostri klausuuri ehitusarheoloogiline uurimine 1981. a. 1. köide. Leiumaterjali analüüs* (Tallinn, 1982, Report in the Archives of the National Heritage Board), 6.

[57] Tallinn City Museum [Tallinna Linnamuuseum, TLM], 7709ab.

[58] TLA, R-242-1-270, 109.

[59] See, e.g.: Voldemar Vaga, "Tallinna keskaegne elamu", *Eesti NSV ajaloo küsimusi, I*, TRÜ Toimetised, 87 (Tartu, 1960), 41–88, Fig. 25.

Castle.[60] In the Council Chamber of the Tallinn Town Hall (built in 1404), a room heated by means of a heat storage hypocaust, there was a special niche near the hot plate to keep the sooty hot plate covers.[61]

There is information of a hypocaust furnace in which, rather than the perforations of the hot plate being opened after the stones had been heated, a hand was stuck through a hole in the hot plate and a cover was removed from an opening in the top of the furnace. Such a furnace was discovered a few years ago in a building unearthed in the inner side of the outer ward of the Haapsalu Castle.[62] Even the copper cover was there on the bottom of the intermediate chamber floor.

Small ceramic dishes have been found immediately under the holes of a hot plate cover slab where they rested on the stones.[63] It has been presumed that water was poured into them to increase air humidity. The fragment of a clay dish that could have originated from a plate of the same function was discovered on the heat accumulation stones in a hypocaust in the building at Küüni Street 5[64] in Tartu. A small carved limestone bowl about 30 cm in diameter was found at Kuninga Street 6 in Tallinn and the architecture historian Rasmus Kangropool has speculated that it was located under the hot air opening in the hypocaust cover slab.[65]

In Tallinn's medieval homes, as well as in the Town Hall, the smoke escaped through a smoke flue inside the wall. It started in the front part of the furnace and was conducted one story higher into the smoke hood above the black kitchen on the ground floor.[66] In the Pirita Convent, the smoke was conducted into special flues inside partition walls and probably passed into the chimney higher up. In the Tallinn Town Hall, a smoke channel measuring 55 by 36 cm inside the damper could be closed from the kitchen wall above the stoker's room.[67] The damper in the uptake of the hypocaust in the Rakvere Castle was located on the heated floor above the furnace.[68] The smoke flue of the hypocaust in the north-west wing of

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60 Aus, *Rakvere linnuse uurimis- ja projekteerimistööd*, 6, photo 3.
61 Böckler, "Tallinna raekoja kütte- ja sanitaarseadmed", 54–62, 56.
62 Russow, "Archäologische Forschungen in der Bischofsburg zu Haapsalu", 121–134.
63 Raam, *Pirita klooster*, 56.
64 Piirits, *Tartu Küüni t. 5 arheoloogilised päästekaevamised*, 12.
65 TLA, R-242-1-270, 90.
66 See, e.g.: Vaga, "Tallinna keskaegne elamu", Figs. 23, 24.
67 Böckler, "Tallinna raekoja kütte- ja sanitaarseadmed", 56.
68 Aus, *Rakvere linnuse hüpokaustahjude uurimine*, 24.

the Kuressaare Castle had a damper made of a stone slab measuring 31 by 37 cm, up to 11 cm thick. The extant depression in the flue proves this.[69]

There were also buildings without chimneys heated by hypocaust furnaces. In such cases, the smoke escaped through an opening in the upper front part of the furnace. The mouth and the stoker's room of such a furnace were usually outside the heated building; the stoker's room, also serving as a woodshed, was actually nothing more than a hollow covered by some kind of light roof. For example, the furnaces used to heat wooden houses on stone foundations in the Altene Order Castle were of that type.[70] In the Maasilinna Order Castle, the limestone main building was heated by means of a hypocaust furnace, and it has been presumed that access to it was via a one-storied stone lean-to on the outside of the building.[71]

Also the furnace discovered in the house next to the wall in the outer ward of the Haapsalu Castle was exceptional in that there was no flue leading the smoke into the chimney; rather, the smoke escaped through a narrow opening in the front wall of the furnace into the stoker's room. The stoker's room was situated apart from the other rooms, and the smoke escaped either through a smoke flue that started in the stoker's room or through the stoker's room door. Such furnaces where the smoke escaped through an opening in the front wall of the furnace were by no means rare. They were used even in the mother-house of the Brigittine Convent in Vadstena, Sweden.[72]

Soot collected between the stones in the course of heating, and it was necessary to remove it from time to time. The heat accumulation stones, the walls and the vault of the firebox crumbled due to heat and needed replacement after a certain time. For that purpose, there was a special opening in the upper part of the front wall of the furnace, which may have been closed by a metal hatch. If there was no such hatch, the front wall had to be fully or partly dismantled to repair the furnace. As a rule, the front wall of hypocaust furnaces was laid separately between the sides of the furnace. The stones of the front wall of the furnace in the grooms' house of the Viljandi Castle were built on clay, not lime mortar, contrary to the body of the furnace. Apparently, clay was used for easier renewal of the furnace.

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[69] Aluve, *Eesti keskaegsed linnused*, 76.

[70] Graudonis, "Altene", Plate IV:3.

[71] Kalvi Aluve, "Maasi ordulinnus", *Eesti arhitektuur*, 2 (Tallinn: Eesti Entsüklopeediakirjasus, 1996), 70–71.

[72] Iwar Anderson, *Vadstena Gard och Kloster* (Stockholm: Almquist & Wiksell, 1972), Fig. 41b.

Stoker's room

There was a windowless stoker's room (*prefernium*), with wall niches in front of the hypocaust furnace, in Tallinn private residences. It was situated under the black kitchen and was usually only slightly bigger than the area of the furnace itself. At Viru Street 11 in Tallinn, the size of the hypocaust was about 2.25 by 2.25 metres[73], but at Aida Street 6 it was only about 2 by 1.2 metres[74]. In private residences, the stoker's room and the bedroom (*dörnse*) were usually connected by a flight of stairs.

The small size of the stoker's room can also be seen in strongholds and monastic buildings. There was a very small stoker's room in front of the hypocaust furnaces in the Rakvere Castle, so the dimensions of two of the stoker's rooms were only 168 by 141 cm and 184 by 74 cm.[75]

The floor of the stoker's room could have been at the same level as the floor of the furnace (for example in the grooms' house in the Viljandi Castle) or a few dozen centimetres lower than the floor of the furnace, as in the case of some hypocausts of the Rakvere Castle.[76] The hypocaust furnace at No 6 Kuninga Street in Tallinn is an exception, due to the fact that the mouth of the firebox stands almost under the stoker's room ceiling.[77] At least in one case, in the furnace found during the restoration of Vene Street 22 in Tallinn, there was a hearth laid of brick in front of the furnace mouth.

The stoker's rooms were often so small that there was no room to keep firewood in them, and in town houses firewood was kept in some other basement room, in the case of the Rakvere and Narva Castles presumably in the inner yard of the keep. The entrance to the stoker's room of the hypocaust furnace in the east wing of the Narva keep was immediately at the level of the yard.[78] In the Franciscan Monastery in Viljandi, there was a special shaft through the monastery wall for getting firewood into the stoker's room in the basement, probably from the yard (Fig. 12).

In public buildings, and occasionally also in private residences, there were hypocaust furnaces of which the mouth did not open into the narrow

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[73] Vaga, "Tallinna keskaegne elamu", Fig. 12.

[74] Helmi Üprus, "Das Wohnhaus in Tallinn vor 1500", *Häuser und Höfe im Ostseegebiet und im Norden vor 1500*, Acta Visbyensia, V (Visby, 1976), 141–162, Fig. 17.

[75] Aus, *Rakvere linnuse hüpokaustahjude uurimine*, 7.

[76] *Ibidem*.

[77] Zobel, *Tallinn (Reval) keskajal*, Figs. 106 and 107.

[78] J. Tamm, K. Alttoa, T. Aus, E. Lepp, *Ülevaade Narva Hermanni linnuse ehitusarheoloogilistest uurimistest 1986. aastal*, Köide IV (Tallinn, 1987, Report in the Archives of the National Heritage Board), 14

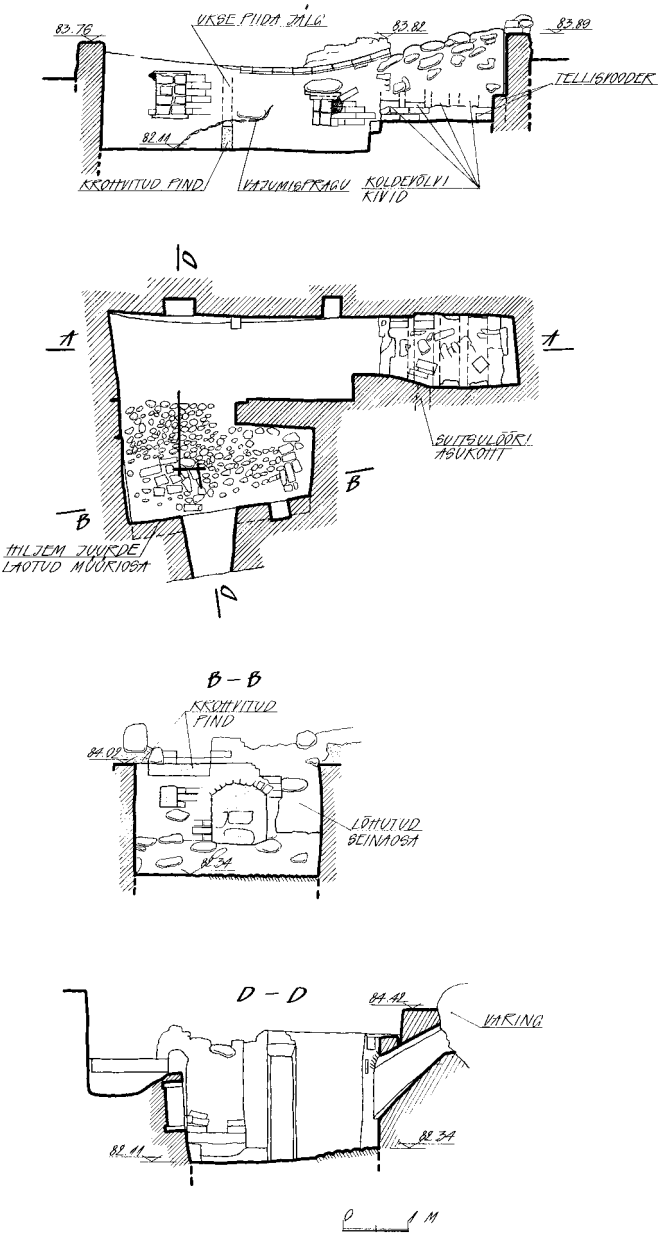

Fig. 12. Heat storage hypocaust and its stoker's room excavated in the north wing of the Franciscan Monastery in Viljandi (after drawings made under the supervision of Urmas Selirand and Kaur Alttoa in 1981 and kept at National Heritage Board).

stoker's room but into a bigger room. Such was the case in the south wing of the keep in the Tallinn Order Castle. A similar furnace, heated by a 72 m^2 vaulted kitchen, was found in the north wing of St Michael's Cistercian Convent.[79] The mouth of a hypocaust furnace studied in the Paide Castle opened into a room of about 46 m^2.[80] In the medieval building found between the Pirita Convent and the river, the mouth of the hypocaust furnace seems to have opened into a room of about 20 m^2, which was immediately connected with an even bigger vaulted room.[81] Also, the mouth of the heat storage hypocaust found in a Kompanii Street house in Tartu seems to have opened into a room that was as big as the *dörnse* above it.[82] The hypocaust furnace at Raekoja Plats 12 seems to have had a similar location.[83]

The Great Guild House in Tallinn had two furnaces, with one of them heating the large and the other the small guildhall. The furnaces had a common stoker's room located in the basement under the black kitchen.

Heating capacity of the heat storage hypocaust

There is no written data on the efficiency of the medieval hot air heating systems in Old Livonia. Neither are there any furnaces in working order or a reconstructed furnace by which experiments could be made. In the residence of the High Master of the Teutonic Order in the Marienburg Palace (today's Malbork in northern Poland), there were heat storage hypocaust systems in working order as late as the 19th century. Several experiments were conducted at the beginning of the 19th century to find out the effectiveness of these furnaces.

In April 1822, the Remter (festive hall), measuring about 850 m^3, of the Marienburg Castle was heated by means of a heat storage hypocaust. On 3 April a cold furnace was heated for 3.5 hours, in the course of which 0.7 m^3 of spruce wood was burnt. When the vents in the hot plate were

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[79] Tamm, Mäll, *Building Archaeology Investigations in the Cistercian St. Michael's Nunnery*, 73–87, Fig. 3.

[80] Kaur Alttoa, Toivo Aus, Kalle Lange, Jaan Tamm, "Neue Angaben zur Baugeschichte der Burgen in Rakvere, Paide und Narva", *TATÜ*, 4 (1987), 391–398, Fig. 3.

[81] Villu Kadakas, "Uut informatsiooni Pirita ajaloolisest asustusest", *Muinsuskaitse 2004. Aastaraamat* (Tallinn, 2004), 73–74.

[82] Kalle Lange, "Über die Mittelalterlichen Steinbauten an der Kompanie-Straße in Tartu", *TATÜ*, 4 (1994), 409–412, Fig. 2; Estonian Historical Archives [Ajalooarhiiv, EAA], 5238-1-113/164.

[83] Zobel, *Tallinn (Reval) keskajal.*

opened, hot air at 200° C rushing into the room brought the temperature in the hall from 6ºC to 22.5ºC in 20 minutes. The outside temperature at the time was 0ºC. The air vents were closed and by the morning of 4 April the air temperature in the room had fallen to 14ºC. The air vents were opened and the 148ºC air escaping from them raised the temperature in the room to 19ºC in one hour. On 5 April the temperature of the air escaping from the openings was 94ºC and the room temperature rose to 16ºC from 10ºC in half an hour. On 6 April the temperatures were respectively 63ºC, 10ºC and 12ºC, and on 9 April 46ºC, 8ºC and 10ºC.[84]

The heating capacity of the furnaces and their efficiency depended on their size and structure, as well as on the structure and location of the flues and the chimney. But it was possible to determine that in winter the heat storage hypocaust kept the heated room warm enough for several days.

Development of the heat storage hypocaust

The hypocaust of ancient Rome served as an example for the hot air heating systems used in the Baltic countries in the late Middle Ages. Compared with the Roman system, the medieval hot air heating system had important differences. In the Roman hypocaust, the combustion gases and hot air passed through channels immediately under the floor and through the walls, heating the rooms.

A preliminary type of the hot air heating system used in Old Livonia in the Middle Ages was developed in north-central Europe in the 10th to the 14th centuries for the heating of the only warm room in large monasteries, the *calefactorium*.[85] Originally such furnaces were located under the heated room and lacked a heat storage device. The air was heated through the hot vault of the firebox and the walls of the furnace. As Christianity and monasteries spread to the shores of the Baltic Sea and to colder climes elsewhere in northern Europe, such a heating system turned out to be insufficient. In the first half of the 14th century, if not earlier, the practise of piling granite stones for the accumulation of heat on the vault of the firebox began[86] and the heat storage hypocaust (German *Steinkammer-Luftheizung*, Estonian *kerishüpokaust*) was born.

The hypocaust of ancient Rome kept rooms warm only while it was heating and the heat accumulation capacity was low. Adding a stone chamber

[84] Bingenheimer, "Die Luftheizungen des Mittelalters", 160–161.
[85] *Ibidem*, 109–143.
[86] Bingenheimer, "Die Luftheizungen des Mittelalters", 146.

made it possible to better accumulate heat. So it was no longer necessary to constantly heat the furnace because, once heated, the furnace gave off its warmth during a longer period of time.

The invention turned out to be so successful and necessary that the heat storage hypocaust furnace spread throughout the German cultural space, from monasteries and castles to other public buildings, such as almshouses, town halls and guild houses, and finally into private residences. The cooling of the climate in Europe in the 13th century may have also contributed to the spread of the new and more efficient heating method.

Comparing the hypocaust furnaces found in Estonia with those in northern Germany[87], Lithuania[88], Denmark[89], Sweden[90] and Finland[91], it is clear that the heat storage hypocaust furnaces were very similar everywhere. It seems that the heat storage hypocaust as an innovation spread very rapidly throughout the Baltic Sea area during the 14th century at the latest. The spread of the hypocaust was certainly connected with the fact that medieval monks and knights of the Order, as well as builders, were quite mobile and many of them often travelled from one monastery to another or changed their places of service.

It is difficult to say who was responsible for the invention of decisive importance for increasing the heating capacity of the *calefactorium* furnaces – adding the stones for the accumulation of heat to the furnace. Perhaps this new idea had a concrete example. In fact, indigenous inhabitants of the territory of Finland, Estonia and Latvia had been widely using heat storage furnaces since the 7th or the 8th century.[92] There is no firm information to prove it but it cannot be ruled out that a builder, a monk or a knight of the Order who had lived in Livonia and seen a heat storage

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[87] *Ibidem*.

[88] M. Bertašius, "Mittelalterliche Hypokaust-Heizungen in Kaunas und Litauen", *Zeitschrift für Archäologie des Mittelalters*, 35 (Bonn, 2007), 109–120.

[89] J. Hertz, "Some Examples of Medieval Hypocausts in Denmark", *Etudes de Castellologie médiévale VII: Actes du colloque international tenu à Blois (France), 2-7 septembre 1974*, Centre de recherches archéologiques médiévales Université de Caen (1975), 127–139.

[90] Iwar Anderson, "Varmluftugnar i Vadstena Kloster", *Fornvännen*, 2–3 (1961), 110–129; H. Widén, "Svenska fynd av hypocaustplattor från medeltiden", *Fornvännen*, 4 (1954), 241–245.

[91] Carl Jacob Cardberg, *Åbo slott under den äldre vasatiden* (Helsinki: Suomen muinaismuistoyhdistys, 1959).

[92] Ain Lavi, "An addendum to the study of smoke cottages", *Eesti Arheoloogia Ajakiri*, 9/2 (2005), 132–155.

furnace in a peasant's cottage struck on the idea of adding stones for the retention of heat to the hypocaust furnace.

Typology and dating of Estonian heat retention hypocausts

It is difficult to find any characteristics in the structure of Estonian heat storage hypocausts that would allow their dating. This is partly due to the fact that heat retention hypocausts from the 14th century or even earlier were destroyed in the course of later reconstruction. It was necessary to constantly renew the furnaces and, as a rule, the furnace fell out of use in connection with the spread of glazed tile stoves.

The size of the furnace or its location in the building, as well as the location of the stoker's room and the flues, depended mainly on the building and its use. The furnaces and their location in Tallinn's merchant houses were quite similar to each other. Exceptional furnaces were built into unique buildings, such as the Tallinn Town Hall or the Great Guild House. There are hypocausts in towers of Pikk Hermann and Landskrone of the Toompea Castle and at least in towers of Bremen and Helleman of the town wall.[93] It can be presumed on the basis of the hypocausts of the Pirita Convent that the hypocausts of monasteries differed from hot air heating systems in castles and private residences. In some cases, the exceptional character of a furnace was due to the fact that it had been built into an earlier structure. This explains the lack of a special stoker's room in the building at Raekoja Plats 12 in Tallinn[94], and the exceptional height of the firebox on the floor level in Kuninga Street 6[95]. Hypocausts that were heated from outside the building do not seem to form a separate chronological group either. There are such hypocausts in buildings erected in the 13th century (Otepää Castle), in the 14th century (Maasilinna Castle) and at the beginning of the 15th century (Pirita Convent).

As it is not possible to point out any changes in the construction of the furnaces over the course of time at the present stage of research, concrete furnaces can only be dated on the basis of when a building or its part used for heating was built.

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[93] The closest parallel known to the author of the current article is situated in southern Sweden, in Helsingborg (medieval Danmark), in the Tower of Kärnan. See K. Drake, "Die Heizung der Köningskammer im Wohnturn Kärnan in Helsingborg", *Castella Maris Baltici, 8. The proceedings of a symposium held in Turaida, Latvia, on 5–9 September 2005*, ed. by A. Caune, I. Ose (Riga, 2007), 31–36.

[94] Zobel, *Tallinn (Reval) keskajal*, Fig. 110.

[95] *Ibidem*, Figs. 106 and 107.

The furnace found in the Otepää Bishop's Castle can be firmly dated to the 14th century, as the castle was destroyed in 1396. But in the dating of the Otepää furnaces, it is necessary to take into consideration the fact that the buildings in which the furnaces were located were erected in the 13th century.[96] So the hypocausts of the Otepää Castle can be regarded as the oldest known heating installations of that type in Livonia. Unfortunately they have been completely destroyed – a large part of the remaining walls of the Otepää Bishop's Castle was excavated in the 1950s to the 1970s, but the ruins remained at the mercy of the elements and disintegrated rapidly before they could be conserved.

Villem Raam has dated to the first half of the 14th century the heat storage hypocausts of the Padise Monastery; he has also dated the heat storage hypocausts of the Kuressaare castle to the 14th century. The construction of the Pikk Hermann Tower of Tallinn's Toompea Castle, in which there was a hypocaust heating system, started in 1371.[97] The newer part of the main building of the Maasilinna Castle, in which the hypocaust furnace was located, is said to have been built during the rule of Master of the Order Goswin von Herike (1345–59).[98] Some of the furnaces in the Rakvere Castle have been dated to the 15th century.[99]

The hypocaust furnace found under the floor of the hall in the small Keila Castle dates from a wooden building that was older than the stone fortress.[100] As the stone part of the castle was probably built around the middle or in the latter half of the 15th century[101], the furnace described is older than the castle. But it is unfortunately not possible to say how much older.

There are numerous hypocausts in the Pirita Convent, built in the 15th century. The Tallinn Town Hall, the Great Guild House and many private residences in Tallinn, complete with their hot air heating systems, were built at the beginning of the 15th century. In fact, most of the heat storage hypocausts that have been preserved in Estonia date from the first half of the 15th century.

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96 O. Prints, *Otepää piiskopilinnuse varemete 1961. a. konserveerimis- (ja uurimis-)tööde aruanne* (Tallinn, 1962, Report in the Archives of the National Heritage Board).

97 Mati Mandel, "Die Ausgrabungen in Keila", *TATÜ*, 4 (1994), 393–395.

98 Aluve, "Maasi ordulinnus", 70–71.

99 Aus, *Rakvere linnuse hüpokaustahjude uurimine*, 42.

100 Mandel, "Die Ausgrabungen in Keila", 393.

101 Aluve, *Eesti keskaegsed linnused*, 47.

Glazed tile stoves pushed heat storage furnaces into farm buildings

The period of use of the heat storage hypocausts was rather short. Already in the 15th century, glazed tile stoves spread in the Baltic countries, as they were more convenient to use compared with the hypocaust and they also consumed less fuel. Generally, use of the heat storage hypocaust was given up during the 16th century in Old Livonia.[102]

A glazed tile stove was often built directly where the old hypocaust furnace had been located, as was done in the Tallinn Town Hall[103] and in the Haapsalu Castle[104]. Stoves built of stylish glazed tiles, decorated in relief, became a real craze and a status symbol in the 15th to the 16th centuries; the use of glazed tile stoves made it possible to express even religious or political views.[105] The hot air heating system was not noticeable in the room decoration and could not perform that function.

The last report of the use of a hypocaust furnace in Estonia dates from 1560. At the beginning of the 17th century, Dionysius Fabricius, a Jesuit chronicler, described events and circumstances connected with the closure of the Franciscan Monastery in Viljandi. He wrote about a monk who went into the stoker's room of the hypocaust in order to remove lice from his clothes. But the door of the stoker's room closed and the monk suffocated. The victim was found only after the hot air vents were opened and the smell of roasted flesh from the hypocaust rushed into the monastery's refectory.[106] It was apparently the same hypocaust that was found in the course of archaeological excavations in 1981 (Fig. 12).

But hypocaust furnaces were not wiped out altogether. In its appearance, dimensions and structure, the medieval hypocaust furnace of Old Livonia was largely similar to the later closed threshing barn furnaces in the barn dwellings in Estonia and northern Latvia (Fig. 13), which were used until the 20th century.

As the barn dwelling, a type of farmhouse that united the function of a private residence and of a threshing barn, started to spread in the territory

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[102] Ieva Ose, "Heizanlagen in den mittelalterlichen Burgen Lettlands", *Castella Maris Baltici*, V (Rudkøbing, 1991), 133.

[103] Böckler, "Tallinna raekoja kütte- ja sanitaarseadmed", 55.

[104] Russow, "Archäologische Forschungen in der Bischofsburg zu Haapsalu", 121–134, Fig. 4.

[105] Aldur Vunk, "Mentaliteedi peegeldus Pärnu kahlileidudel. Linnaarheoloogia teoretilisi aspekte", *Eesti Areholoogia Ajakiri*, 4:2, (1992), 151–174; Erki Russow, "Kahhelahjud: pildid, mis soojendasid", *Eesti kunsti ajalugu*, 2 (Tallinn, 2005), 148.

[106] Alttoa, *Lõuna-Eesti arhitektuur*, 170.

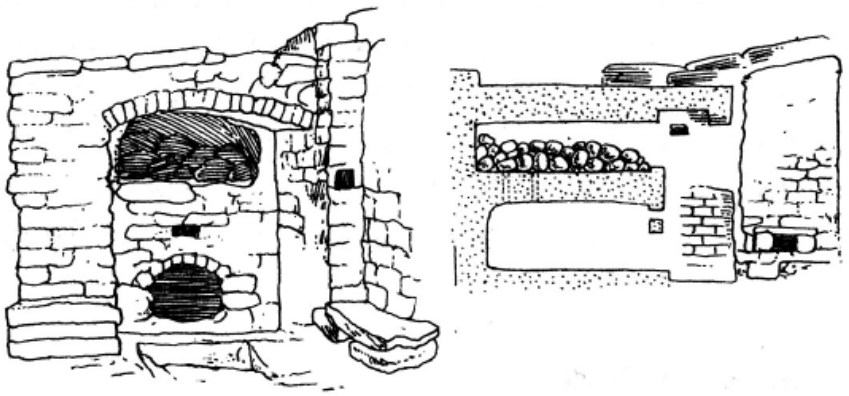

Fig. 13. Heat storage furnace of an Estonian barn dwelling (after Ants Viires and Gea Troska, *Eesti rahvakultuuri leksikon* (Tallinn: Eesti Entsüklopeediakirjastus, 1995), 14.)

of Estonia in the 16th and 17th centuries[107], there is an apparent developmental historical link between these two types of furnaces. Namely, it is possible to assert that, on the basis of the archaeological investigation of Estonian rural settlements, consistent growth in the dimensions of furnaces in farm dwellings took place in the 14th to the 17th centuries[108]. As the heat storage hypocaust was also used in manors and vassal castles, it may have induced peasants to improve their earlier heat storage furnaces on the basis of what they had seen there.

Conclusion

The heat storage hypocaust was a widespread heating system in monasteries, castles, almshouses and town halls in Europe north of the Alps and in the Baltic Sea areas in the period from the 14th to the 16th centuries. It was particularly characteristic of Old Livonia, in the territory of present-day Estonia and Latvia. Nearly 95 hypocausts from the 13th to the 16th centuries have been preserved or documented in Estonia; they were located

[107] Ain Lavi, "Rehielamu kujunemisloost arheoloogia andmetel", *Eesti Arheoloogia Ajakiri*, 5:1 (2001), 47–77.
[108] *Ibidem*, 60.

in castles, monasteries, almshouses, the Tallinn Town Hall, the House of the Great Guild and in defence towers of the Tallinn city wall. The largest number of them are known in medieval Tallinn private residences. The territory of Estonia and Latvia seems to be the only area where that heating system found wide use in private residences and even manor halls.

The central part of the heat storage hypocaust was a large heat storage furnace, whose heat accumulated in a pile of stones above the firebox and heated the room by means of hot air conducted through special air vents.

It is likely that the heat storage furnaces widely used beginning in the second half of the first millennium AD in the territory settled by western Finnic tribes served as an example for the heat storage hypocaust. The idea of using large granite stones as accumulators of heat was probably picked up in the German cultural space on the Baltic Sea from dwellings of the indigenous inhabitants of Old Livonia. Use of the heat storage hypocaust was given up during the 16th century when glazed tile stoves were taken into use in Livonian cities, castles and manors. The central element of the heat storage hypocaust, however, a large heat retention furnace, persisted in use as the furnace in the barn dwellings of Estonian and Latvian peasants into the 20th century.

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KOKKUVÕTE: *Kerishüpokaustahi Eesti keskaegses arhitektuuris*

Kerishüpokaust on 14. ja 16. sajandil Alpidest põhjapoolses Euroopas ning Läänemere piirkonnas kloostrites, linnustes, seegihoonetes ja raekodades levinud küttesüsteem. Eriti iseloomulikuks oli see Vana-Liivimaal, tänapäevase Eesti ja Läti alal.

Eestis on säilinud või dokumenteeritud ligikaudu 95 13.–16. sajandi kerishüpokausti, mis paiknevad linnustes, kloostrites, seekides, Tallinna raekojas ja Suurgildi hoones ning Tallinna linnamüüri kaitsetornides. Enim on neid teada Tallinna keskaegsetes elumajades. Eesti ja Läti näivad olevat ainsad alad, kus see küttesüsteem leidis laialdast kasutamist ka linnakodanike elumajades ja isegi mõisahoonetes.

Kerishüpokausti keskseks osaks oli suur kerisahi, mille kütmisel kerisekividesse salvestunud soojus soojendas õhku, mis pärast kütmise lõpetamist läbi spetsiaalsete õhuavade köetavasse ruumi juhiti.

Kerishüpokausti eeskujuks võib pidada Läänemere idakalda läänemeresoome aladel juba alates I aastatuhande teisest poolest pKr laialdaselt kasutatud kerisahjusid. Maakivide soojussalvestina kasutamise idee jõudis Läänemere saksa kultuuriruumi oletatavasti Vana-Liivimaa algasukate elamutest.

Kerishüpokausti kasutamisest loobuti 16. sajandi jooksul, mil Liivimaa linnades, linnustes ja mõisates võeti kasutusele kahhelahjud. Kerishüpokausti keskne element – suur kerisahi – püsis aga laialdaselt kasutusel Eesti ja Läti talupoegade rehielamu ahjuna kuni 20. sajandini.